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(continued on inside front cover)

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YIELD ESTIMATION AND THE ASSESSMENT OF IN-SEASON NITROGEN STATUS OF PERENNIAL RYEGRASS FOR SEED PRODUCTION USING REMOTE SENSING

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Introduction

Currently, growers rely on yield goal estimates and experience to formulate spring nitrogen (N) rates in perennial ryegrass. Using this approach, N rates may be insufficient or excessive in any given year. This approach results in reduced profitability for growers through reduced yields and/or increased fertilizer costs. Thus, improved methods that optimize spring N rates are required.

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

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

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

Research was initiated in 2006 to examine these potential uses of remote sensing in perennial ryegrass. Our first objective was to determine if remote sensing could assess the plant N status of perennial ryegrass. Second, we wanted to determine if remote sensing could estimate seed yield prior to harvest.

Methods

Site and Agronomic Description

Research was conducted at the Hyslop Crop Science Farm near Corvallis, Oregon in 2007 and 2008. In 2008, research was also conducted at an additional on-farm location (Macpherson Farm) also located near Corvallis, Oregon. At Hyslop, a randomized complete block design with 21 N treatments and four replications was used. Nitrogen treatments were arranged in a factorial design with three fall N rates (0, 40, and 80 lb/a N) and seven spring N rates (0, 40, 80, 120, 160, 200, and 240 lb/a N). Treatments were applied to the perennial ryegrass variety 'Topgun', which was established on a Woodburn silt loam in the spring of 2006. At the Macpherson site, a randomized block design with three N treatments and three replications was used. Nitrogen treatments consisted of a control (0 lb/a N), a fall application of 0 lb/a N followed by 180 lb/a N in the spring, or a fall application of 40 lb/a N followed by 140 lb/a N in the spring. Nitrogen treatments at this site were applied to a second year stand of 'Quest 2' perennial ryegrass established in 2006.

At both locations, the fall and spring N treatments were applied using an Orbit-Air seeder. Urea (46-0-0) was used as the N source for both applications. At the Hyslop location, fall N applications were made on October 27 and October 12 in 2007 and 2008, respectively. Spring applications were applied on March 6 and March 10 in 2007 and 2008, respectively. At the Macpherson site, the fall N application was made on October 13 and the spring N application was made on March 21.

In 2007, treatments were sampled on February 21 and March 26 to determine in-season plant N status. Treatments were sampled on February 18 and March 25 at Hyslop in 2008. The Macpherson site was sampled on February 22 and April 10. A linear transect was used to determine sampling locations in each treatment. Samples were collected from one-foot sections of adjacent rows by clipping all plant tissue above the soil surface. Samples were analyzed for dry biomass and whole-plant N concentration. Nitrogen uptake for each treatment was calculated by multiplying dry biomass by whole plant N concentration.

Treatments at Hyslop were swathed on July 5 in 2007 and July 3 in 2008 using a modified John Deere 2280 swather. After drying a Hege 180 combine was used to thresh the treatments on July 16 and July 28 in 2007 and 2008, respectively. Treatments at the Macpherson site were swathed on July 12 and combined on July 28. Seed was weighed and a bulk sample was taken for cleaning using a two-screen Clipper cleaner. Clean seed yield for each treatment was determined using the cleanout percentage from the bulk sample.

Aerial Images

Aerial images of the research site were obtained on February 17, April 3, and May 23 in 2007. Aerial images of the 2008 research sites were obtained on February 14, April 1, and May 15. Imagery was provided by John Deere Agri Services in 2007 and Eagle Digital Imaging, Inc. in 2008. Imagery consisted of four spectral bands; B (400-500 nm), G (500-600 nm), R (600-700 nm) and NIR (700-900 nm). Spectral reflectance values for each band were derived using ERDAS Imagine software. In addition to examining the reflectance from individual bands, several spectral indices were calculated and analyzed. These included, a normalized NIR, normalized difference vegetation index (NDVI), green normalized difference vegetation index (GNDVI), ratio vegetation index (RVI), difference vegetation index (DVI), soil-adjusted vegetation index (SAVI), and optimized soil-adjusted vegetation index (OSAVI).

Reflectance values from the individual bands and spectral indices were compared to the plant N status and yield obtained from each N treatment. The February and April images were compared to the dry biomass, whole-plant N concentration, and nitrogen uptake values determined from the plant tissue samples. The May images were compared to the clean seed yield. Data was analyzed as Pearson correlations in SAS software. Both linear and quadratic relationships were examined.

Results and Discussion

Early-Season Image (Mid-Feburary)

At the Hyslop site, where a large range of N concentration and N uptake values were present, both N concentration and N uptake were significantly related to spectral measurements (data not shown). There was not a significant relationship between N concentration or N uptake and spectral measurements at the Macpherson site. This was likely due to the small range of N concentration and N uptake values at the site. There was not a significant relationship between biomass and spectral measurements at either Hyslop in 2007 or the Macpherson site. There was a significant relationship between biomass and several spectral measurements at Hyslop in 2008. However, these relationships were very weak and not of practical use.

In 2007 a strong linear relationship was found between NDVI and both N concentration and N uptake (Figures 1 and 2). However, this relationship was found to be inconsistent across years (Figures 3 and 4). In addition, the 2008 Hyslop site was more heavily influenced by the soil background which resulted in high values in the red region of the spectrum and led to negative NDVI values. This was due in part to the cold winter temperatures which delayed spring growth and resulted in a two week delay in 2008 compared to 2007. Thus, while a significant linear relationship between N concentration or N uptake and NDVI was present in each year, the data can not be combined across years. A possible solution to this problem may be to time the image and sampling data to a significant growth stage or heat unit measurement. This approach has been successful in improving the relationships across years and sites for other crops and may lead to a more robust model in perennial ryegrass as well. Future research should focus on defining the proper timing for imagery and sampling. Other research priorities include; developing a direct relationship between spectral measurements and optimum spring N fertilizer rate, determining the influence of variety and management on spectral measurements, and comparing narrow and broad band imagery sources.

Mid-Season Image (Early-April)

The mid-season image has the potential to be used for a variety of applications. Currently the grass seed industry is using images taken at this time to develop variable rate plant growth regulator application maps. This application of remote sensing technology is based on a strong relationship between spectral measurements (most commonly NDVI) and biomass. At the Hyslop site, biomass was significantly related to spectral measurements including NDVI (data not shown). However, the relationship was weak and at most accounted for 25% of the variation in biomass. Biomass and spectral measurements were not significantly related at the Macpherson site. Based on our data, it would appear that the application of plant growth regulator based on a relationship between NDVI or another spectral measurement and biomass is unjustified. However, our research is based on a very limited dataset and further research is required to verify our results.

Both N concentration and N uptake were significantly related to spectral measurements at the Hyslop site (data not shown). There was not a significant relationship between either N concentration or N uptake and spectral measurements at the Macpherson site. However, the N concentration and N uptake values at the Macpherson site were high and likely indicate that the site will be unresponsive to N.

Unlike the early image, a ratio index such as NDVI was able to account for differences across years and sites (Figure 5). Figure 5 shows the curvilinear relationship between N uptake and NDVI across all three experimental sites. NDVI accounted for 63% of the variation in N uptake across all three sites. This indicates that it may be possible to develop a robust model to predict N uptake and/or spring N requirement across sites and years in perennial ryegrass seed production using NDVI. In addition, our research indicates that it may not be necessary to use in-field reference strips in such a model. This would make adoption of such a technique much more viable for growers.

Similarly, the NIR band can also be used to account for differences across sites and years. Figures 6 and 7 shows the curvilinear relationship between relative NIR values and N concentration and N uptake. Relative NIR accounted for 58% of the variation in N uptake and 48% of the variation in N concentration across all three sites. Relative NIR values were derived by dividing each NIR value by the highest NIR value at the site. This would indicate that it might be possible to develop a robust model to predict either N uptake, N concentration, and/or spring N requirement across sites and years in perennial ryegrass using the NIR band. However, unlike NDVI the use of relative NIR values would require a high N reference strip to be placed in the field.

Our results so far are very promising and indicate that remote sensing might be a useful tool for managing N in perennial ryegrass production. However, we have a very limited dataset and further research is required. Future research priorities should include developing a direct relationship between spectral measurements and optimum N rate, the influence of management and varieties on spectral measurements, and comparing narrow and broad band imagery sources.

Late-Season Image (May)

Clean grass seed yield was significantly related to several spectral measurements approximately two months prior to harvest at Hyslop in 2007. In 2008, there was a significant seed yield loss at Hyslop due to barley yellow dwarf virus. Even under these circumstances, there was a significant relationship between clean seed yield and several spectral measurements. However, there was not a significant relationship between clean seed yield and spectral measurements at the Macpherson site. This was likely due to the small range of seed yield values at the site. Both linear and quadratic models were evaluated, however quadratic or curvilinear models most accurately represent the data. Since many spectral indices were equal, NDVI was chosen for further study due to its wide use in remote sensing applications.

Similar to the mid-April image, a ratio index such as NDVI was able to account for differences between years and environments. Approximately two months prior to harvest, NDVI explained 59% of the differences in clean grass seed yield across all three sites (Figure 8). This indicates that it may be possible to develop a robust model to predict clean seed yield across sites and years in perennial ryegrass seed production using NDVI. In addition, our research indicates that it may not be necessary to use an in-field reference in such a model. This would make adoption of such a technique much more viable for growers.

Based on this preliminary data remote sensing appears to be an excellent technique for estimating clean seed yield in perennial ryegrass. Future research is needed to determine a robust relationship between clean grass seed yield and a spectral index across locations and environments.

Acknowledgements

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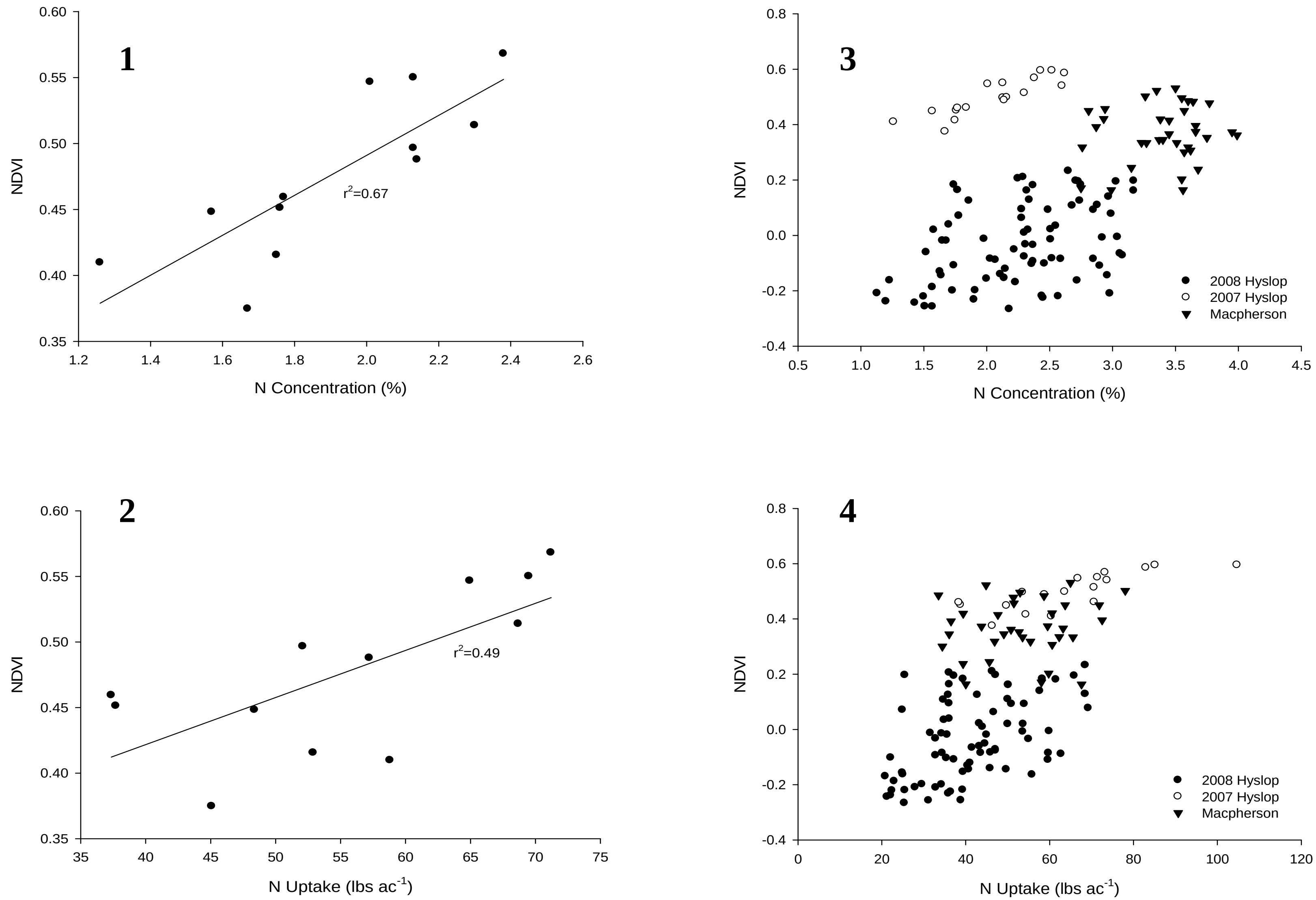
References

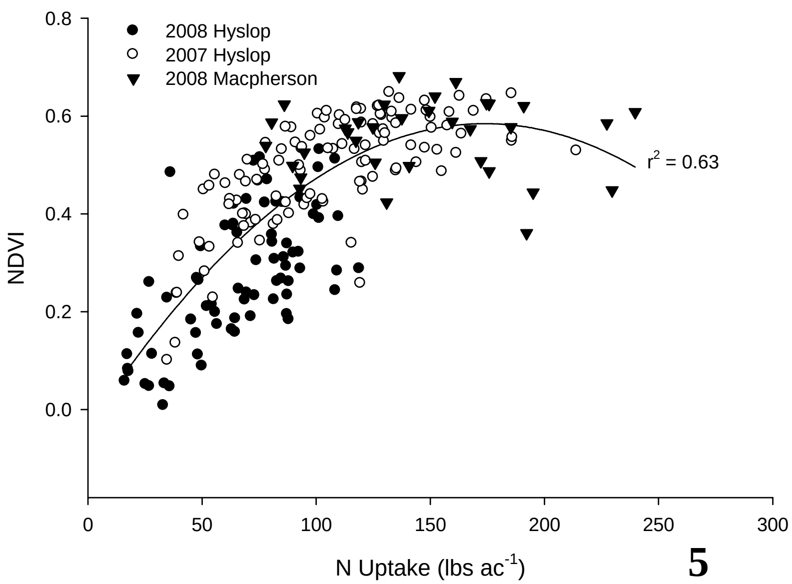
Gates, D.M., H.J. Keegan, J.C. Schleter, and V.R. Weidner. 1965. Spectral properties of plants. Appl. Optics 4:11-20.

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

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



Figures 1-4. Early-season (FEB) relationships between plant N status (N concentration and N Uptake) and the Normalized Difference Vegetation Index (NDVI) at Hyslop in 2007 (Figs. 1 and 2) and all three locations in 2007 and 2008 (Figs. 3 and 4).



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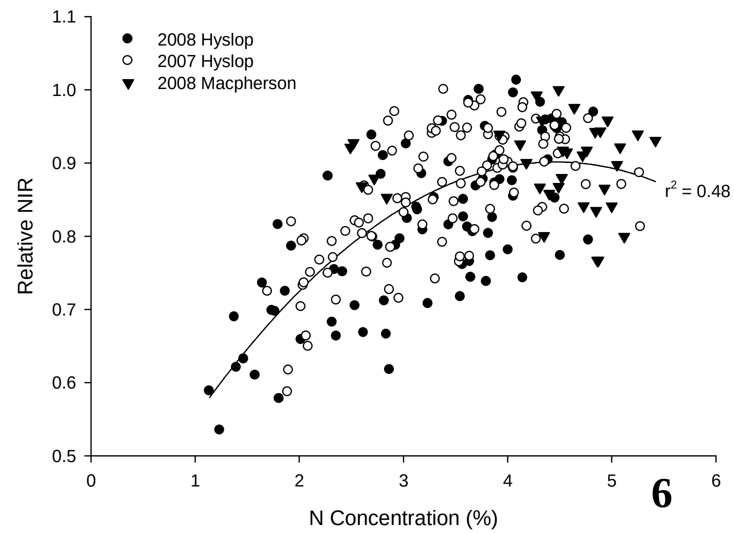

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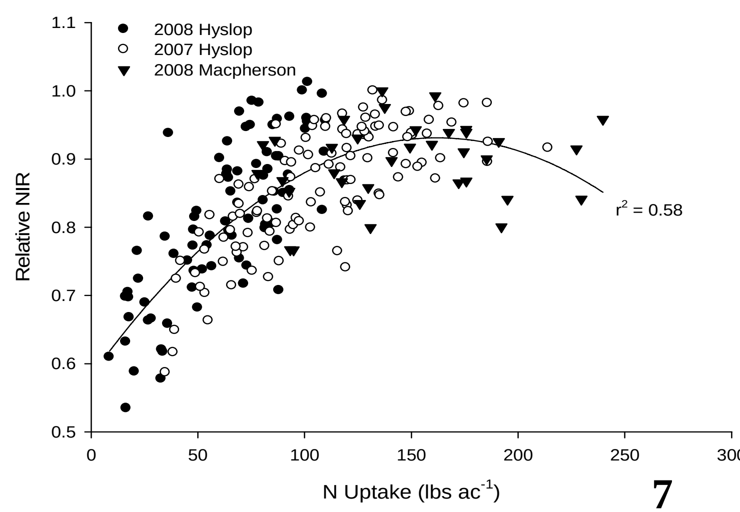

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Figures 5 - 7. Mid-season (APR) relationships between plant N status (N concentration and N uptake) and the Normalized Difference Vegetation Index (NDVI; Fig. 5) or relative NIR values (Figs. 6 and 7) at three locations in 2007 and 2008.

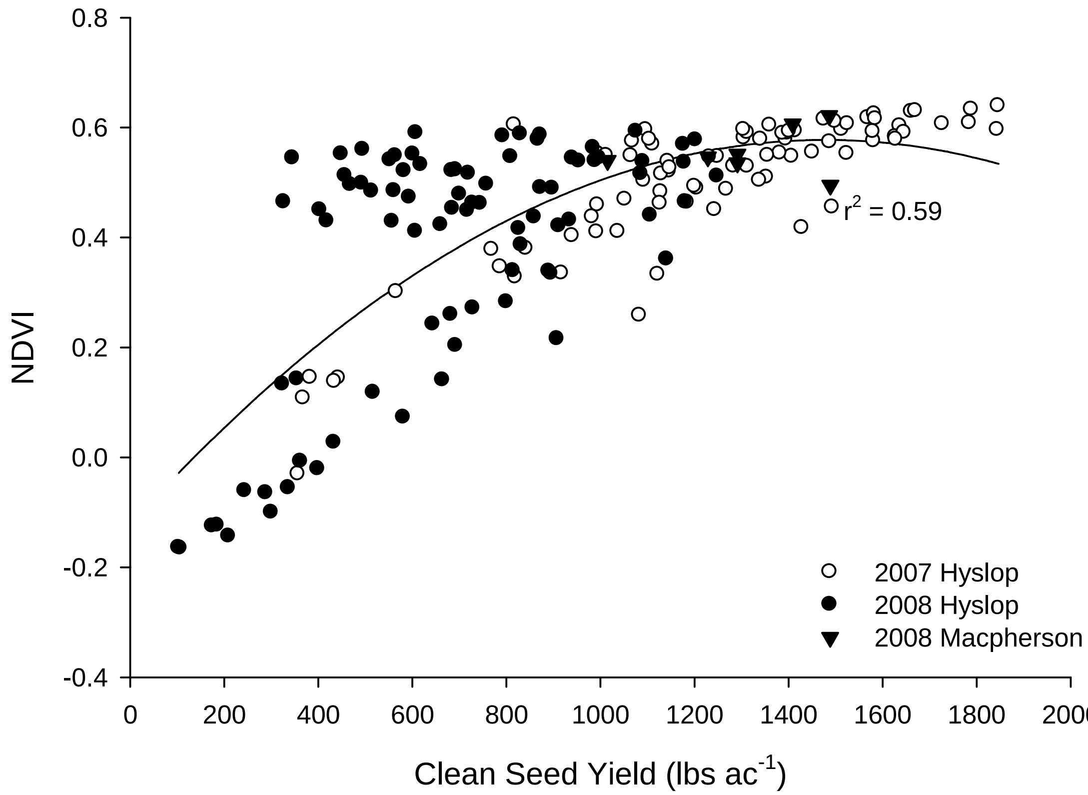

Figure 8. Late-season (MAY) relationship between clean seed yield and the Normalized Difference Vegetation Index (NDVI) at three locations in 2007 and 2008.

FALL N APPLICATION FOR PERENNIAL RYEGRASS

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

Cool season perennial grass seed producers can apply a low rate of nitrogen in the fall followed by a spring N application to supply most of the crop need, or apply N only in the spring. Fall N is recommended for tall fescue seed production as it substantially increases fertile tiller number and to a lesser degree spikelet number (Young et al., 2003). These authors showed that ¼ to ⅓ of the total N for the crop could be supplied in the fall or conversely, if no fall N was applied, spring N rate needed to be increased to obtain the same seed yield as when fall N was applied.

OSU production guides recommend fall application of 30 to 40 lb N/a based on the tall fescue research (Hart et al., 2005). While working with non thermal straw management, Jackson (1983, 1984 and 1986) and Jackson and Christensen (1985) observed that fall N application increased perennial ryegrass seed yield. However, this work was not designed to determine the need for fall N or the optimum combination of fall N and spring N.

The purpose of our work was to evaluate the need for fall N and measure the impact of various fall N – spring N combinations on seed yield of perennial ryegrass.

Methods

Research was conducted at the Hyslop Crop Science Farm near Corvallis, Oregon in 2007 and 2008 using a randomized complete block design with 21 N treatments and four replications. Nitrogen treatments were arranged in a factorial design with three fall N rates (0, 40, and 80 lb N/a) and seven spring N rates (0, 40, 80, 120, 160, 200 and 240 lb N/a). Treatments were applied to the perennial ryegrass variety 'Topgun', which was established on a Woodburn silt loam in the spring of 2006.

The N treatments were established using an Orbit-Air seeder to apply urea (46-0-0). The fall N applications were made on October 27, 2007 and October 12, 2008. Spring applications were applied on March 6, 2007 and March 10, 2008.

Treatments were swathed on July 5 in 2007 and July 3 in 2008 using a modified John Deere 2280 swather. After drying, a Hege 180 combine was used to thresh the treatments on July 16, 2007 and July 28, 2008. Seed was weighed and a bulk sample was taken for cleaning using a two-screen Clipper cleaner. Clean seed yield for each treatment was determined using the cleanout percentage from the bulk sample.

Results

Application of N, in spring, fall, or both, increased perennial ryegrass seed yield (Figure 1). Near maximum seed yields were obtained with spring application of 160 lb N/a, regardless of fall N rate. Seed yield for treatments receiving 80 lb N/a in the fall was not significantly greater ($P = 0.5$) than seed yield for treatments receiving 40 lb N/a in the fall. The treatments receiving 40 or 80 lb N/a in the fall and 0 N in spring produced a higher seed yield than the treatment receiving 0 N in fall and spring. The application of 80 lb N/a in the spring where 0 N was applied in the fall produced a seed yield equivalent to the seed yield of treatments receiving 40 or 80 lb N/a in the fall and 80 lb N/a in the spring. This interaction illustrates that the N requirement for perennial ryegrass can be met with various combinations of fall and spring N as long as at least 40 lb N/a is applied in the spring

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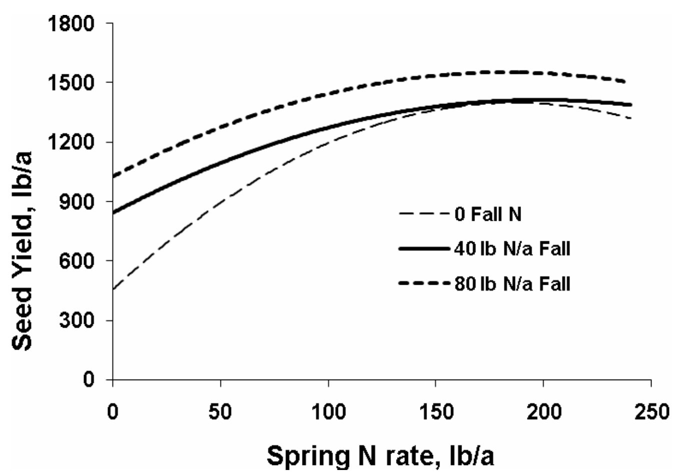

Figure 1. Seed yield of "Top Gun" perennial ryegrass as influenced by fall and spring N application at Hyslop Farm in 2007.

A slight rearrangement of the data assists understanding the implications for perennial ryegrass nutrient management. Rather than spring N, total N (fall + spring) is plotted against seed yield for the three fall N rates (Figure 2). Results show that seed yield response to total N is the same for all fall N rates. The total N required for maximum economic yield (90 to 95% of maximum yield) is between 150 and 200 lb N/a. The N requirement of perennial ryegrass can be met by applying N in the fall and spring or all in the spring. The data support OSU recommendations of 30 to 40 lb N/a in the fall and 120 to 160 lb N/a in the spring(Hart et al., 2005).

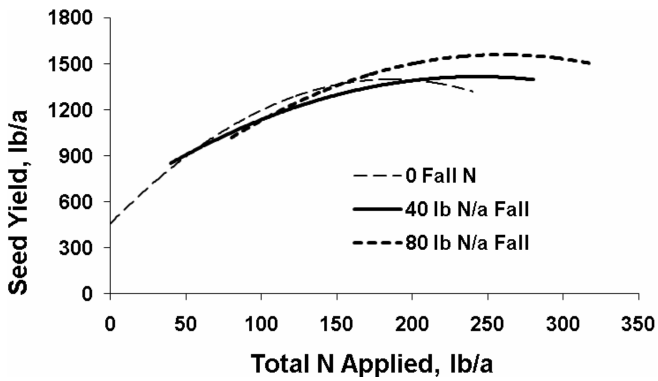

Figure 2. Seed yield of "Top Gun" perennial ryegrass as influenced by fall and total N application at Hyslop Farm in 2007.

Seed yield was substantially lower in 2008 compared to 2007. The mean yield for all treatments was almost 1300 lb/a in 2007 but only 685 lb/a in 2008. Maximum yield averaged 1100 lb/a in 2008 as compared to almost 1600 lb/a in 2007. The decreased yield was attributed to an infection of barley yellow dwarf virus.

Even with the depressed seed yield in 2008, the yield response to spring N rate was similar to results from 2007 (Figure 3). However, N fertilizer rate effects on seed yield could not be separated from the negative impact of barley yellow dwarf virus.

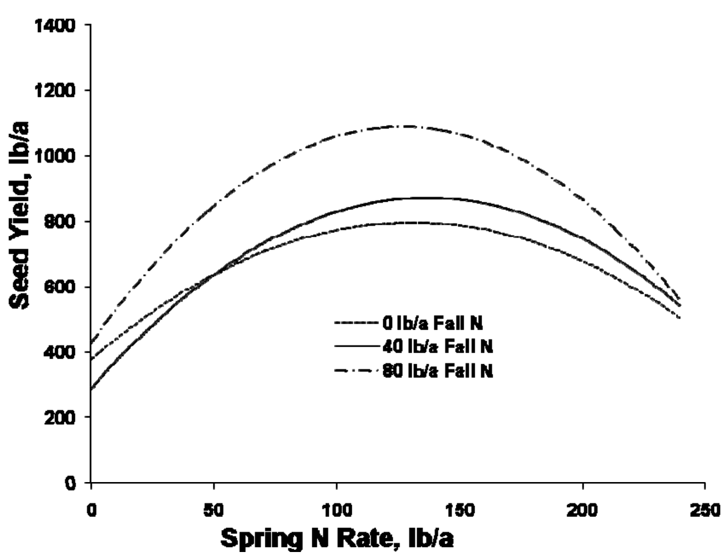

Figure 3. Seed yield of "Top Gun" perennial ryegrass as influenced by fall and spring N application at Hyslop Farm in 2008.

A new experiment was established in the fall of 2008 and the same treatment scheme will be used to evaluate the need and influence of fall N. Since the non disease influenced data reported in this article are from one year only, do not change N management based on these results. Major changes in N management should not be based on a single year's data.

References

Hart, J.M., M.E. Mellbye, D.A. Horneck, G.A. Gingrich, W.C. Young III, and T.B. Silberstein. 2005. Perennial ryegrass grown for seed (western Oregon). Oregon State Univ. Extension Service FG 46-E.

Jackson, T.L. 1983. Straw decomposition and disease suppression. Report to Field Burning Commission on Interagency Agreement. Contract dated 28 June 1982.

Jackson, T.L. 1984. Straw decomposition and disease suppression. Report to Field Burning Commission on Interagency Agreement, DEQ Contract No. 15-84, September 28.

Jackson, T.L. 1986. Report submitted to Field Burning Commission on Interagency Agreement, DEQ Contract No. 17-86, October 1986.

Jackson, T.L. and N.W. Christensen. 1985. Nitrogen fertilizer effects on straw decomposition and old crown growth. Report to Field Burning Commission on Interagency Agreement, DEQ Contract No. 10-85, October.

Young, W.C. III, T.B. Silberstein, T.G. Chastain, and C.J. Garbacik. 2004. Fall nitrogen on tall fescue. In W.C. Young III (ed.) *2003 Seed Production Research at Oregon State University USDA-ARS Cooperating.* Dept. of Crop and Soil Science Ext/CrS 123, 3/04.

COMPARISON OF UREA WITH POLYMER COATED UREA IN PERENNIAL RYEGRASS SEED PRODUCTION

J.M. Hart, N.W. Christensen, M.E. Mellbye, W.C. Young III, C.J. Garbacik and T.B. Silberstein

Insuring that nitrogen availability is synchronized with crop demand is a long standing and universal goal of growers. Higher prices for nitrogen fertilizer in the last two years have stimulated interest in efficient use of nitrogen. Grass seed growers are seeking methods to reduce N application rate or increase seed yield without increasing N application rate.

In an effort to meet their goals, growers experimented with a controlled release fertilizer, polymer coated urea. Controlled release fertilizer products have been available for decades. Urea or other fertilizer materials have been coated with sulfur, starch, and other organic materials. If the coating maintains its integrity, coated urea will provide N gradually rather than in a large "dose". This feature is desirable for situations such as turf where even growth and color are desired.

By matching release rate with crop demand, controlled release N can also reduce loss where leaching may move nitrate-N below the root zone. The potential for leaching loss of N is highest when the entire season's N is supplied before or at planting to an annual crop such as corn. Rain-fed corn production systems in the mid-west and southeastern US have a potential for N to be leached if all or a substantial amount is applied early in the growing season. A number of nitrification inhibitors and controlled release materials were produced for this environment.

Leaching loss is not considered a problem for cool season perennial grass seed production in western Oregon. Crop demand and N supply can be synchronized by timing N application to meet N demand and by splitting spring N application, common practices of most grass seed growers.

The objective of this project was to test if perennial ryegrass seed yield was increased more by application of polymer coated urea than by application of urea.

Materials and Methods

Polymer coated urea was used in several N rate experiments since 1998 but data were not published. To test whether polymer coated urea was superior to urea, comparable seed yield data from all years and sites was evaluated with a paired t-test.

Data from ten site-years are reported. The first evaluation of polymer coated urea was in a series of large-scale N-rate experiments in grower fields.

Polymer coated urea was used in an N rate experiment during 1998 and 1999. In 1998, large-scale on-farm plots averaging 4.2 acres per site were established at six locations prior to fertilizer application. Individual treatments were approximately 22 feet wide and 300 feet long and replicated three times. Spring fertilizer rates from 0 to 270 lb N/a were applied in increments of 45 lb N/a. All sites were fertilized between February 26 and April 13 using a 50/50 split application about four weeks apart. At two perennial ryegrass sites and two tall fescue sites, a polymer coated urea treatment was applied. The additional treatment consisted of 40 lb N/a as a polymer coated urea (Polyon®) mixed with 20 lb N/a supplied by urea for the first application. The second application was 75 lb N/a as urea for a total N rate of 135 lb/a.

At one site the polymer coated urea treatment consisted of 80 lb N/a as Duration® plus 100 lb N/a as urea applied at one time. More information about the on-farm N-rate study is available in the 1998 and 1999 Seed Production Research reports (Young et al., 1999, 2000).

The second trial was a small-plot experiment at Hyslop Field Research Laboratory during 2007 using a randomized complete block design with three fall N rates (0, 40, and 80 lbs N/a) and seven spring N rates (0, 40, 80, 120, 160, 200, and 240 lbs N/a) and four replications. An Orbit-Air seeder was used to apply urea (46-0-0) on 21 treatments of the perennial ryegrass variety 'Topgun', which was established on a Woodburn silt loam in the spring of 2006. Two additional treatments received polymer coated urea, ESN® manufactured by Agrium, 80 lb/a in the fall and 120 lb N/a in the spring,. The fall N application was made on October 27, 2007 and spring application was applied on March 6, 2007.

Treatments were applied using an Orbit-Air seeder to apply urea (46-0-0) to the perennial ryegrass variety 'Topgun', which was established on a Woodburn silt loam in the spring of 2006. The fall N application was made on October 27, 2007 and spring application was applied on March 6, 2007. Polymer coated urea, applied at 80 and 120 lb N/a in the spring, was ESN® manufactured by Agrium.

In 2008, a randomized block design with three N treatments and three replications was used on large-scale plots in two grower fields. Nitrogen treatments consisted of a control (0 lb N/a), a fall application of 0 lb N/a followed by 180 lb N/a in the spring, or a fall application of 40 lb N/a followed by 140 lb N/a in the spring. Spring N treatments of urea or 50% urea and 50% polymer coated urea were applied using an Orbit-Air seeder.

Results and Discussion

Average annual seed yield when urea or polymer coated urea was used to supply N in the spring is presented in Table 1. Between 40 and 120 lb N/a was supplied by polymer coated urea in ten experiments. No significant relationship was found between the rate of N from polymer coated urea and the difference in seed yield between polymer coated urea and uncoated urea.

The difference in seed yield from plots fertilized with polymer coated urea vs. uncoated urea ranged from -64 to +199 lb/a. The average difference in seed yield was small, 56 lb/a or 3.5% greater than yield produced by urea application.. A paired t-test comparing yield of treatments receiving polymer coated urea with urea showed no difference between treatments (p=0.05).

Summary

The seed yield increase from polymer coated urea application was not consistent or significantly different from urea application (p=0.05) and no relationship existed between polymer coated N supply and seed yield increase. For these reasons, application of polymer coated urea is not recommended for perennial ryegrass seed production in western Oregon.

References

Young, W.C. III, M.E. Mellbye, G.A. Gingrich, T.B. Silberstein, S.M. Griffith, T.G. Chastain, and J.M. Hart. 1999. Defining Optimum Nitrogen Fertilization Practices for Perennial Ryegrass and Tall Fescue Seed Production Systems in the Willamette Valley. In: W.C. Young III (ed.), 1998 *Seed Production Research at Oregon State University USDA-ARS Cooperating*, Department of Crop and Soil Science Ext/CrS 112, 4/99, Corvallis, OR.

Young, W.C. III, M.E. Mellbye, G.A. Gingrich, T.B. Silberstein, S.M. Griffith, T.G. Chastain, and J.M. Hart. 2000. Defining Optimum Nitrogen Fertilization Practices for Perennial Ryegrass and Tall Fescue Seed Production Systems in the Willamette Valley. In: W.C. Young III (ed.), 1999 *Seed Production Research at Oregon State University USDA-ARS Cooperating*, Department of Crop and Soil Science Ext/CrS 112, 4/00, Corvallis, OR.

Table 1. Average annual seed yield when urea or polymer coated urea was used to supply N in the spring.

Year	N Rate	N from Urea	N from Polymer	Seed yield	Difference in seed yield
	(lb/a)			(lb/a)	
1998	135	95	40	2148	
	135	135		1998	+150
1998	135	95	40	2144	
	135	135		2078	+66
1998	180	100	80	1935	
	180	180		1986	-51
1999	135	95	40	1517	
	135	135		1461	+56
1999	135	95	40	1409	
	135	135		1403	+6
1999	180	100	80	1767	
	180	180		1775	-8
2007	160	80	80	1432	
	160	160		1233	+199
2007	160	40	120	1561	
	160	160		1421	+140
2008	140	70	70	1090	
	140	140		1017	+73
2008	140	70	70	1357	
	140	140		1420	-64
Average					+57

SEASONAL PRODUCTION OF INFECTIVE ASCOSPORES OF THE CHOKE PATHOGEN, *EPICHLOË TYPHINA*, IN ORCHARDGRASS IN THE WILLAMETTE VALLEY

J.M. Kaser, S. Rao and S.C. Alderman

Introduction

Choke disease has been a major concern in orchardgrass seed production in Oregon since it was first recorded in the Willamette Valley in 1996 (Pfender and Alderman, 1999). Between 1999 and 2003 the average yearly increase in choke was 5 to 8 percent, with yearly increases up to 29 percent in individual fields (Pfender and Alderman, 2006). Pfender and Alderman (2006) found that each percent increase of choke incidence resulted in an equal percentage of seed yield loss.
The causal agent of choke is the fungus *Epichloë typhina,* which grows intercellularly within the infected host plants throughout the year (White, 1987). Infection of new plants is believed to be principally caused by airborne propagules called ascospores (Chung and Schardl, 1997). Currently, there is little information on the diurnal or seasonal occurrence of *E. typhina* ascospores in orchardgrass seed production fields. In order to develop strategies to manage choke disease and minimize new infections in the field, it is critical to understand when ascospores are released. The objectives of this study were to quantitatively determine the seasonal and daily timing of airborne ascospores within an orchardgrass field near Corvallis, Oregon, and assess the implication of this information for future research, and management of choke disease.

Materials and Methods

Ascospore sampling was conducting using a Burkard 7-day volumetric spore trap (Burkard Manufacturing Co., Ricksmanworth, Hertfordshire, U.K.) (Figure 1) which was placed above an irrigation pumphouse located in the center of a cultivated orchardgrass field several hundred feet off US 20/34 between Corvallis and Tangent, Oregon. The Burkard spore trap consisted of a chamber into which acscospores were sucked through an air intake. Inside the chamber was a rotating drum onto which plastic tape coated with a silicone grease mixture was attached for capture of ascospores. Air intake was generated by a suction fan powered by a 27V deep cycle RV battery. The intake was approximately 7 ft above the ground. By determining the location of a given spore along the silicone coated tape, we could approximate the date and hour that the spore entered the trap. Intake was monitored at least once per week and maintained at approximately 10 L/minute air throughput. Trap tape was exchanged weekly. The spore tape was cut into daily sections and hourly sections marked using templates provided by the manufacturer. The tape segments were mounted on slides, stained with aniline blue and spores were counted under a compound microscope at 40X

Figure 1. Burkard 7-day volumetric spore trap placed in an orchardgrass field.

magnification. Spore identification was based on morphology, compared to similarly prepared slides of known *Epichloë typhina* ascospores.

Results:

We analyzed 2011 hourly counts of ascospores trapped between May 2 and July 25, 2008 (Figure 2). The presence of the first spore was recorded on May 15. Ascospore counts increased to > 1000 spores per day by May 25. The maximum hourly spore count for the observation period was 6,447, which was recorded on June 22 between 1:30 and 2:30 am. The maximum daily count, which occurred on June 21, was 50,765 spores.

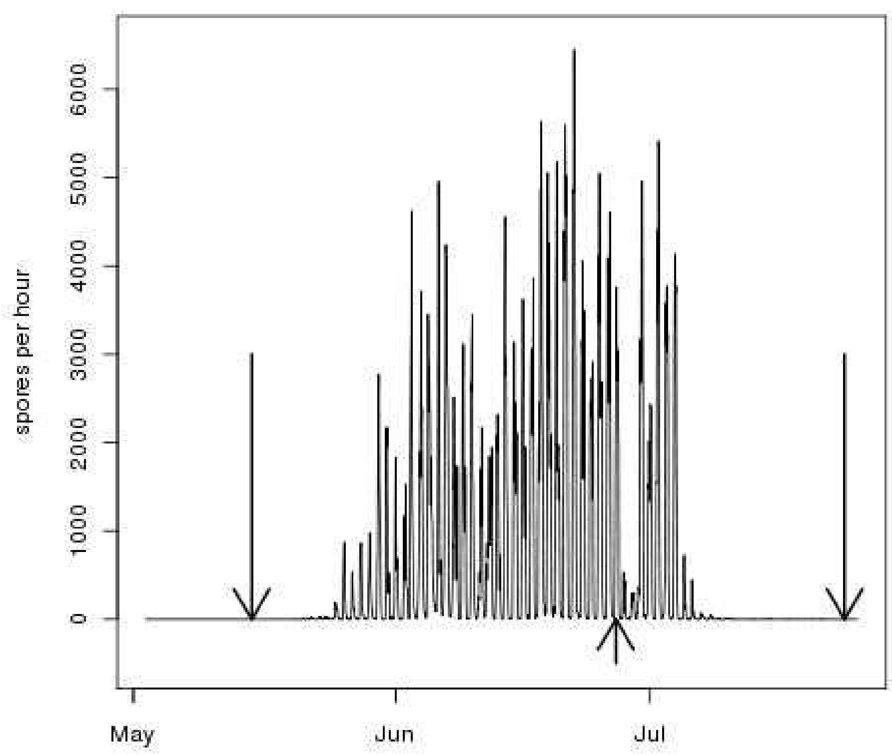

Figure 2: Hourly *E. typhina* ascospore counts from May 2 through July 27, 2008. The arrows represent the first spore observation on May 15 (top left), when grass was swathed on June 27 (bottom center), and the last spore observation on July 24 (top right).

On June 27 there was a decline in spore count from 23,923 to 2,571 the following day. This drop coincided with swathing in the field. Most orchardgrass fields in the vicinity were swathed on or within a few days of June 27. By July 2, the daily count had climbed back to 32,050 spores, but slowly declined thereafter. The last spore observed during the period of the study was trapped on July 24.

A quadratic regression model fit the log transformed data for the entire season (adjusted $R^2 = 0.8481$) (Figure 3). An integer of one was added to all daily count averages prior to log transformation in order to account for values equal to zero. The fitted plot demonstrates that counts remained high for a prolonged period of time between late May and early July.

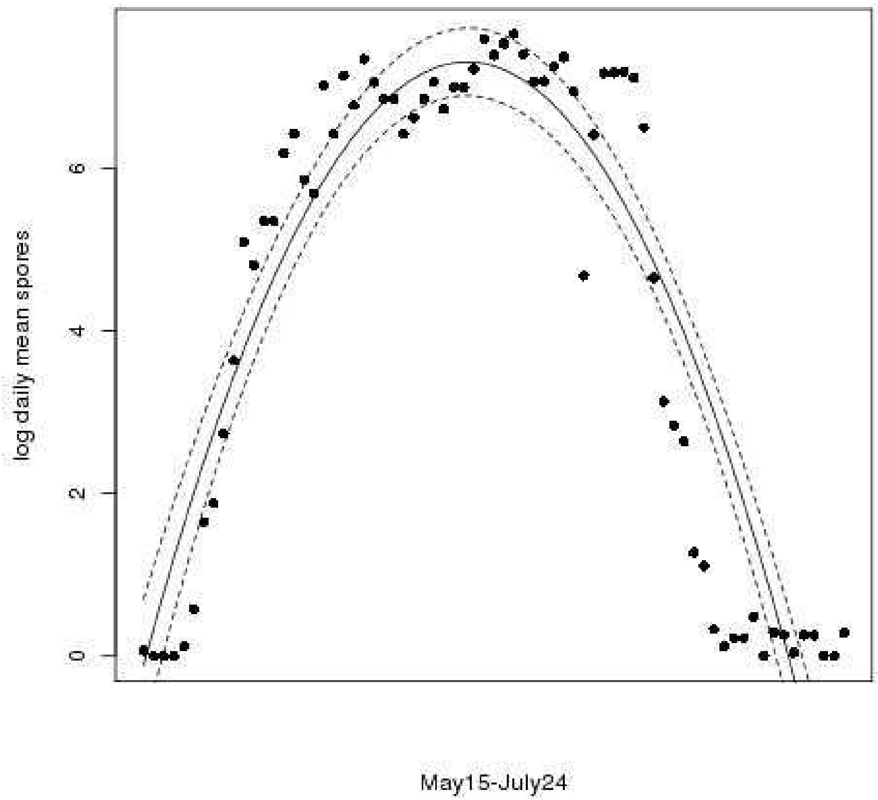

Figure 3: Hourly spore counts averaged for each day (plus one and log transformed), from May 15 through July 24. Fitted quadratic regression model is shown with the solid line (adjusted $R^2 = 0.8481$; 95% confidence interval is shown with dashed lines).

Spore counts peaked and declined each day in a regular pattern. On average, spore counts peaked at 1:08 am (sd 2.97 hours; n=65). A plot of the daily maximum counts through the season shows that the peaks occurred between late evening and early morning (Figure 4). A simple linear regression of the peak hours showed a slight shift forward in the mean of 4.18 minutes with each consecutive day (95% confidence interval was between 2.1 minutes 6.27 minutes per day).

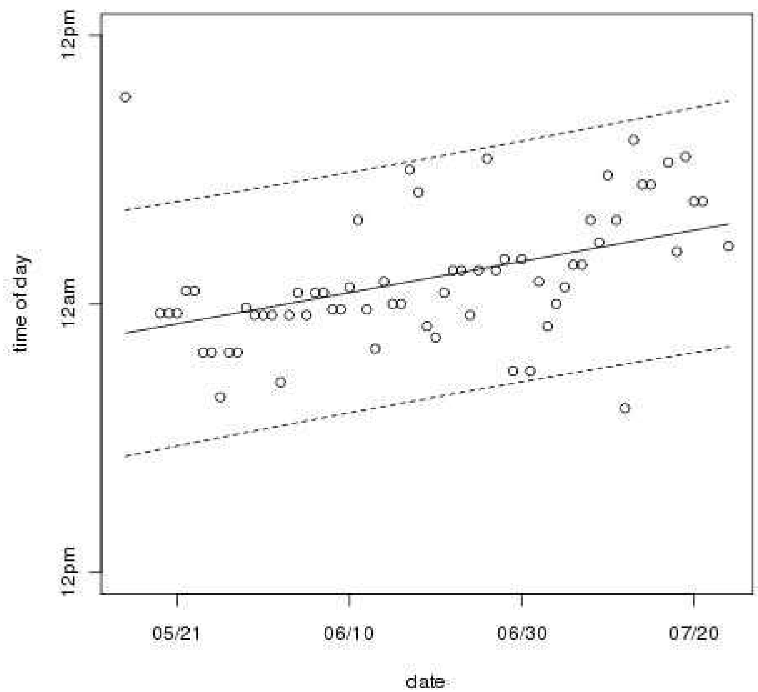

Figure 4. Time of day that peak spore count was reached (for all days with cumulative counts > 0). A simple linear regression of peak hour with day fit the data ($R^2 = 0.2036$; dashed lines show the prediction interval).

Discussion

The study, which is the first to document *E. typhina* ascospore release in the field, provides valuable insights about intensity, timing and duration of airborne ascospores in cultivated orchardgrass in the Willamette Valley. Based on the current study, ascospores are present in the air for a very long period of time, released over 2 months from mid May through late July.

The observations in this study represent counts from a single spore trap located in one non-randomly chosen orchardgrass field. Hence, we need to be cautious while making inferences from this study to ascospore occurrence elsewhere in the Willamette Valley. However, based on these observations, clearly, any management tactic aimed at preventing new infections must take into account the duration of infection pressure by airborne ascospores, i.e. when plants are at risk for infection.

Further research is needed for us to get a better understanding of the mechanism(s) by which the choke disease fungus enters and establishes itself within the host plant. For example, are mechanically damaged plants at greater risk of infection? We found that ascospore production continued for well over a week after swathing. This could turn out to be an important period of time for initiating new infections, as suggested by Western and Cavett (1959). Alternatively, plants with newer green growth might be at higher risk of infection than plants with older dry tissue (Leyronas and Raynal, 2008). If this is true, late May or early June might represent periods of high risk. Future studies should be aimed at discovering more precisely how new infections occur. Combined with the observations from this study, we might then determine when during the season preventative management strategies should be focused.

The daily fluctuation in spore production, with high abundances occurring largely during the night, is suggestive of an adaptive strategy by the fungus. Cooler temperatures, increased moisture and other abiotic factors which might correlate with spore ejection should be investigated in order to discover conditions under which the fungus benefits. With this information we might implement strategies to make conditions less favorable for fungal development. It would be useful to examine spore production patterns at multiple sites throughout the Willamette Valley, and to examine whether the observed synchronization of spore release is common throughout the *E. typhina* population range.

References

Chung, K. R. and C. L. Schardl. 1997. Sexual cycle and horizontal transmission of the grass symbiont, Epichloe typhina. Mycological Research 101: 295-301.

James, D. and K. Hornik. 2008. chron: Chronological Objects which Can Handle Dates and Times. http://CRAN.R-project.org/.

Leyronas, C. and G. Raynal. 2008. Role of fungal ascospores in infection of orchardgrass (*Dactylis glomerata*) by Epichloe typhina agent of choke disease. Cryptogamie Mycologie 29: 11-17.

Pfender, W. F. and S. C. Alderman. 1999. Geographical distribution and incidence of orchardgrass choke, caused by Epichloe typhina, in Oregon. Plant Disease 83(8): 754-758.

Pfender, W. F. and S. C. Alderman. 2006. Regional development of orchardgrass choke and estimation of seed yield loss. Plant Disease 90(2): 240-244.

R Development Core Team. 2008. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org

Western, J. H. and J.J. Cavett. 1959. The choke disease of cocksfoot (Dactylis glomerata) caused by *Epichloe typhina* (Fr.) Tul. Transactions of the British Mycological Society 42: 298-307.

White, J. F. and T. L. Bultman. 1987. Endophyte-Host Associations in Forage Grasses .8. Heterothallism in Epichloe-Typhina. American Journal of Botany 74(11): 1716-1721.

TEMPORAL PROGRESSION IN DEVELOPMENT OF CHOKE DISEASE PATHOGEN AND CHOKE FLY IN AN ORCHARDGRASS SEED PRODUCTION FIELD IN THE WILLAMETTE VALLEY

S. Rao and K.M. Ackerman

Choke disease in orchardgrass is caused by the endophytic fungus, *Epichloë typhina*. The fungus, native to Europe, was inadvertently introduced into the Willamette Valley in the late 1990's (Alderman et al., 1997). The disease spread rapidly through orchardgrass fields in the valley within a few years (Pfender and Alderman, 1999). By 2003, close to 90% of the fields surveyed, in a study by Pfender and Alderman (1999) were infected. Infected tillers are prevented from producing the inflorescence, and hence the pathogen has a direct negative impact on seed yield.

The choke pathogen initially develops internally without any external symptoms. The first sign that an orchardgrass plant is infected is the appearance, in early spring, of large white stromata covering emerging tillers. When the stroma is fertilized, orange perithecia develop and disperse large numbers of ascospores which infect new plants. A fly species, *Botanophila lobata*, which develops on the stroma (Rao and Baumann, 2004), is reported to be critical for fertilization of the fungus (Bultman and White, 1988). Female flies lay eggs on the fungus. The eggs are white, elongated and easy to detect in the field. When the eggs hatch the larvae feed on the fungus. Just prior to harvest, the larvae drop to the ground and pupate. Adults emerge the following spring. Based on our studies in the past (Rao and Baumann, 2004; Rao et al., 2008), there is a high abundance of choke flies in orchardgrass seed production fields in the Willamette Valley.

Currently there is considerable information on the incidence of choke disease and the presence of its fly vector in the Willamette Valley, but little is known about their development through the season. This information is critical for insights on weak links to target for development of appropriate management strategies for choke disease. Fungicides that were evaluated by Pfender and Alderman (2003) were observed to be ineffective. Hence alternative tactics are needed for suppression of the disease.

In 2008, we conducted a weekly monitoring study on choke disease to examine its progression through the season. We flagged individual stroma that emerged each week, and tracked each one until harvest to determine the duration of emergence of new stroma, the number of stroma per plant, and periods when stroma are fertilized, choke fly eggs are laid, and when the eggs hatch. Implications for choke disease management strategies are discussed.

Materials and Methods

The study was conducted in an orchardgrass seed production field in the Willamette Valley in spring 2008. On March 25, we flagged 100 stromata on 31 plants and recorded the length of each stroma. Subsequently, each week until harvest, the flagged stromata were measured to determine the increase in the size of the stroma, if any. In addition, we flagged each new stroma that had emerged on the same plant since the previous week's sampling, and measured its length. During weekly observations, we also noted the presence and extent of fertilization on each stroma, and the number of fly eggs and larvae. A record was also maintained of the condition of each stroma, whether it was well developed, dried, eaten or diseased.

By mid-April, due the high increase in the number of flagged stromata on the 31 plants, we reduced the number of plants under observation to 10. In all, weekly observations were made for 14 weeks until June 25, just prior to when the field was swathed.

Results and Discussion

<u>Emergence of choke fungus:</u> Each of the 10 plants that we monitored weekly through the season initially had between 1 to 3 stromata, but by harvest the number of stromata per plant ranged from 25 to 110. We recorded an average of 1.8 stromata per plant on March 26. By June 25, the averaged increased to 52.8 stromata per plant. (Figure 1). The largest increase in the number of new stroma was observed between April 24 and May 1.

Overall, observations were made through the season on 528 stromata on the 10 plants. Of these, 132 dried up or were infected with some other disease. The length of each stroma gradually increased each week for several weeks. The largest stroma was 12.5 cm while the smallest (newly emerged) was 0.2 cm.

<u>Fertilization of choke fungus</u>: The first signs of fertilization of the fungus were observed on 44 stromata on May 1 during the sixth week of observation. During that week, < 5% of the stromata surface was fertilized. Thereafter, the number of fertilized stromata and the extent of fertilization increased weekly. The stroma that emerged early in the season were fertilized within 5 to 6 weeks. However, late emerging stroma were fertilized within a week. By June 4, 98% of the stromata were fertilized. The remaining 2% that were not fertilized had just emerged during the past few weeks. We observed 75 to 100% fertilization of stromata by June 25 (Figure 2).

Progression in appearance of eggs and larvae of the choke fly: The first eggs of the choke fly were observed on May 6. Subsequently, the numbers increased each week until the end of the study on June 25. In all, we recorded 228 eggs laid on 153 stromata on the 10 plants. The number of eggs laid per plant ranged from 8 to 75 with 3 of the plants having 60% of the egg population.

By May 20, the first eggs had hatched and by June 26, 108 larvae were present on the stromata under observation (Figure 3). Early in the season, egg hatch occurred within 2 weeks but as the season progressed, eggs hatched within a week A few eggs (= 41) could not be tracked. These were either eaten or dropped off the stroma.

Conclusions

The study highlighted the challenge in timing management tactics aimed at suppressing the emergence of the fungus, minimizing fertilization or controlling the choke fly. New stroma emerged over the entire duration of the study from late March until the end of June. Fertilization was recorded as early as May 1, and each week additional stromata were fertilized all through spring. Hence if a control strategy is aimed at suppressing the emergence of the fungus or suppressing fertilization, multiple applications will be needed. Given how early fertilization occurs, ascospore release could also be prolonged, increasing the period when new plants are at risk of being infected. Fly development also progressed all through spring. Hence if any insecticides have potential for suppressing populations of the choke fly vector, multiple applications will be needed. Future research is planned to determine other options for management of the choke fungus and the choke fly.

References:

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

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

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

Pfender,W. F. and Alderman, S. C. 2003. Evaluation of post-harvest burning and fungicides to reduce the polyetic rate of increase of choke disease in orchardgrass seed production. Plant Disease 87:375-379.

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

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

Rao, S., Ackerman, K., and Biboux, T. 2008. Insects, slugs, and mites associated with choke in orchardgrass in the Willamette Valley. *In* Young, W. C., Ed., Seed Production Research, Oregon State University Publication 127: 24-26.

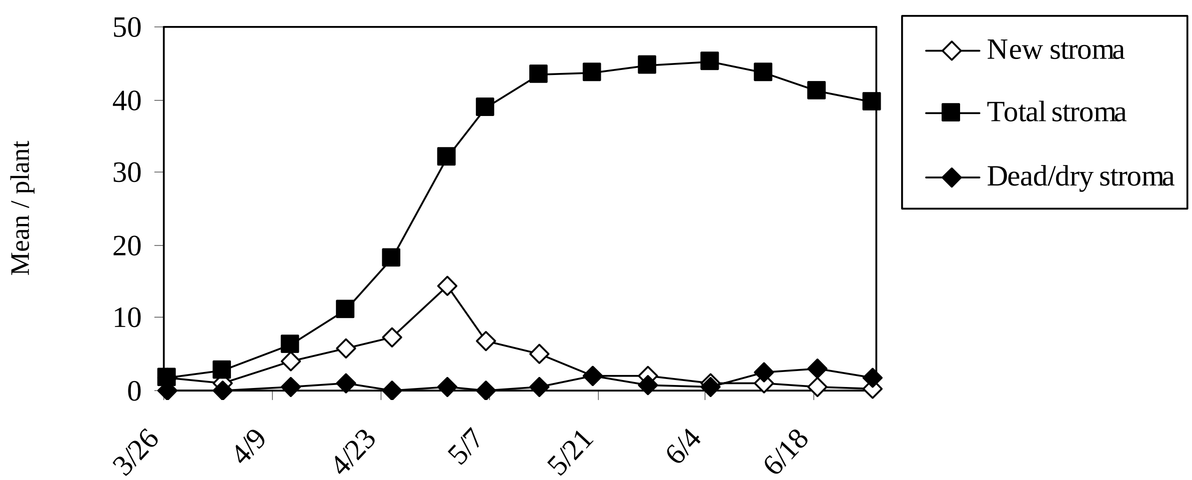

Figure 1. Mean number of stroma per plant observed through the season in one orchardgrass field in the Willamette Valley in 2008 (n=10 plants).

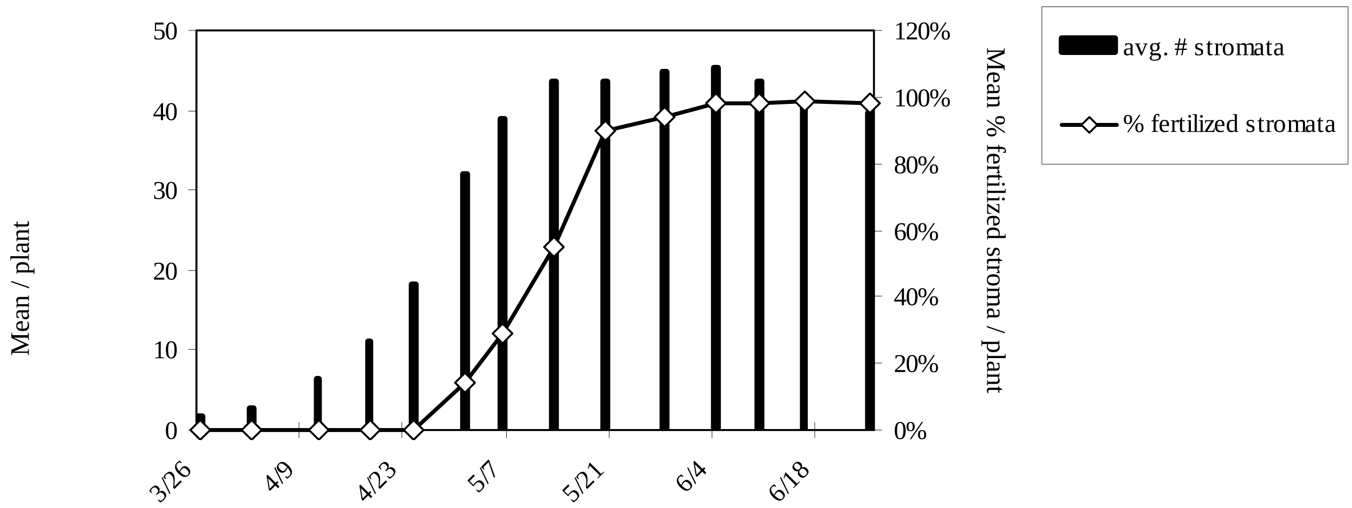

Figure 2. Progression of fertilization of stroma on infected tillers in an orchardgrass field in the Willamette Valley in 2008 (n=10 plants).

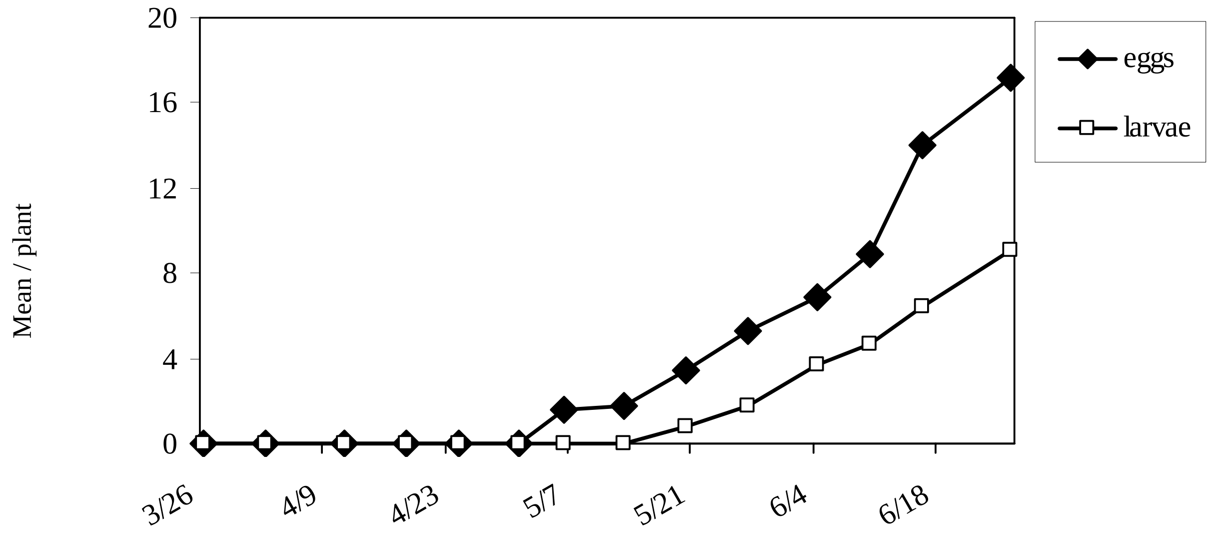

Figure 3. Average number of choke fly eggs and larvae per plant (n=10 plants).

SUMMARY OF CHOKE CONTROL STUDIES -2008

S.C. Alderman, S. Rao, R.L. Spinney, P.K. Boren and J.F. Cacka

Evaluation of copper fungicide for prevention of fertilization of *Epichloe typhina* stromata in orchardgrass
In preliminary greenhouse trials, copper fungicides applied to unfertilized stromata of *Epichloe typhina* in orchard grass were found to prevent fertilization and subsequent development of the fungal stomata, effectively preventing the production and release of ascospores, the primary source of infection of *E. typhina* (the choke fungus). In 2008, a large scale field trial was designed to evaluate the efficacy of a copper fungicide (Kocide®) on the formation, development, and maturation of the *E. typhina* stromata, which develops as a dense fungal growth on the developing inflorescence.

The fungicide trial was established in cooperation with Crop Production Services, Inc. (CPS), and included a 10 acre block treated with Kocide in each of 6 grower fields (replicate sites). In each field, an adjacent block was not treated and served as a control. Kocide® 3000 was applied May 2 at 4 lb/acre and included 3.2 oz/acre of Hi-Wett® spreader. Sprays were applied using a broadcast application method with 20 gallons of water/acre, a boom height of about 18 inches over the crop height, and a tractor speed of 8-10 mph. A second spray was similarly applied on May 19. All fields were located within a 15 mile radius. Weather conditions were similar at all locations, all of the fields were grazed with sheep, and growth stage of orchardgrass was similar in all fields.

Assessments were made at about 10 days following spray application (May 15-16) and just prior to swathing (June 18-20). Ten to twenty tillers were arbitrarily collected along each of 5 transects in a zig-zag pattern from treated and control blocks from each field, providing a total of 50-100 stromata per block. Stromata from each block were bulked, placed in a plastic bag, and transported over ice to the National Forage Seed Production Research Center (NFSPRC), Corvallis, where assessments and data analysis were completed.

Each stroma was examined to determine the percentage stroma surface fertilized. A standardized key was prepared and was used to determine percentage stroma surface fertilized. All stroma were examined within 24 hours. The value for each stroma was recorded as the percentage stroma surface fertilized. Because control and treated blocks were adjacent (paired) in each field, a paired t-test was used to determine whether the percentage stroma surface fertilized differed between treated and control groups. Separate counts were made for the number of eggs and larvae on each stroma. Only larvae with obvious feeding sites were counted.

Results: In the early assessment (May 15-17), the percentage of stromata that had at least the early stages of fertilization ranged from 40 to 80% (Figure 1), while the mean percentage stroma surface fertilized ranged from 9% to 33% (Figure 2). There was no significant difference in percentage stroma surface fertilized between the treated and control groups. However, small spots were observed on the stroma sprayed with Kocide (Figure 3). The spots are consistent with the effect of Kocide on stromata under laboratory conditions. These spots were not observed on any stroma from the control blocks. The size and density of the spots were not enough to have any significant effect on stroma surface fertilized. Immature perithecia were observed on the stromata, but at the time of collection, no stromata were mature enough to release ascospores. The effect of Kocide on the choke fly (*Botanophila* sp.) larva was not established. A larva was observed feeding near a spot (Figure 3), but a greater surface of the stromata would need to be covered by fungicide to evaluate the effect on the larvae. The choke fly is the primary initiator of fertilization of *E. typhina* stromata.

At the early assessment date, choke fly eggs were found on 89 +/- 6% of fertilized stromata per treatment block. Choke fly larvae were associated with 38 +/- 8% of these stromata. Eggs were found on 13 +/- 10% of the unfertilized stromata. If the eggs were freshly laid, fertilization would not yet be apparent. The association of choke flies on 89% of the fertilized stromata and absence of the flies on 87% of the unfertilized stromata supports the currently accepted concept that the choke fly is largely responsible for the early fertilization of stromata. Little variation was observed among fields, suggesting widespread and high populations of choke flies within orchardgrass fields. A range of fly developmental stages were observed, from recently deposited egg (Figure 4), to well developed larva (Figure 5).

At the second assessment date, all stromata were fertilized, with percentage of stroma surface fertilized ranging from 65% to 85% (Figure 6). In a paired t-test, mean percentage stroma surface fertilized in the copper fungicide treated plots was significantly lower than in the untreated check plots (Figure 7). In the first copper application, clear spots on the stroma surface were clearly visible. Clear spots were not observed on the fertilized portion of the stromata just prior to swathing. In addition, there was no indication that the choke fly larvae were affected by the fungicide application.

Discussion/Conclusion**:** The 8% reduction in stroma fertilization, although significant, would not likely result in fewer new infections. Copper fungicides are clearly lethal to *E. typhina* but, as a contact fungicide, obtaining complete coverage of stromata under field conditions is probably not possible.

Fungicide trial for choke control

A fungicide trial, including 23 treatments and 3 application dates was established in cooperation with CPS for choke control in orchardgrass. Applications were applied on April 17, May 1 and May 30, 2008 to this second seed crop stand. A randomized complete block trial design containing four replications was used. The dimension of each plot was 10 ft x 20 ft. The systemic fungicides were applied using a 9 ft boom powered by a CO_2 sprayer delivering 20 gal/a. of finished spray with 8002 tee-jet flat fan nozzles at 30 psi., while the contact fungicides (coppers) were applied using a Stihl 400 air blast backpack sprayer using a 2 gal/min nozzle applying 100 gal/a. of finished spray solution. Samples were collected and assessed by Oregon State University (OSU) and NFSPRC scientists. Twenty-five to 50 stromata were collected from each plot on June 25. Stromata from each plot were placed in a separate bag and placed in an ice chest to keep cool. Samples were delivered to the NFSPRC lab on June 26, and assessment was completed by June 28. For assessment, the percentage of each stroma fertilized was estimated, based on a standard assessment key. An assessment of choke fly larvae was not made, although viable larvae were observed in bags from each plot.

Analysis: Analysis of variance (ANOVA) was based on the average percentage stromal surface fertilized for each plot. The Holm-Sidak method of multiple comparisons vs control was used to determine whether any of the treatments differed significantly from the control treatment.

Results and Discussion: The efficacies of the 23 treatments for control of choke, based on percentage of stromal surface fertilized, are summarized in Table 1. No phytotoxicity effects were observed where systemic fungicides were applied, however, some leaf necrosis was observed where Kocide 3000 and Copper-Count-N were applied with the air blast sprayer, and these could be of concern if seed heads were to be exposed to these treatments. Although a significant reduction in stromal surface fertilized occurred in some treatments, the differences were minimal and not likely to provide any measurable reduction in disease spread.

Mowing trial

A mowing trial was also established by CPS to determine if wounding caused by mowing seedling fields when ascospores are airborne results in an increased incidence of choke. In addition, subplots were included in the design to determine if fungicides applied after mowing would protect the freshly cut leaf surfaces. The mowing/fungicide subplots were established using a completely randomized block design, four replications and four treatments: each plot was 20 ft x 30 ft. The treatments were as follows: 1) Untreated control, (not mowed, no fungicide), 2) Not Mowed, with Prosaro™ 421 SC applied at 24.6 fl. oz. /ac. (3 applications), 3) Mowed (no fungicide), and 4) Mowed followed by Prosaro™ 421 SC (3 applications). Mowing occurred on June 6 and the first fungicide application was applied on June 8 with subsequent applications on July 9 and July 30, 2008. Mowing occurred when the seedling orchardgrass was 2-5 inches tall and was mowed using a riding lawn mower to a 1-3 in height. The fungicide treatment was applied using a CO_2 power hand sprayer, 9 ft boom, 30 psi., 8002 tee-jet flat fan nozzles, on 18 in spacings.

The trial will be evaluated during the spring of 2009.

Variety trial

A replicated orchardgrass variety trial was established by CPS during the spring of 2008 to determine if there are any cultivar differences in susceptibility.

The trial will be evaluated during the spring of 2009.

Insecticide trial for evaluation of impact of choke fly involved in fertilization of stromata of the choke fungus in orchardgrass

A greenhouse insecticide trial for control of the choke fly larvae on orchardgrass plants was established by CPS and OSU. The choke fly is involved in fertilization of the choke disease fungus. Female flies feed on the fungus when it emerges to the outside in spring. While the flies move from stroma to stroma, they defecate the fungal spermatia as they drag their egg laying apparatus and in the process they fertilize the fungus. They lay eggs on the stroma and the larvae feed on the fungus (Figure 4, Figure 5).

Surveys in past years have determined that high numbers of the choke fly are present in orchardgrass fields in Oregon. Suppression of the fly could reduce fungus fertilization and thereby reduce further spread of the disease. Hence a study was conducted to determine if insecticides currently registered for use in orchardgrass could kill larvae of the fly that develop on the fungus.

The experiment was conducted on potted plants of orchardgrass set up as a completely randomized design with 4 replications and 11 treatments (Table 2). Potted plants were sprayed with the insecticide or water (control) outdoors, allowed to air dry and then were returned into the greenhouse for further evaluation after several days. BreakThru, a 100% polyether polymethylsiloxane-copolymer surfactant, was added to all treatments except treatment 11.

Assessment and data analysis: For determination of the impacts of the insecticides, from each pot, ten choked tillers per plant were evaluated. Each choked tiller was examined and the numbers of live and dead fly larvae were recorded. The data were analyzed using analysis of variance to determine if the treatments differed in their activity related to killing fly larvae.

Results and Discussion. The results are presented in Table 2. The analysis indicated that Lorsban® and dimethoate produced the highest mortality. Next in efficacy were Baythroid®, Orthene®, Mustang® and Warrior®. In contrast, Success®, Capture® and Lannate® were the least effective. Unfortunately, the presence of BreakThru, which was added as a surfactant to all treatment except a water control, masked the impact of the insecticide. When applied to the control (water), fly larval mortality was high. Hence it was not possible to separate the effect of the insecticide alone.

Fly larval mortality in the control without BreakThru was higher than expected. This is likely due to impact of odor from the insecticides as all plants were placed close together in a greenhouse where the temperature was high. A preliminary trial in the field with BreakThru alone showed that it was not effective in killing the fly.

We plan to repeat this experiment in a commercial orchardgrass field in 2009. The insecticides will be tested without the addition of BreakThru. Choke incidence will be evaluate the following year to determine if there is a reduction in fungal fertilization as a result of insecticide application. If fly suppression results in reduced fertilization, insecticide application can be viewed as a management strategy for reducing the production of ascospores thereby reducing the number of new plants infected in the field.

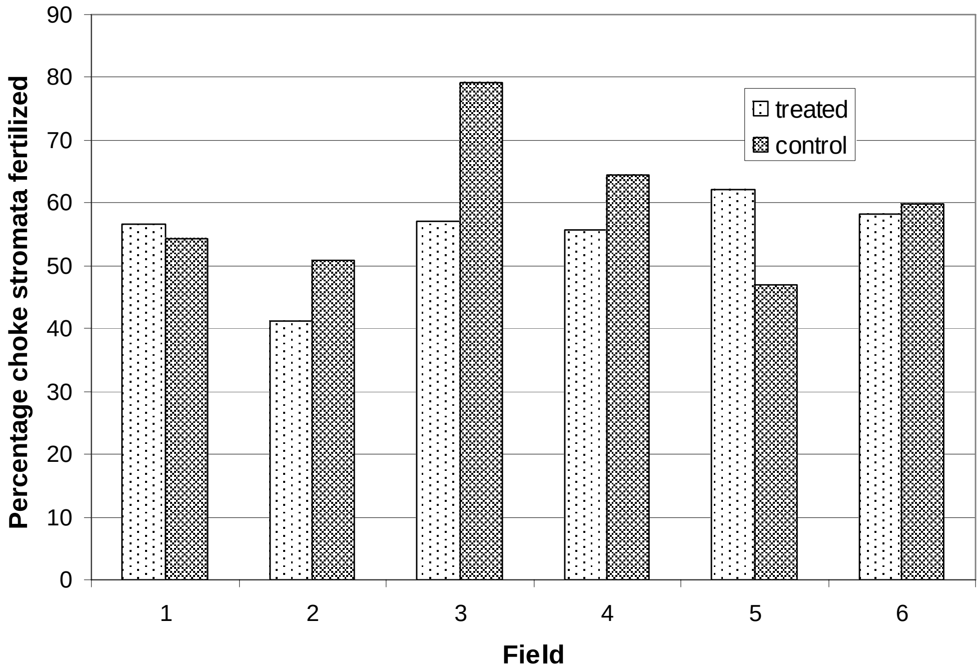

Figure 1. Mean percentage of fertilized choke stromata in orchardgrass in Kocide® treated and control blocks in each of 6 fields, about 2 weeks after fungicide application.

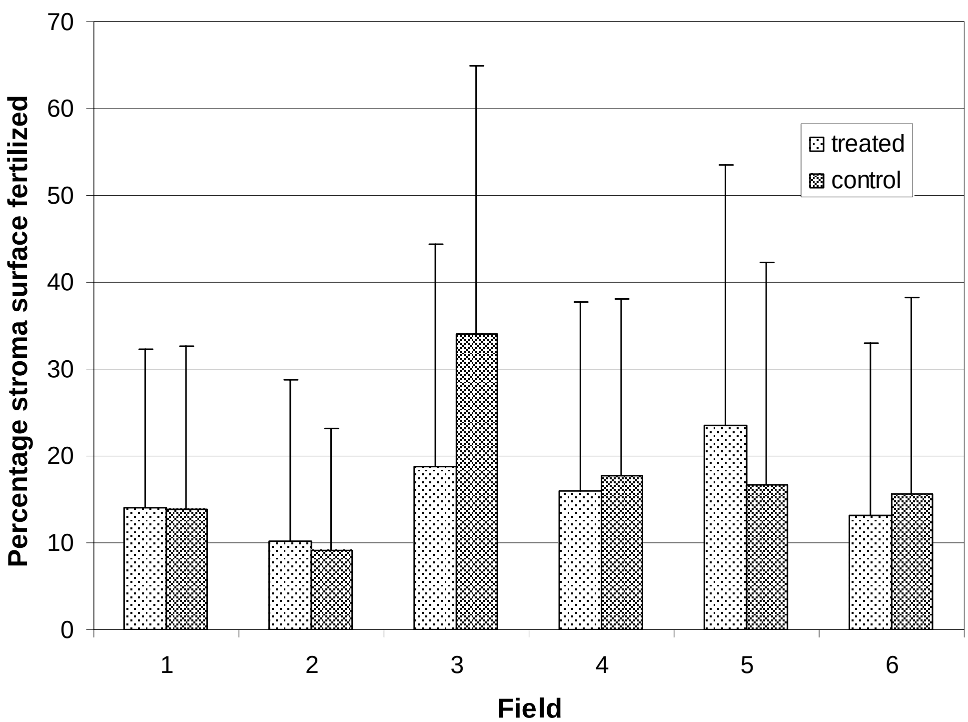

Figure 2. Mean percentage *Epichloe typhina* (choke) stroma surface fertilized in control and Kocide® treated blocks in each of 6 fields, about 2 weeks after treatment. Error bars represent standard deviation.

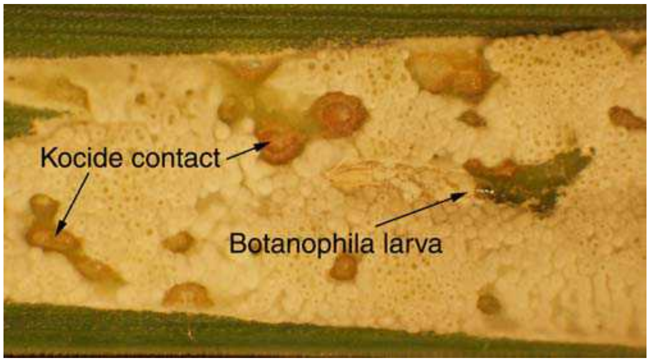

Figure 3. Points of contact of Kocide® droplets on immature stroma of *Epichloe typhina*.

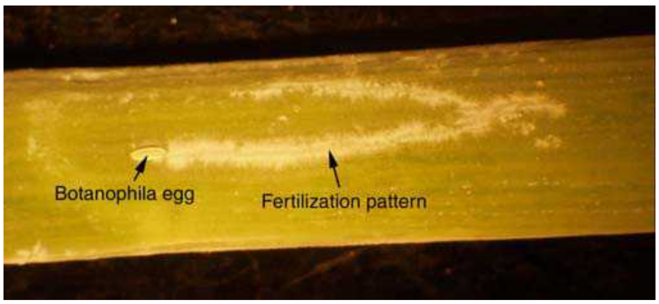

Figure 4. Pattern of conidia deposition by *Botanophila* fly preceding deposition of the egg.

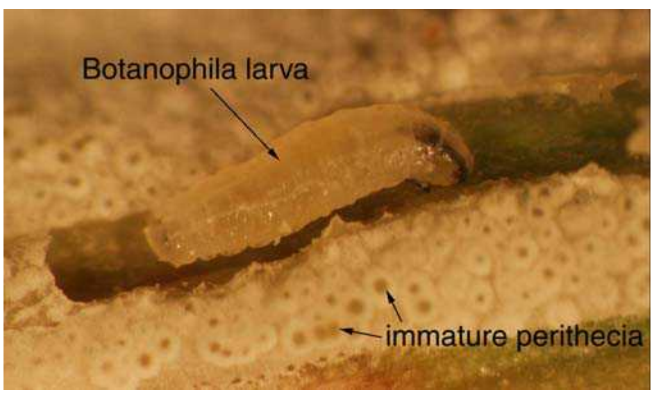

Figure 5. Well developed *Botanophila* larva feeding on a fertilized but immature stroma.

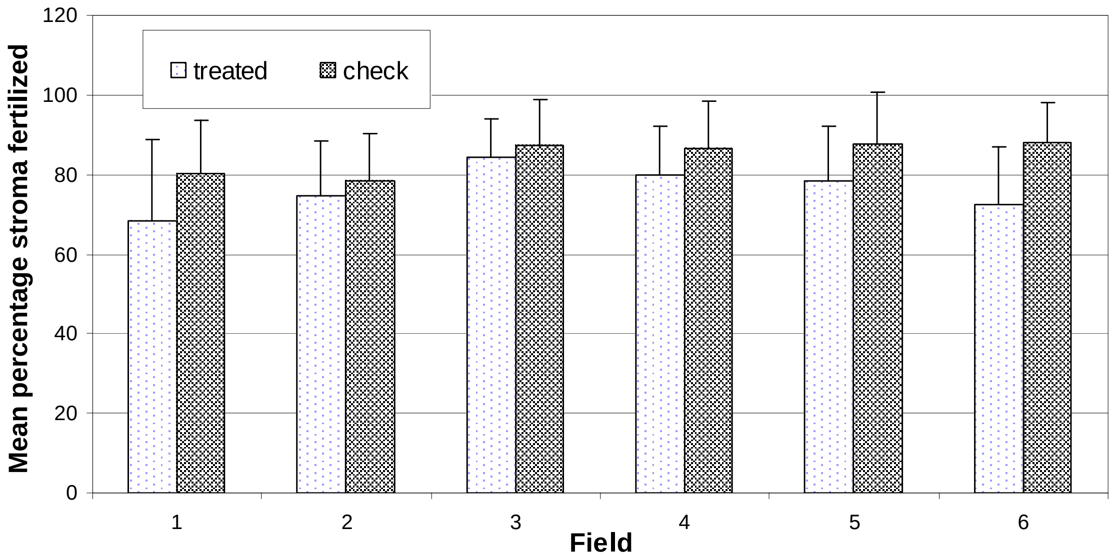

Figure 6. Mean percentage stroma fertilized in large blocks of each of 6 fields just prior to swathing.

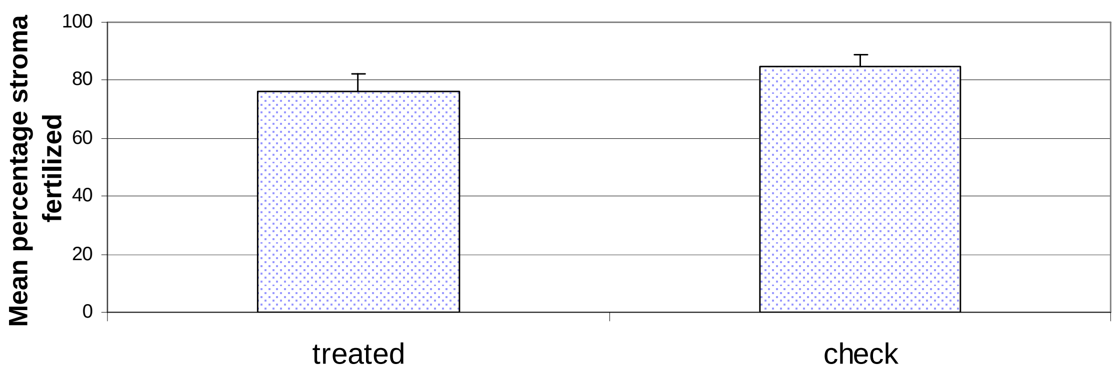

Figure 7. Mean percentage stroma surface fertilized in Kocide® and control blocks in the large scale fungicide trial for choke control.

Table 1. Effect of fungicide treatments on mean percentage stroma surface fertilized in orchardgrass field plots.

Treatments	Timing	Rate of product per acre	Mean % stroma fertilized	Standard error of mean	Significance vs control (P > 0.05)
			(%)		
Tilt + A Plus Spreader	A,B	6 oz. + 0.5%v/v	72.5	3.5	no
Tilt + A Plus Spreader	A,B	18 oz + 0.5%	73.0	2.8	no
Quadris + MSO	A,B	8 oz + 1.5 pt.	72.5	1.2	no
Quadris + MSO	A,B	24 oz + 1.5 pt.	66.0	2.3	*yes*
Quilt + MSO	A,B	27.5 oz + 1.5 pt.	71.3	2.4	no
Quilt + MSO	A,B	82.5 oz. + 1.5 pt.	62.0	4.0	*yes*
Absolute 500SC + MSO	A,B	7 oz + 1.5 pt.	71.5	0.7	no
Absolute 500SC + MSO	A,B	21 oz + 1.5 pt.	72.5	2.9	no
Prosaro 421 SC + MSO	A,B	8.2 fl oz + 1.5 pt.	70.0	3.4	no
Prosaro 421 SC + MSO	A,B	24.6 fl oz + 1.5 pt.	63.0	2.2	*yes*
Rovral 4F + A Plus Spreader	A,B	2 pts. + 0.5%	68.5	1.6	*yes*
Rovral 4F + A Plus Spreader	A,B	6 pts. + 0.5%	74.5	1.0	no
Gem 500 SC + MSO	A, B	3.8 fl oz + 1.5 pt.	71.0	1.8	no
Gem 500 SC +MSO	A, B	11.4 fl oz. + 1.5 pt.	69.8	2.1	no
Endura + MSO + AMS Plus	A,B	11 oz. + 1.5 pt. + 1.5 lbs.	76.5	0.5	no
Endura + MSO + AMS Plus	A,B	33 oz. + 1.5 pt. + 1.5 lbs.	72.5	3.1	no
Kocide 3000	A,B	3 lbs.	69.0	2.0	*yes*
Kocide 3000	A,B	9 lbs.	66.0	2.2	*yes*
Calirus 150 + A Plus Spreader	A,B	2.5 gals. + 0.5%	74.3	3.7	no
Calirus 150 + A Plus Spreader	A,B	5.0 gals.+ 0.5%	72.3	1.0	no
Copper-Count-N	A,B	3 qts.	70.8	2.2	no
Copper-Count-N	A,B	9 qts.	73.5	1.7	no
Untreated Control**	None	None	76	1.8	no

Timing: A = week of April 17 after the first white stroma appear on tillers, B = week of April 14 days later.

Table 2. Effect of insecticide treatments on survivorship of larvae of choke fly that is responsible for fertilization of the choke disease in orchardgrass.

Treatment	Product rate per acre	Amount of product per 600 sq. ft.	Larval survivorship
Control – Water + Break Thru	20 gals. + 0.1% v/v	1,043 ml. + 1.0 ml	3.48
Mustang + Break Thru	24 fl. oz. + 0.1% v/v	1.6 mls. + 1.0 ml.	12.65
Warrior + Break Thru	3.8 fl. oz. + 0.1% v/v	1.5 mls. + 1.0 ml.	14.15
Dimethoate 267 + Break Thru	1.5 pts. + 0.1% v/v	9.8 mls. + 1.0 ml.	1.25
Lorsban + Break Thru	1 qt. + 0.1% v/v	13.0 mls. + 1.0 ml.	0.83
Baythroid XL + Break Thru	1.9 fl. oz. + 0.1% v/v	0.8 mls. + 1.0 ml.	7.79
Lannate LV + Break Thru	3 pts. + 0.1% v/v	19.6 mls. + 1.0 ml.	35.09
Success + Break Thru	6 fl. oz. + 0.1% v/v	2.4 mls. + 1.0 ml.	17.84
Capture 2EC + Break Thru	5 fl. oz. + 0.1% v/v	2.0 mls. + 1.0 ml.	21.85
Orthene 97	1 lb. + 0.1% v/v	6.3 gr. + 1.0 ml.	9.17
Water	none	none	73.88

FIVE YEAR FIELD EVALUATION SUMMARY OF THE USDA STEM RUST MODEL FOR PERENNIAL RYEGRASS

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

Introduction

Each year approximately $10 to $20 million is spent on fungicide spray programs for stem rust control in grass seed fields in western Oregon, making stem rust the most costly disease problem in PNW grass seed crops. Timely applications of fungicides are critical in obtaining effective control and keeping application costs to a minimum. Research has shown that under severe rust pressure, seed yields of perennial ryegrass can be reduced more than 70% when the disease is not controlled. However, the severity of rust, and therefore the need for fungicide applications, can differ significantly among fields and from year to year. In response, a model of stem rust disease based on weather patterns and scouting was developed by researchers at USDA-ARS as a tool to help decide if and when sprays are needed.

The objective of this study was to determine the effectiveness of fungicide applications applied according to information provided by the USDA Rust Model in comparison to traditional application programs. The rust model is still in the process of development, and these tests were part of the effort to test and adjust the model. This report is a summary of five years of field testing.

Methods

Seed yield and rust control data in this report were obtained from large scale, on-farm yield trials conducted on turf type perennial ryegrass from 2004-2008 as part of an on-going OSU Extension Service testing of fungicide products. A weather station was installed in each test field. Data from the weather stations were used to predict potential rust infection initiation and severity and provide information for fungicide applications. Trials were conducted at two locations each year, one in Marion County (North Valley) and one in Linn County (South Valley). Fields selected ranged in age from 1 to 3 years old. Most were first year stands. Fungicides and product rates used were:

Propiconazole (Tilt® 428 GS) at 6 oz/a
Azoxystrobin (Amistar®, Quadris®) at 9 oz/a
Pyraclostrobin (Headline®) at 9 oz/a
Azoxystrobin/Propiconazole mix (Quilt®) at 20 oz/a
Strobilurin/DMI fungicide mix (Absolute™) at 7.5 oz/a

Fungicide applications were made using an ATV mounted sprayer with a 20 ft boom equipped with TeeJet 11002 VS nozzles calibrated to apply 15 gpa at 30 psi. Spray adjuvant (COC or manufacture recommended product) at 0.5% vv was added to each fungicide treatment. Plots were arranged in a randomized complete block design with three replications. Individual plot size was 24 feet wide by 250 to 400 feet long. Grower equipment was used to harvest individual plots and a weigh wagon was used to determine seed yield. Sub-samples of the harvested seed from each plot were collected to determine percent cleanout, 1000 seed weight, and to calculate total clean seed yields. Among the experimental treatments at each location was one in which spray decisions were made based on the rust model outputs, derived by operating the publicly-available stem rust estimator webpage (http://pnwpest.org/cgi-bin/stemrust1.pl). Automated weather stations located at each site were among a group of stations (approximately 15 each year) sited throughout the Willamette Valley that provided weather data for running the model on the website.

In addition to the rust model spray program and an unsprayed check plot, field treatments included a comparison of Tilt, Absolute, Quadris, and Quilt sequences which were applied according to standard industry spray schedules and the protocol established to test these materials by participating companies. The seed yield and rust control averaged across all these fungicide treatments were used to provide the "standard" treatment results in this report. Complete data from individual site-years was reported in previous Seed Production Research Reports (2004-2007, Dept. of Crop and Soil Science Ext/CrS 124-127). Statistical significance of the difference in seed yield between the model treatment and the standard treatment was determined with a single-degree of freedom linear contrast with $p = 0.05$.

Results

The severity of stem rust on the perennial ryegrass fields selected for this study varied from low to severe over the 5-year course of this study (Table 1). Rust infection level in years of "severe" disease pressure ranged from 44% to 85% in unsprayed check plots (late June to early July ratings). Under these condition, the increase in seed yield from fungicide applications, when compared to the non-treated check plot, ranged from 630 to 1245 lb/acre. In such years, the money spent on fungicides was returned 10-fold or more. In contrast, the yield response to fungicides in years of low rust pressure ranged from zero to 190 lb/acre. In these low-pressure years the cost of fungicides was returned at a much lower rate, or sometimes was even a loss.

Overall, excellent control of stem rust was achieved with registered fungicides using either the standard or the rust model spray programs, even in years with severe rust pressure. The number of spray applications was related of course to the severity of rust in the field. Where rust developed early and severely, the number of applications suggested by the rust model was the same as the number used without the model. However where rust developed later or less severely, the model suggested using a smaller number of sprays.

There were two ways that the rust model was of economic benefit, namely by decreasing fungicide cost and/or by increasing seed yield. Over the 10 site-years shown in Table 1, there were three cases in which the use of the model was no different from the standard treatment, either in fungicide use or yield. In five of the cases fungicide use (and therefore cost) was less in the model treatment, with no reduction in yield. In one case the model treatment yielded significantly more seed than the standard treatment even though the number of fungicide treatments was the same, perhaps due to better fungicide timing recommended by the model. And in one case, there was an increase in yield as well as a decrease in fungicide use, again due to better timing of applications. The last column in Table 1 shows the net gain, ranging from $0 to $143 per acre, associated with using the model instead of the standard treatment. The average benefit of using the model, year in and year out, was about $39 per acre per year, and the model did not result in economic loss in any of the cases. So the rust model appears to be a safe addition to existing tools for making rust management decisions.

In summary, we expect that use of the stem rust model in perennial ryegrass will reduce the number of sprays when averaged over a period of years. Even when the number of applications is not reduced compared to traditional application schedules, the model will help optimize the timing, and therefore the control obtained by the fungicide applications.

Appreciation

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

Table 1. Summary of a 5-year comparison of the USDA Rust Model and standard fungicide applications for stem rust control on perennial ryegrass in the Willamette Valley, Oregon (2004-2008).

Year	Variety	Seed crop year	Location (County)	Treatment	Number of fungicide sprays	Rust level (July)	Seed yield	Yield difference, model vs standard		Fungicide cost	Economic advantage, model vs standard
						(%)	(lb/acre)	(lb/acre)	($/acre)	($/acre)	($/acre)
2004	Extreme	1	Linn	Check	0	60	1279			$0.00	
				Standard	3	2	1780			$94.50	
				Rust model	2	15	1952	172	$111.80	$63.00	$143.30
	Paragon	1	Marion	Check	0	85	963			$0.00	
				Standard	3	7	1594			$94.50	
				Rust model	3	16	1552	ns	0	$94.50	$0.00
2005	Paragon	3	Linn	Check	0	58	1015			$0.00	
				Standard	2	6	1213			$63.00	
				Rust model	1	6	1322	ns	0	$31.50	$31.50
	Stellar	1	Marion	Check	0	73	544			$0.00	
				Standard	3	10	1923			$94.50	
				Rust model	3	2	1865	ns	0	$94.50	$0.00
2006	OS	1	Linn	Check	0	44	1337			$0.00	
				Standard	2	2.4	2558			$63.00	
				Rust model	2	1.3	2582	ns	0	$63.00	$0.00
	Margarita	1	Marion	Check	0	trace	1317			$0.00	
				Standard	2	0	1343			$63.00	
				Rust model	1	0	1188	ns	0	$31.50	$31.50
2007	VNS	1	Linn	Check	0	72	1362			$0.00	
				Standard	2	2	2007			$63.00	
				Rust model	2	3	2145	138	$89.70	$63.00	$89.70
	VNS	1	Marion	Check	0	<1	1475			$0.00	
				Standard	1	<1	1368			$31.50	
				Rust model	0	1	1294	ns	0	$0.00	$31.50
2008	LS 2000	1	Linn	Check	0	1.7	1697			$0.00	
				Standard	1	0.8	1841			$31.50	
				Rust model	0	1.2	1887	ns	0	$0.00	$31.50
	Silver Dollar	2	Marion	Check	0	0	1974			$0.00	
				Standard	1	0	2056			$31.50	
				Rust model	0	0	2039	ns	0	$0.00	$31.50
Average				Check			1296			$0.00	
				Standard			1768			$63.00	
				Rust model			1783			$44.10	$39.00

One fungicide application = $31.50/acre and includes application costs (2009 cost).
Perennial ryegrass seed at $0.65/lb.
Significance of seed yield differences determined as a linear contrast, p= 0.05.

CONTROLLING POWDERY MILDEW AND STRIPE RUST IN SEEDLING KENTUCKY BLUEGRASS WITH ABSOLUTE®, TILT®, AND QUILT® FUNGICIDES IN THE LOWER COLUMBIA BASIN

P.B. Hamm and N.L. David

Introduction

Powdery mildew (*Erysiphe gramins*) and stripe rust (*Pucinnia striiformis*) are common foliar fungal pathogens that reduce yield on Kentucky bluegrass (KBG) in the Columbia Basin of Oregon and Washington. They are controlled primarily with systemic fungicides that have a single site mode of action. A study was initiated in the fall of 2006 on seedling KBG to determine the efficacy of the systemic fungicide Absolute®, a mixture of trifloxystrobin and tebuconazole fungicides, on powdery mildew and stripe rust in seedling Kentucky bluegrass and compare it to other strobilurin and triazole fungicides currently labeled for grass seed production.

Materials and Methods

KBG variety Baron, which is highly susceptible to both powdery mildew and stripe rust, was planted on August 22, 2006 in the north east quadrant of Pivot 3 at the Hermiston Agricultural Research and Extension Center near Hermiston, Oregon. Water applications were made based upon local evapo-transpiration rates for grass seed. The trial was fertilized with 109 lb/a nitrogen, 50lb/a phosphorus, 50 lb/a potassium, 66 lb/a sulfur, 14 lb/a magnesium and 0.5 lb/a zinc by October 31, 2006, then an additional 100 lb/a nitrogen and 25 lb/a sulfur were applied as ammonium sulfate on February 6, 2007. Plots were swathed on June 30 and combined on July 11, 2007.

Treatments were assigned in a randomized complete block design with four replications. Individual plots were 4 ft wide x 30 ft long. Fungicide applications were mixed with 1% crop oil and applied in 16 4 GPA of water using XR-8002 teejet nozzles at 30 psi on April 11, April 30 and May 22.

Three areas within each plot were evaluated for powdery mildew symptoms using a scale of 0-3 on April 11, 18, 25, May 3, 10, 17, and 24. A rating of 0 indicated no disease while a rating of 3 indicated the leaf in the area observed was entirely covered with powdery mildew. The cumulative amount of disease observed in each treatment throughout the study period was calculated using area under disease progress curves (AUDPC). Seed yields were determined by harvesting each plot with a Hege 140 plot combine. Seed was then de-bearded and cleaned using a Clipper Eclipse 324 seed cleaner. Analysis of variance was performed using PROC GLM in SAS v.9.1 and when significant, means were separated using Duncan's multiple range test.

Table 1. Treatment description and application dates.

Code	Description	Date of Application
Control	Untreated	
Abs MSO[1]	Absolute (7.7 oz.) 1% v/v	4/11, 4/30/ 5/22
Abs NIS[2]	Absolute (7.7 oz.) 1% v/v	4/11, 4/30/ 5/22
Topsin MSO	Topsin (4.5 oz.) 1% v/v	4/11, 4/30/ 5/22
Teb MSO	Tebuzole (4 oz.) 1% v/v	4/11, 4/30/ 5/22
Teb + Tops1 MSO	Tebuzole (2 oz.) Topsin (8 oz.) 1% v/v	4/11, 4/30/ 5/22
Folicur MSO	Folicur (4 oz.) 1% v/v	4/11, 4/30/ 5/22
Tilt MSO	Tilt (4 oz.) 1% v/v	4/11, 4/30/ 5/22
Quadris MSO	Quadris (6.2 oz.) 1% v/v	4/11, 4/30/ 5/22
Headline MSO	Headline (6.2 oz.) 1% v/v	4/11, 4/30/ 5/22

[1]methylated seed oil (surfactant)
[2]nonionic surfactant

Results

Powdery mildew pressure was high during the 2007 growing season, but no stripe rust was observed in this trial. Powdery mildew was observed in late March before treatments began. The analysis of variance revealed significant differences between fungicide programs for powdery mildew control ($p \leq .0001$). All fungicide programs except Quadris reduced powdery mildew compared to the untreated control (Table 2). Folicur, Tebuzole, Tebuzole+Topsin, Tilt and Absolute reduced powdery mildew to lower levels than Quadris, Topsin and Headline, but there were no significant differences between any of these treatments. The control achieved by Absolute was the same when it was mixed with a methylated seed oil or a non-ionic surfactant.

Table 2. Effect of fungicide program on powdery mildew and seed yield in KBG.

Program	Powdery mildew[1]	Seed yield
		(lb/a)
Control	123 a[2]	927 bc
Quadris	115 ab	673 d
Topsin	105 bc	1132 ab
Headline	99 c	1023 ab
Folicur	74 d	1078 ab
Teb	72 d	1118 ab
Teb+Tops1	70 d	1014 ab
Teb +Tops2	70 d	1055 ab
Tilt	66 d	1196 a
AbsNIS	60 d	777 cd
AbsMSO	60 d	1128 ab
P - value	≤.0001	≤.0002

[1] Values are the accumulated total amount of powdery mildew present in each treatment throughout the experiment (AUDPC).
[2] Values followed by the same letter are not significantly different from each other.

The analysis of variance indicated that Tilt was the only fungicide treatment that resulted in higher yields than the untreated control (Table 2). Interestingly, Quadris resulted in significantly lower yields than the untreated control and all other fungicide treatments except the Absolute + NIS treatment. Adding NIS to Absolute resulted in significantly lower grass seed yield when compared to Absolute + MSO during 2007.

Summary

Powdery mildew significantly reduced seed yield in KBG variety Baron in the Columbia Basin of Oregon when left untreated during 2007. The fungicide Absolute appears to have the same efficacy against powdery mildew on KBG as Tilt or Folicur. According to these results, Absolute + NIS may result in lower grass seed yields compared to Absolute + MSO.

FUNGICIDE REGIMENS FOR THE CONTROL OF POWDERY MILDEW AND STRIPE RUST IN SEEDLING KENTUCKY BLUEGRASS IN THE LOWER COLUMBIA BASIN

P.B. Hamm and J.E. Eggers

Introduction

Powdery mildew (*Erysiphe graminis*) and stripe rust (*Puccinia striiformis*) are common foliar fungal pathogens that reduce yield in Kentucky bluegrass (KBG) in the Columbia Basin of Oregon and Washington. Control is achieved with systemic fungicides applied during the months of March, April and May. Two studies were initiated in the fall of 2007 to further the understanding of controlling these two fungal diseases. One study compared the efficacy of four fungicides applied at 3 and 4 week intervals. The second study compared the efficacy of eight fungicides. Seed yield was also measured in both of these trials.

Materials and Methods

Test plots were treated with Vapam at 40 gal/acre on August 14, 2007. Kentucky bluegrass var. Midnight was planted at a rate of 5 lb/acre on September 6, 2007 in the south east quadrant of Pivot 4 at the Hermiston Agricultural Research and Extension Center near Hermiston, Oregon. Water applications were made based upon local evapo-transpiration rates for grass seed. The trial was fertilized with 80 lb/acre nitrogen on October 26, 2007. Additional 110 lb/acre nitrogen was applied by March 20, 2008 as well as 162 lb/acre 11-52-0 (mono-ammonium phosphate) and 200 lb/acre gypsum. Application of Aim™ and Banvel® were applied at a rate of 3 and 8 oz/acre respectively on March 20, 2008, for weed control.

Individual plots were 4 ft wide x 30 ft long and seeded with KBG var. Midnight, which is highly susceptible to both powdery mildew and stripe rust. Grass was 2-3 inches high at the first fungicide application and at the head-boot stage on the remaining application(s). A CO_2 backpack sprayer with flat fan (XR8002) nozzles at 30psi applying 16 gallons/acre was used for applying treatment in both studies. All treatments included 1% crop oil. A randomized complete block design with four replications was used in both studies.

Study 1 (Application Frequency)

Five fungicide treatments including the untreated control (Table 1) with two fungicide application frequencies (Table 2) was used. Table 2 identifies when fungicide application begun.

Table 1. Fungicide rates for frequency of application study.

Fungicide[1]	Application rate
Tilt®	4.0 oz/acre
Quadris®	6.2 oz/ac
Quilt®	14.0 oz/ac
Absolute™	7.7 oz/ac
Folicur®	4.0 oz/ac

[1]1% crop oil was added to all treatments

Table 2. Fungicide application dates for frequency study.[1]

Application Interval	Application dates
3 weeks	4/17, 5/8, 5/27, 6/12
4 weeks	4/17, 5/15, 6/12

[1]Table 1 identifies fungicides used.

Study 2 (Fungicide efficacy)

This study compared the efficacy of 9 fungicide treatments to control stripe rust and powdery mildew. Treatments are listed in Table 3. An untreated control was used to compare each of the fungicide treatments. The first application of fungicide occurred with the grass was approximately 2-3 inches high (April 17, 2008) and at the head-boot stage (May 15) on the remaining applications.

Table 3. Treatments and rates for fungicide efficacy trial.

Fungicide[1]	Application rates
Absolute™	7.7 oz/ac
Quilt®	14.0 oz/ac
Flint®	3.1 oz/ac
Headline®	6.2 oz/ac
Evito™	3.7 oz/ac
Quadris®	6.2 oz/ac
Folicur®	4.0 oz/ac
Tilt®	4.0 oz/ac
Evito™	2.0 oz/ac

[1]1% crop oil was added to all treatments.

Data collection

For both studies three areas at each evaluation time within each plot were individually evaluated for powdery mildew and stripe rust infection using a scale of 0-3. A rating of 0 indicated no disease while a rating of 3 indicated the leaves were entirely infected with powdery mildew or stripe rust. The cumulative amount of disease observed in each treatment throughout the study period was calculated using area under disease progress curves (AUDPC). These values represent a measurement of the accumulated amount of disease that occurred through the period the plots are rated. Disease ratings for both powdery mildew and stripe rust were conducted on June 7, 12 and 19, 2008. Plots were harvested on July 16, 2008 with a Hege 140 plot combine and yield was determined after seed was de-bearded and cleaned using a Clipper Eclipse 324 seed cleaner utilizing a 7 round scalper screener, a 7 round top split flow screen, and a 6x34 mesh bottom split flow screen. Analysis of variance was performed using JMP 7 statistical software by the SAS Institute Inc. Significant treatment means were separated using Tukey-Kramer HSD.

Results and Discussion

Study 1 (Application frequency)

Powdery mildew and stripe rust pressure was low during the 2008 growing season. Powdery mildew AUDPC (Table 4) and strip rust AUDPC (Table 5) were significantly reduced compared to the control in all fungicide treatments. All fungicides and both application frequencies equally reduced the level of disease caused by both fungal pathogens. However, seed yield was not significantly affected by the different fungicides and application intervals (Table 6).

Table 4. Effect of frequency of fungicide application on powdery mildew.

Fungicide	Application interval	Powdery mildew AUDPC[1]
Untreated	NA	25.30 a
Tilt	4 weeks	0.00 c
Tilt	3 weeks	0.90 bc
Quadris	4 weeks	1.63 bc
Quadris	3 weeks	2.46 b
Quilt	4 weeks	0.30 bc
Quilt	3 weeks	0.15 bc
Absolute	4 weeks	0.06 bc
Absolute	3 weeks	0.00 c
Folicur	4 weeks	0.70 bc
P-value	--	0.0001

[1] Values are the accumulated total amount of powdery mildew present in each treatment throughout the experiment (AUDPC). Numbers followed by the same letter are not significantly different.

Table 5. Effect of frequency of fungicide application on stripe rust.

Fungicide	Application interval	Stripe rust AUDPC[1]
Untreated	NA	27.30 a
Tilt	4 weeks	0.60 b
Tilt	3 weeks	0.75 b
Quadris	4 weeks	0.19 b
Quadris	3 weeks	0.31 b
Quilt	4 weeks	0.43 b
Quilt	3 weeks	0.01 b
Absolute	4 weeks	0.00 b
Absolute	3 weeks	0.00 b
Folicur	4 weeks	0.02 b
P-value	--	0.0001

[1] Values are the accumulated total amount of powdery mildew present in each treatment throughout the experiment (AUDPC). Numbers followed by the same letter are not significantly different.

Table 6. Effect of fungicide program on seed yield.

Fungicide	Application interval	Seed yield[1]
		(lbs)
Untreated	NA	0.60
Tilt	4 weeks	0.98
Tilt	3 weeks	0.88
Quadris	4 weeks	0.99
Quadris	3 weeks	1.03
Quilt	4 weeks	0.89
Quilt	3 weeks	1.03
Absolute	4 weeks	0.85
Absolute	3 weeks	0.84
Folicur	4 weeks	0.98
P-value	--	0.77

[1]Average amount of clean seed from a 6 ft X 35 ft plot.

Study 2 (Fungicide efficacy)

Analysis of variance indicated a significant decrease in powdery mildew on plants treated with Absolute, Quilt, Flint, Quadris, Folicur, and Tilt when compared to the control. Absolute, Headline and Evito were more effective than the other fungicides in suppressing powdery mildew (Table 7).

Evito applied at the 2.0 oz/acre did not significantly reduce powdery mildew on plants when compared to the control.

Table 7. Effect of fungicides on powdery mildew AUDPC.

Fungicide	Application rate	Powdery mildew AUDPC[1]
Untreated	--	25.70 a
Absolute	7.7 oz/a	0.19 c
Quilt	14.0 oz/a	0.58 c
Flint	3.1 oz/a	0.73 c
Headline	6.2 oz/a	16.44 b
Evito	3.7 oz/a	18.35 b
Quadris	6.2 oz/a	6.00 c
Folicur	4.0 oz/a	3.42 c
Tilt	4.0 oz/a	1.40 c
Evito	2.0 oz/a	18.88 ab
P-value	--	0.001

[1] Values are the accumulated total amount of powdery mildew present in each treatment throughout the experiment (AUDPC Numbers followed by the same letter are not significantly different.

Each product tested significantly reduced the amount of stripe rust on plants when compared to the untreated control (Table 8). Analysis of variance indicated no effect on seed yield related to the treatments (Table 9).

Table 8. Effect of fungicides on stripe rust AUDPC.

Fungicide	Application rate	Stripe rust AUDPC[1]
Untreated		15.41 a
Absolute	7.7 oz/a	2.81 b
Quilt	14.0 oz/a	1.81 b
Flint	3.1 oz/a	0.53 b
Headline	6.2 oz/a	0.34 b
Evito	3.7 oz/a	0.09 b
Quadris	6.2 oz/a	0.00 b
Folicur	4.0 oz/a	0.00 b
Tilt	4.0 oz/a	0.00 b
Evito	2.0 oz/a	0.00 b
P-value	--	0.001

[1] Values are the accumulated total amount of powdery mildew present in each treatment throughout the experiment (AUDPC). Numbers followed by the same letter are not significantly different.

Table 9. Effect of fungicides on seed yield.

Fungicide	Application rate	Seed yield[1]
		(lbs)
Untreated		0.91
Absolute	7.7 oz/a	0.85
Quilt	14.0 oz/a	1.00
Flint	3.1 oz/a	0.99
Headline	6.2 oz/a	1.08
Evito	3.7 oz/a	1.04
Quadris	6.2 oz/a	1.01
Folicur	4.0 oz/a	1.00
Tilt	4.0 oz/a	0.99
Evito	2.0 oz/a	1.03
P - value		0.1776

[1]Average amount of clean seed from a 6 ft X 35 ft plot.

Summary

These results indicate that there is wide range of products available that can effectively control powdery mildew and stripe rust on KBG. There also is an indication that there are only minor difference in efficacy between 3 week and 4 week spray intervals. However, if disease pressure had been more typical to what is often seen in the Columbia Basin, then a shorter application frequency may have been better for controlling one or both of these diseases. During previous trials, fungicides belonging to the strobilurin fungicide group have not been as effective at controlling powdery mildew. These same fungicides however have been effective in controlling stripe rust. Given that limitation, these products (Quadris, Evito and Headline) are not recommended at this time for the control of powdery mildew.

MONITORING OF ERGOT (*CLAVICEPS PURPUREA*) ASCOSPORE RELEASE TO BETTER TIME FUNGICIDE APPLICATION IN NE OREGON GRASS SEED PRODUCTION

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

Introduction

Ergot (*Claviceps purpurea*) is an important floral disease of grasses, characterized by the conversion of seed into elongated black sclerotia. In grass seed production fields, seed yield losses result from the direct replacement of seed with sclerotia, and during recleaning of seed to remove the sclerotia to meet seed certification standards. In recent years, ergot incidence and severity has increased in seed production fields in NE Oregon. To better understand the host and environmental factors that contribute to ergot development, a study was conducted in 2008 to monitor soil moisture conditions, timing of host flowering, and airborne ascospore density of *C. purpurea* in two fields of Kentucky bluegrass fields near LaGrande, OR, and one field each of Kentucky bluegrass and perennial ryegrass near Hermiston, OR during 2008. The locations differ in elevation and soil moisture holding capacity. The field sites were established in areas of known ergot occurrence. Burkard volumetric spore traps were used to monitor airborne ascospore densities.

Currently, one or more applications of fungicides are used to lower ergot infections at anthesis. Ascospores serve as the primary inoculum of the disease, however, the dynamics of ascospore release and duration of flights in the region are not well understood. Because soil moisture is required for sclerotial germination and production of ascospores, soil moisture conditions may be used to predict the occurrence of ascospores of *C. purpurea* relative to flowering in grasses. Anticipated results from the study will be used to develop an IPM approach to reduce ergot losses through better timing of fungicide applications, based on timing of host flowering and ascospore occurrence.

Objectives

The objectives of this study were to: 1) Monitor known ergot-infested commercial Kentucky bluegrass (Grande Ronde Valley) and perennial ryegrass (Columbia Basin) seed production fields/plots to determine the timing of release and density of airborne ascospores; 2) Determine the influence of environmental conditions and soil moisture that promote the production and release of ascospores in Kentucky bluegrass and perennial ryegrass fields/plots; and 3) Evaluate the timing of fungicide applications in Kentucky bluegrass and perennial ryegrass for optimum ergot control, and estimate the cost/benefit of control, including seed yield and seed loss during recleaning.

Materials and Methods

Grande Ronde Valley (GRV) – Union Co.

Two commercial fields of established Kentucky bluegrass known to be ergot-infested were selected in the GRV to monitor timing of release and ascospore density. Site 1 was a forty acre field of "Midnight II" variety planted May 2004 in a wheel-line irrigated field grown in rotation with winter wheat and peppermint (elevation ~2750 ft). Site 1 was also utilized to evaluate fungicide application timing for optimum ergot control and included on-site weather data collection equipment. Site 2 was Kentucky bluegrass var. "SR 2100" planted May 2004 in a center pivot irrigated field grown in rotation with alfalfa and small grains (elevation ~2720 ft.). The source for weather data at Site 2 was from the Imbler Agri-Met station located approximately 4 miles due north of the field site.

At Site 1, a WatchDog 2900ET weather station (provided by the Union Co. Seed Growers Association) was used to collect data on evapo-transpiration, air temperature, relative humidity, dew point, wind speed & direction, PAR light sensor, leaf wetness, precipitation, volumetric soil moisture at 1 inch depth, and soil temperature at 1 inch depth. Data collected from the Imbler Agri-Met station included: evapo-transpiration, air temperature, precipitation, solar radiation, relative humidity, wind speed and direction, and dew point. Soil moisture and soil temperature data were not collected at this station.

The fungicide trial at Site 1 included four treatments arranged in a randomized complete block with three replications. The fungicide chosen for this study was a commercial package mix of azoxystrobin (0.62 lb a.i./gallon) + propaconazole (1.04 lb a.i./gallon) formulated as Quilt® and is registered for use on grasses grown for seed in Oregon. Application rate was according to label instructions for Kentucky bluegrass and was applied at 14 oz product/acre plus Stylet oil at 1% v/v. Fungicide treatments included: 1) single application at Early Heading; 2) two applications timed at Early Heading and Early Anthesis; 3) three applications timed at Early Heading, Early Anthesis, and Post-Anthesis; and 4) untreated check.

To accommodate the use of commercial size equipment (field sprayer, swather, combine, etc.) plot size was set at 90 ft by 1000 ft (total study area = approx. 25 acres). The cultural production aspects of the site were managed by the cooperating grower and included common commercial production practices for the area regarding fertilization, weed/insect management with agricultural chemicals, and irrigation management. Fungicide application to the field/study site was managed by the investigator. A commercial field sprayer equipped with a 90 ft boom was used by a local agriculture service provider to apply fungicide treatments at prescribed application timings in consultation with the investigator. Sprayer volume was 16 gpa at early heading, 18 gpa at early anthesis, and 18 gpa at post-anthesis.

The study was swathed on July 12. Two swaths per plot were harvested on August 1 using the growers' combine. The harvested area within each plot measured 29 ft by 600 ft. A weigh wagon was used to measure bulk seed weight harvested from each plot (seed weight/acre in the dirt). Sub-samples collected during harvest from each plot were delivered to the Hermiston Agriculture Research and Extension Center (HAREC) for processing to determine clean seed yield and percent ergot contamination.

Columbia Basin (CB) – Umatilla Co.
Sites 3 and 4 were in the Columbia Basin near Hermiston, OR. Site 3 was in an established 125 acre center pivot irrigated field planted the fall of 2005 with perennial ryegrass variety "Pavilion" (elevation ~800 ft). The field included the following rotational crops, lima beans and potatoes, in 2004 and 2005, respectively. Normal cultural and chemical applications typical to the area were used during the growing season. In particular, fungicides were applied via chemi-gated to control ergot on June 4, 16, and 30 and included Headline® (6 oz/a), Quilt® (6 oz/a), and Headline® (6 oz/a), respectively. Estimated crop growth stage was just prior to anthesis (confirmed by pollen counts) at the first fungicide application. No weather information was collected at this site and no samples were taken to determine ergot infection levels. However, after cleaning seed harvested from this field, the grower reported ergot levels 40% less than the previous year from the same field.

Site 4 was located on the Hermiston Agricultural Research and Extension Center (HAREC, elevation ~638 ft) within a mix of perennial ryegrass, Kentucky bluegrass and tall fescue plots planted in the fall of 2006 and 2007. The plots at Site 4 were planted in two center pivot irrigated fields located adjacent to each other. One-quarter of each of the two 30-acre fields were planted into replicated trials to investigate different nutritional and disease issues for each of the grass seed species. The fields follow a rotation of potato; grass seed for 1-2 years; corn, canola, or wheat; and back to potato over a 4 year period. The Hermiston Agri-Met station located a few hundred meters away provided similar weather data as described above for Imbler.

A fungicide trial to control ergot was also located at Site 4. The trial was planted September 7, 2007 to perennial ryegrass variety "Americus" with treatments replicated four times and arranged in a randomized complete block. Individual plots were 4 ft wide x 30 ft long. The variety "Americus" has been found to be susceptible to ergot in previous experiments. Ergot sclerotia were "seeded" within all replications on January 10, 2008 at a rate of 51,062 sclerotia per replication. Ten treatments were included in the trial: untreated, Absolute™ (8 oz/a), Folicur® (6 oz/a), Tilt® (8 oz/a), Punch™ (8 oz/a), Quadris® (12 oz/a), Headline® (12 oz/a), Evito™ (6 oz/a), and Quilt® at two rates (14 oz/a and 12 oz/a). Treatments were applied approximately 2-3 days prior to heading and continued on approximately a 5-day application schedule (5/21, 5/27, 5/31, 6/5 and 6/12). A CO_2 backpack sprayer was used to apply fungicides in 6 gpa at 30 psi. Boom width was 6 ft with 4 nozzles on 18 inch spacing and XR 8002 flat fan tips. Normal fertility, weed, and irrigation management practices common to the area were followed. The trial was swathed and harvested on July 2 and July 16, respectively. Harvested seed was weighed and cleaned with a Clipper Eclipse 324 seed cleaner set-up with a 10 round scalping screen, 1/18 slot top split flow screen, and a 6/40 mesh bottom split flow screen. Ergot evaluations used both un-cleaned and cleaned seed. This method uses a 25-gram subsample of seed which is spread out and the number of ergot sclerotia/weight is determined for each treatment.

Spore Trapping
A Burkhard 7-day spore trap was installed at each site (in both the Grande Ronde Valley and Columbia Basin) mid-May 2008 and operated until July 11, 2008 (just prior to swathing). The trap provided a continuous record of airborne ascospore density before, during, and after Kentucky bluegrass anthesis, and also pollen levels.

Results and Discussion
Results from the 2008 field studies indicate the number (density) of ascospores trapped varied at each study location and ranged from 0 – 2500 ascospores 14.4 m^3 air day^{-1}. The most significant observation from the two Kentucky bluegrass sites (Site 1 and 2 in GRV) and the perennial ryegrass (Site 3 in CB) is that the beginning of grass seed crop pollination (dotted line in Figure 1) coincided with the end of ascospore occurrence. Therefore, by the time the grass seed crop was at peak pollination (solid line in Figure 1), there were few airborne ascospores available for floral infection. The low density of ascospores during flowering corresponded to the very low levels of ergot infection at each site.

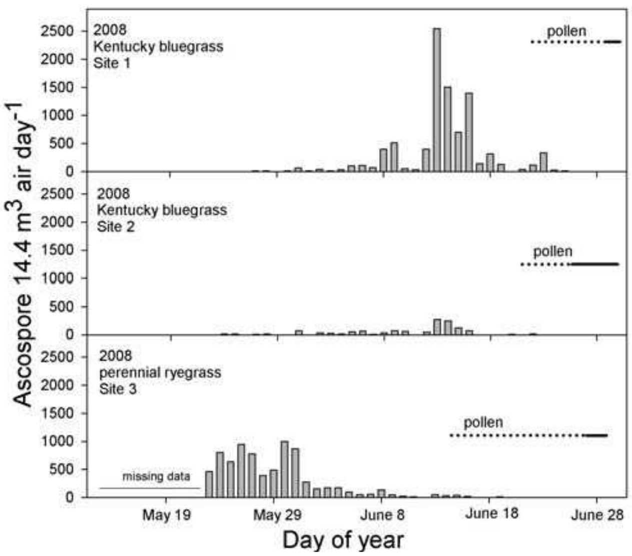

Figure 1. Daily ergot ascospore density and grass pollen occurrence in Kentucky bluegrass (GRV) and perennial ryegrass (CB).

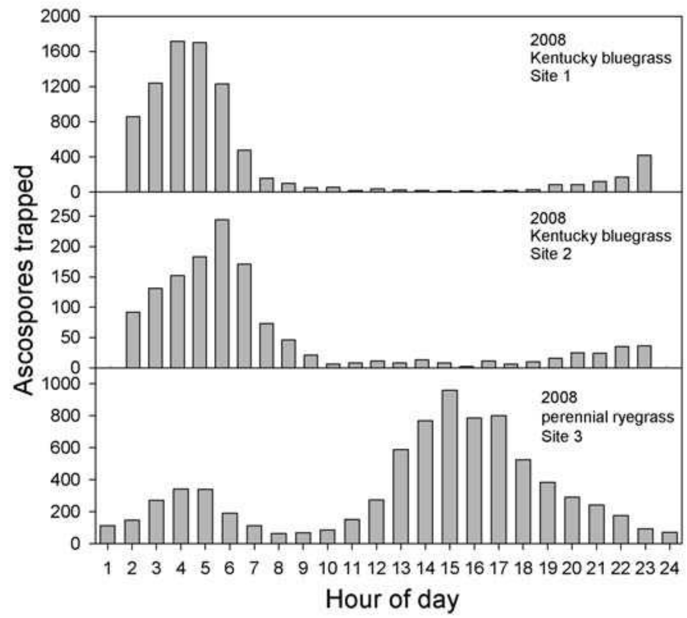

Figure 2. Diurnal periodicity and density of airborne ergot ascospores in Kentucky bluegrass (GRV) and perennial ryegrass (CB).

In Kentucky bluegrass (Figure 2), most ascospores were airborne at night with peak spore numbers trapped between 2:00 to 6:00 a.m. in the Grande Ronde Valley. These results are consistent with previously published spore trapping studies for peak *C. purpurea* in Kentucky bluegrass grown in western Oregon (Alderman, 1993). However, at the CB site ascospores were trapped during the early morning hours (3:00 to 6:00 a.m.) and again during the mid to late afternoon (2:00 to 5:00 p.m.). The reason for this dual occurrence is not known at this time. Clearly additional research is needed to further understand the timing of sclerotia and spore release. In addition, a comparison of the sclerotia originating from Kentucky bluegrass and perennial ryegrass production areas is planned to determine if host specificity or environmental specialization has occurred. This is particularly important since ergot in Kentucky bluegrass in the GRV and perennial ryegrass in the CB is increasing and has caused significant losses while ergot has not been consequential in CB Kentucky bluegrass production.

At this time, it is too early to determine if there are any direct associations between soil moisture conditions in the top 1 inch of the profile and the density of ascospores captured with the Burkhard spore trap. Peak ascospore numbers occurred on June 13 at Site 1. However, soil moisture and temperature conditions (one inch soil depth) leading up to this date do not appear to have influenced ascospore release and subsequent trap catch (Figure 3). Further analysis and data collection from the Grande Ronde Valley and the Columbia Basin will continue to explore the possibilities of using soil moisture monitoring (within the one inch soil depth where sclerotia would most likely be found) as a tool to predict ergot ascospore release. It is certain that additional investigation will be needed to further define germination requirements for ergot sclerotia under field and/or controlled climate conditions, particularly given the environmental differences between the GRV and CB.

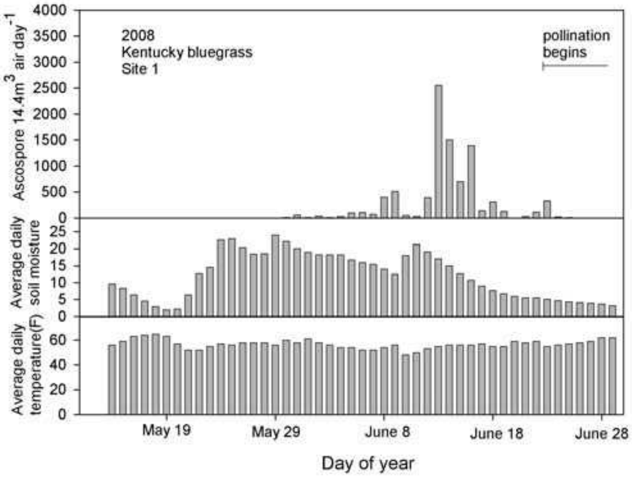

Figure 3. Average daily 1 inch depth soil temperature, average daily volumetric soil moisture content, and ascospore densisty in Kentucky bluegrass (Site 1 GRV).

Ergot levels were lower than expected in both the GRV and CB during 2008, and included an absence of ergot in field plots and seed screenings following cleaning (Table 1 and 2). Given the increasing incidence of ergot in seed during the last several years in the GRV and the CB, this reduction was not anticipated. In 2008, observations from GRV Site 1 suggest that single or sequential fungicide applications were not warranted for ergot suppression in this particular field, thus, would have represented a savings up to $60/acre (Table 1). Since non-pollinated, open flowers are susceptible to infection, and for the most part, ascospore levels peaked when grass was not flowering (evidence by pollen levels) then alignment of the life cycles of the host with the pathogen did not occur in 2008. While soil moisture and temperature data does not clearly suggest a relationship between sclerotia germination and the subsequent release of ascospores, the cooler spring temperatures experienced at both locations may have delayed grass maturity (flowering) while not delaying the germination of sclerotia and ascospore release. Comparisons of environmental conditions with grass maturity, ascospore production and ergot infection will be particularly interesting in future studies.

Table 1. Seed yield, ergot contamination, and fungicide treatment cost in Kentucky bluegrass (Site 1) - Grande Ronde Valley, Union County - 2008.

Fungicide application timing[1]	Seed yield[2]	Ergot	Treatment cost[3]
	(lb/acre)	(%)	($/acre)
Early Heading	1383	0	$20
Early Heading + Early Anthesis	1448	0	$40
Early Heading + Early Anthesis + Post Anthesis	1377	0	$60
Untreated	1369	0	$0
LSD (0.05)	NS	--	--

[1] Fungicide applied as Quilt® at 14 oz prod./acre + Stylet Oil at 1% v/v.
[2] Seed yield reported as dirt weight prior to cleaning.
[3] Spring 2008 treatment cost includes fungicide and Stylet oil only.

Table 2. Seed yield and ergot contamination levels from trial located at the Hermiston Agriculture Research and Extension Center, Umatilla County – 2008.

Treatment[1]	Dirt seed yield[2]	Clean seed yield[3]	Ergot[4]
	----(lb/treatment)	---	(%)
Untreated	6.30	3.38	0
Absolute (8 oz/ac)	6.11	3.14	0
Folicur (6 oz/ac)	7.04	3.55	0
Tilt (8 oz/ac)	5.93	2.80	0
Punch (8 oz/ac)	6.83	3.50	0
Quadris (12 oz/ac)	6.25	3.06	0
Headline (12 oz/ac)	6.00	3.50	0
Evito (6 oz/ac)	6.83	3.69	0
Quilt (14 oz/ac)	6.88	3.96	0
Quilt (12 oz/ac)	6.69	3.61	0
	P=0.46[5]	P=0.10[5]	

[1] Treatments applied with CO_2 backpack sprayer delivering 6 gpa + Stylet Oil at 1% v/v.
[2] Average seed weight (in lbs) collected from the four replicated plots (4 ft X 30 ft) after threshing.
[3] Average seed weight (in lbs) from the four replicated plots (4 ft X 30ft) after cleaning with Clipper seed cleaner.
[4] No ergot was found within dirty or clean seed samples.
[5] Differences between values in the same column are not statistically different.

References

Alderman, S.C. 1993. Aerobiology of Claviceps purpurea in Kentucky Bluegrass. Plant Disease 77:1045-1049.

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USING SEED MOISTURE CONTENT AS A HARVEST MANAGEMENT TOOL TO DETERMINE SWATHING TIME IN GRASS SEED CROPS

T.B. Silberstein

Seed moisture content is probably the best indicator of the physiological maturity in grass seed crops for determining when swathing (windrowing) is to be done for harvesting seed. Since grass seed crops do not pollinate and mature over a uniform time period, there is a wide range of seed maturity within a crop stand. In order to optimize the time to swath grass seed crops, there is a balance between cutting too early and too late. Cutting too early at high moisture content shortens the seed fill period and can cause reduced seed size and increase the number of immature seed. Cutting too late at low moisture content can decrease yield through losses due to seed shattering (Klein and Harmond, 1971; Andersen and Andersen, 1980). Both of these extremes can have an impact on seed quality as well as seed yield. Research was also done in the Willamette Valley of Oregon for tall fescue (Andrade et al., 1994) as well as perennial ryegrass, orchardgrass, and fine fescues (Klein and Harmond, 1971).

With the improvements in swathing and combining equipment to increase overall speed and efficiency, growers are able to swath at a much faster rate and keep up with the harvest maturation. Knowing the range of seed moisture contents that a grower could harvest at would be helpful in prioritizing when to start and which fields are critical to cut on any particular day. This information provides the grower with the ability to prescriptively determine which fields need to be swathed each day (or night). Recent research efforts on perennial and annual ryegrass, reported in the 2004 and 2005 editions of this Seed Production Research Report series, detailed improvements in recommended seed moisture content ranges to begin harvest while maximizing seed yield. With interest from growers and the expanded recommendations on perennial and annual ryegrass, trials were started in 2006 in tall fescue and fine fescue and, with a grant from the Ag Research Foundation, the studies were continued during 2008 in tall fescue, perennial ryegrass, and fine fescue. These trials were designed to compare harvest at different seed moisture contents, verify recommendations previously available and look at the effects of seed storage on germination.

Materials and Methods

On-farm research plots were established in 2008 at the locations listed in Table 1. Plots were swathed at three different seed moistures with the second or third date (depending on the site) the same timing as the normal grower swath time in order to obtain a range of seed moistures. Plots were swathed either early morning or at night while the dew was present. Moisture samples recorded were taken the afternoon prior to each night swathing. All sites were managed by the growers following normal accepted practices for fertility and disease control. Harvested seed yield was determined using a Brent® yield cart to weigh combined plots and sub-samples were also obtained at the same time for cleanout, seed size, and germination tests. Cleanout was determined by using an M2-B clipper cleaner, seed size was measured by taking 1000 seed weights from combine run samples and germination tests were done according to OSTA rules. Trials were designed as three treatment, randomized complete blocks with four replications. Analysis was done using Statistix® statistical software.

Table 1. Swathing study locations, 2008.

Location	Species	Variety
Sandau Enterprises	Perennial ryegrass	Chaparral
Schriever Farms	Perennial ryegrass	Manhattan
Blueline Farms	Tall fescue	Avenger
Pearmine Farms	Tall fescue	Tarheel II
Beiter Farms	Chewings fescue	Ambrose
Doerfler Farms	Creeping red fescue	Windy Jean

Results and Discussion

Tall fescue

Seed yield (Table 1a) at the Avenger tall fescue site was not affected by the differences in seed moisture ranging from the earliest cut swath at 46% seed moisture down to 31% seed moisture cut five days later. All harvest dates resulted in the same levels of cleanout, seed size and seed germination (Table 1b). In contrast, seed yield at the Tarheel tall fescue site was significantly lower (403 lb/a) when swathed earlier at the highest seed moisture of 48%. Not only was seed yield impacted but seed germination was significantly lower at this high seed moisture timing compared to the lowest seed moisture timing. Though there was a germination difference, the seed size was not affected by the range of seed moistures indicating that the seeds were filled, but not all were physiologically mature. The Tarheel tall fescue site did receive irrigation during the seed fill period and this lack of stress may have allowed more seeds to finish maturing. The diminished yield at the 48% seed moisture was similar to the responses of tall fescue in previous trials in 2006. Swathing at 48% seed moisture is too early and the effect of waiting a day or two is well worth the time. Once seed moisture dropped to around 45%, optimum seed yields were obtained at the Avenger site and other trials previously reported in the 2007 Seed Research Reports. Germination was improved by waiting to swath this site at the lower seed moisture (31%), which was different than any of the other three trials over the last three years. It is unclear as to why the irrigated site had this type of effect on seed moisture. This effect will need additional study to verify this response so growers who use irrigation are not diminishing seed germination by harvesting at too high a seed moisture. These ranges for optimum seed yield are similar to prior recommendations for tall fescue. Harvesting tall fescue at much lower seed moistures (low 30's) did not have any negative affect on seed yield, so as long as seed shattering is controlled, lower seed moistures are acceptable.

Perennial ryegrass

Seed yield in perennial ryegrass (Table 2a) was generally not affected by a wide range of seed moisture harvest timings. Swathing timings ranged from 45% down to 23% seed moisture. The only harvest component affected by this range of seed moisture contents at swathing was at the Manhattan perennial ryegrass site. There was a higher yield at the highest seed moisture content. The cause of this is unclear and not obviously related to any measured factors. In addition, seed germination at the Chaparral perennial ryegrass site (Table 2b) was below the acceptable 90% germination requirement for seed certification standards. This particular field was under moisture stress very early in seed fill and the rapid drop in seed moisture from July 13 to July 15 was indicative of the stress from hot dry conditions. The Manhattan perennial ryegrass site did receive a single short set of irrigation after flowering which may have helped improve seed yield considerable as well as alleviate some of the heat stress that was ongoing during this period of time.

Fine fescue

Seed yield response (Table 3a) was stable across a wide range of seed moisture contents at both sites. The Ambrose Chewings fescue site had a slightly higher seed yield and a lower 1000 seed weight at the earliest swath timing (both P values between 0.05 and 0.10). As in the perennial ryegrass, it is not clear as to the cause of this. Seed yield at both sites was good and the yield response to the range of seed moistures measured (39% down to 16%) was similar to prior studies in 2006-07. Even though there is a wide range of response at these sites, the timeframe was pretty short as the seed moisture decreased an average of almost 8% per day. Germination rates were very good across all treatments (Table 3b). It appears that fine fescue is mature and ready for harvest by the time the seed moisture drops into the 30's. Both sites were swathed at night/early morning so the effect of any late swathing shattering was not apparent.

Conclusions

Tall fescue - From these data, a range from the mid 30's to 45% will work for tall fescue, but it is not known how far below 35% the crop can be swathed without having a significant loss in seed yield due to shatter. Swathing above 45% is not recommended as seed yield is limited and seed germination may be affected. Though there was about a 10-15% range of seed moisture to work with in this trial, on hot windy days the seed moisture can decrease 5% or more per day so it is important to follow the crop carefully.

Perennial ryegrass – This and prior research indicate that swathing can begin once seed moisture drops below 45%. Seed yield was not affected between a wide range of seed moisture levels (45-23%) if care to avoid shattering losses are taken.

Fine fescue - There seems to be a wide range of seed moisture that will result in expected seed yield. Germination was unaffected by swathing at seed moisture content in the 30's and lower.

The differences in tall fescue between irrigated and non-irrigated responses need to be further studied to ensure those using irrigation do not swath too early. In addition to the current germination levels tested in these trials, the seed is being stored for a minimum of one year and germination tests will be rerun to determine if the higher moisture swathing timings are affecting the seed performance. The results from the stored seed tests will be reported next year.

References

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

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

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

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

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

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Table 1a. Harvest component responses to seed moisture at swathing time in tall fescue, 2008.

Swath date	Seed moisture	Seed yield	Clean-out	1000 Seed wt.
	(%)	(lb/a)	(%)	(g)
Avenger tall fescue - Blueline Farms				
July 9	46	2994	9.1	2.16
July 12	38	2853	9.6	2.14
July 14	31	3075	8.6	2.22
LSD 0.05		NS	NS	NS
P value		0.520	0.609	0.514
Tarheel II tall fescue – Pearmine Farms				
July 10	48	3376 b	21.0	2.27
July 13	35	3779 a	19.8	2.32
July 14	31	3791 a	19.9	2.35
LSD 0.05		283	NS	NS
P value		0.019	0.489	0.540

Table 2a. Harvest component responses to seed moisture at swathing time in perennial ryegrass, 2008.

Swath date	Seed moisture	Seed yield	Clean-out	1000 Seed wt.
	(%)	(lb/a)	(%)	(g)
Chaparral perennial ryegrass - Sandau Farms				
July 11	45	1167	36.4	1.57
July 13	43	1173	30.0	1.59
July 15	25	1172	29.3	1.58
LSD 0.05		NS	NS	NS
P value		0.987	0.292	0.923
Manhattan perennial ryegrass – Schriever Farms				
July 13	44	2308 a	11.2 ab	1.74
July 16	34	2203 b	9.9 b	1.82
July 18	23	2240 b	11.9 a	1.80
LSD 0.05		66	1.4	NS
P value		0.022	0.033	0.149

Table 1b. Seed germination responses to seed moisture at swathing time in tall fescue, 2008.

Swath date	Seed moisture	Germination 7 day	Germination 10 day	Germination 14 day
	(%)	----------------	(%)	----------------
Avenger tall fescue - Blueline Farms				
July 9	46	79.9	90.5	91.9
July 12	38	80.7	90.8	92.9
July 14	31	80.4	91.7	94.1
LSD 0.05		NS	NS	NS
P value		0.979	0.906	0.620
Tarheel II tall fescue - Pearmine Farms				
July 10	48	63.5 b	85.5 b	88.9 b
July 13	35	67.7 b	85.1 b	90.0 b
July 14	31	74.8 a	91.6 a	93.5 a
LSD 0.05		5.2	3.3	3.1
P value		0.005	0.005	0.027

Table 2b. Seed germination responses to seed moisture at swathing time in perennial ryegrass, 2008.

Swath date	Seed moisture	Germination 7 day	Germination 10 day	Germination 14 day
	(%)	---------------	(%)	---------------
Chaparral perennial ryegrass - Sandau Farms				
July 11	45	72.7	84.2	87.1
July 13	43	72.5	83.7	86.1
July 15	25	75.3	84.9	88.5
LSD 0.05		NS	NS	NS
P value		0.548	0.855	0.508
Manhattan perennial ryegrass – Schriever Farms				
July 13	44	87.7	91.7	93.3
July 16	34	89.8	92.8	93.4
July 18	23	88.5	91.4	93.0
LSD 0.05		NS	NS	NS
P value		0.204	0.252	0.889

Table 3a. Harvest component responses to seed moisture at swathing time in fine fescue, 2008.

Swath date	Seed moisture	Seed yield	Clean-out	1000 Seed wt.
	(%)	(lb/a)	(%)	(g)
Ambrose Chewings fescue - Beitel Farms				
July 11	39	1760 a	8.6	1.08 b
July 12	30	1654 b	8.4	1.09 ab
July 13	23	1638 b	8.5	1.11 a
LSD 0.05(0.1)		(95)	NS	(0.02)
P value		0.091	0.799	0.091
Windy Jean creeping red fescue - Doerfler Farms				
July 9	36	2128	25.4	1.13
July 11	31	2144	24.9	1.15
July 12	16	2105	25.2	1.16
LSD 0.05		NS	NS	NS
P value		0.360	0.640	0.181

Table 3b. Seed germination responses to seed moisture at swathing time in fine fescue, 2008.

Swath date	Seed moisture	Germination 7 day	10 day	14 day	21 day
	(%)	----------------(%)----------------			
Ambrose Chewings fescue - Beitel Farms					
July 11	39	75.1	88.5	91.9	92.6
July 12	30	70.5	91.0	93.4	94.0
July 13	23	69.7	89.0	92.2	92.8
LSD 0.05		NS	NS	NS	NS
P value		0.192	0.181	0.562	0.637
Windy Jean creeping red fescue - Doerfler Farms					
July 9	36	76.9	90.9	93.3	94.0
July 11	31	81.7	92.8	94.0	94.4
July 12	16	74.0	91.9	93.7	94.2
LSD 0.05		NS	NS	NS	NS
P value		0.326	0.490	0.808	0.904

TOLERANCE OF ESTABLISHED BLUE WILDRYE TO HERBICIDES

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

Introduction

Blue wildrye (*Elymus glaucus*), a perennial grass native to the West Coast, is grown on a small acreage in Oregon for seed production. Currently dimethenamid-p (Outlook®) is the only herbicide that is registered for the control of weedy grasses in established blue wildrye. Two trials were conducted to evaluate the tolerance of established blue wildrye to other herbicides that are being used for the control of weedy grasses in grass seed production in the Willamette Valley.

Methods

The 2006-2007 study at the OSU Hyslop Research Farm was comprised of 6.5 ft by 30 ft plots, while the 2007-2008 study at the OSU Schmidt Research Farm consisted of 8 ft by 25 ft plots. Both trials were a collaborative effort with the USDA NRCS Plant Materials Center. The experimental design of both trials was a randomized complete block with four replications. Herbicide treatments were applied in water at 20 gallons per acre at 20 psi. Herbicides included in the 2006-2007 study were flufenacet-metribuzin (Axiom®), pendimethalin (Prowl H_2O®), oxyfluorfen (Goal®), and metribuzin (Sencor®). Oxyfluorfen was omitted from the 2007-2008 trial and flufenacet (Define®) was substituted for fluenacet-metribuzin. Four rates of dimethenamid-p were included in the 2007-2008 study.

The soil at the Hyslop Farm was a Woodburn silt loam with a pH of 5.7 and an organic matter content of 2.9%. The Schmidt Farm soil was a Willamette silt loam with a pH of 5.2 and an organic matter content of 3.9%. The Schmidt site had a moderate infestation of annual bluegrass (*Poa annua*). The blue wildrye stands at both sites had been established by the USDA Plant Material Center for seed increase and were in their third year of production. Visual evaluations of crop injury and annual bluegrass control were conducted periodically after herbicide application. The crop was swathed and threshed in July.

Results

The final visual ratings are included in Tables 1 and 2. Oxyfluorfen caused significant crop stunting at the higher rate of application (Table 1), but seed yield was comparable to that from the untreated check. Visible injury caused by the other herbicide treatments in the Hyslop study was very minor and all seed yields were equal to or greater than those from the check. None of the herbicide treatments in the 2007-2008 study caused significant injury symptoms and there were no statistical differences among the seed yield means (Table 2). Pendimethalin provided less control than the other herbicides on the annual bluegrass in this trial.

Dimethenamid-p may be applied to blue wildrye under conditions and at rates specified on the Outlook label. None of the other herbicides in these two studies are currently registered for use in blue wildrye grown for seed.

Table 1. Visible injury and seed yield of established blue wildrye following herbicide applications at Hyslop Farm, 2006-2007.

Treatment[1]	Rate	Blue wildrye injury[2]	Blue wildrye seed yield
	(lb a.i./a)	(%)	(lb/a)
Flufenacet-metribuzin	0.42	0	91
Flufenacet-metribuzin	0.85	0	126
Pendimethalin	3	5	114
Pendimethalin	6	0	104
Oxyfluorfen	0.19	2	103
Oxyfluorfen	0.38	35	93
Metribuzin	1	5	122
Check	0	0	91
LSD (0.10)		--	21.4

[1] Applied November 8, 2006
[2] Evaluated March 7, 2007

Table 2. Annual bluegrass control and established blue wildrye injury and seed yield following herbicide applications at Schmidt Farm, 2007-2008.

Treatment[1]	Rate	Annual bluegrass control[2]	Blue wildrye injury[2]	Blue wildrye seed yield
	(lb a.i./a)	------(%)------		(lb/a)
Dimethenamid-p	0.66	91	0	278
Dimethenamid-p	0.84	99	0	281
Dimethenamid-p	0.98	96	0	330
Dimethenamid-p	1.96	99	2	267
Dimethenamid-p + pendimethalin	0.66 + 3	99	2	336
Pendimethalin	3	58	0	322
Pendimethalin	6	89	2	329
Flufenacet	0.27	95	5	342
Flufenacet	0.54	95	0	283
Metribuzin	0.38	96	0	346
Metribuzin	0.75	98	1	279
Check	0	0	0	290
LSD (0.10)		--	--	NS

[1] Applied October 3, 2007
[2] Evaluated April 17, 2008

TOLERANCE OF CARBON-SEEDED MEADOW BARLEY AND BLUE WILDRYE TO DIURON

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

Introduction

Several species of grasses native to the Pacific Northwest are being grown for seed on small acreages in the Willamette Valley. There are currently no herbicides registered for the control of grass weeds during stand establishment of these native species. The application of diuron prior to crop emergence where the seed row has been protected with a band of carbon is a standard practice for some of the conventional grass species grown for seed in the Willamette Valley. Although annual bluegrass (*Poa annua*) has developed resistance to diuron on much of the valley grass seed acreage, many other grass and broadleaf weed species are controlled with this decades old practice. Two of the native species that are being tested for tolerance to diuron in carbon seedings are meadow barley (*Hordeum brachyantherum*) and blue wildrye (*Elymus glaucus*). The data being collected from this series of trials will be used in support of potential additions to a diuron label.

Methods

Two trials were initiated in the fall of 2006 at the OSU Hyslop Research Farm and two trials were initiated in 2007 at the nearby OSU Schmidt Research Farm. All trials were a collaborative effort with the USDA NRCS Plant Materials Center. The soil at the Hyslop site was a Woodburn silt loam with a pH of 5.6 and an organic matter content of 2.5%, while the Schmidt Farm soil was a Willamette silt loam with a pH of 5.2 and an organic matter content of 3.9%. The soil was dry when the diuron treatments were applied in 2006 and wet when they were applied in 2007.

The experimental design in both years was a randomized complete block with four replications. Individual plot dimensions were 6.5 ft by 25 ft in 2006 and 8 ft by 25 ft in 2007. Diuron treatments were applied with water at 20 gallons per acre at 20 psi on October 13, 2006, and October 12, 2007—the day after carbon seeding each year. Diuron rates ranged from the lowest recommended rate of 0.8 lb active ingredient per acre to 4.8 lb active ingredient per acre which is twice the maximum rate for any soil type. Activated carbon was applied at a rate of 300 lb per treated acre in a 1-inch-wide band over the seed row at planting. Visual evaluations of crop injury were conducted periodically following diuron application, and the grasses were swathed, threshed and the seed was cleaned.

Results

The final crop injury ratings are presented in Tables 1 and 2. Although visual ratings of both species were zero in 2007, blue wildrye seed yield was reduced by the highest rate of diuron (Table 1). Stunting of both species was recorded at the highest rate of diuron in 2008, but seed yields of neither species were reduced by any of the diuron treatments in that year. Meadow barley and blue wildrye tolerance to diuron in carbon seedings appears comparable to that of other grass species that are currently established with this technique. These data may allow the addition of these and several other native grass species to a diuron label.

Table 1. Visual injury ratings and seed yield of blue wild rye following applications of diuron to carbon seedings.

		Injury[2]		Seed yield[3]	
Treatment[1]	Rate	2007	2008	2007	2008
	(lb a.i./a)	------ (%) -----		---- (lb/a) ----	
Diuron	0.8	0	0	86	427
Diuron	1.2	0	1	82	441
Diuron	2.4	0	8	91	441
Diuron	4.8	0	38	66	440
Check	0	0	0	72	296
LSD (0.10)				18	62

[1]2007 treatments applied on October 13, 2006; 2008 treatments applied on October 12, 2008
[2]2007 treatments evaluated March 7, 2007; 2008 treatments evaluated April 9, 2008
[3]Harvested in July both years

Table 2. Visual injury ratings and seed yield of meadow barley following applications of diuron to carbon seedings.

		Injury[2]		Seed yield[3]	
Treatment[1]	Rate	2007	2008	2007	2008
	(lb a.i./a)	------ (%)------		----- (lb/a) ----	
Diuron	0.8	0	0	60	481
Diuron	1.2	0	1	76	519
Diuron	2.4	0	4	80	532
Diuron	4.8	0	30	86	545
Check	0	0	0	41	380
LSD (0.10)				15	69

[1]2007 treatments applied on October 13, 2006; 2008 treatments applied on October 12, 2008
[2]2007 treatments evaluated March 7, 2007; 2008 treatments evaluated April 9, 2008
[3]Harvested in July both years

WITCHGRASS AND BROADLEAF WEED CONTROL DURING ESTABLISHMENT OF KENTUCKY BLUEGRASS GROWN FOR SEED

D.A. Ball and L.H. Bennett

Introduction

From previous studies, it has been shown that Kentucky bluegrass grown for seed exhibits good tolerance to two herbicides recently registered for use in turfgrass seed production. These herbicides include mesotrione (Callisto®) and flucarbazone-sodium (Everest®). Kentucky bluegrass tolerance to these herbicides appears to be adequate during the period of crop establishment, and possibly as a preemergence application before Kentucky bluegrass seedling germination. In addition, crop tolerance appears to be adequate in established plantings of Kentucky bluegrass grown for seed. However, questions still exist about the spectrum of weeds controlled by these herbicides. Also, current labeling of flucarbazone restricts the use in Kentucky bluegrass for weed control to no less than 365 days from seed harvest, which limits its use for weed control in established bluegrass plantings. Our study objective was to verify the tolerance of Kentucky bluegrass to these two herbicides when applied as preemergence and early postemergence treatments during crop establishment in the spring. An additional objective was to examine the potential for these two herbicides to provide control of several important weed problems, including witchgrass, (*Panicum capillare*), henbit, (*Lamium amplexicaule*), and tumble pigweed, (*Amaranthus albus*). With these objectives in mind, two studies were conducted in commercial Kentucky bluegrass seed fields in Union County, OR during the 2008 growing season to evaluate weed control and crop tolerance from these two herbicides during the crop establishment period.

Methods and Materials

Sites were selected within newly seeded, irrigated, commercial fields of Kentucky bluegrass (KBG) located in the Grande Ronde Valley of eastern Oregon. Both field locations were seeded in early May of 2008, and herbicides applied as either preemergence (PRE) or postemergence (POST) treatments as described in Table 1. Herbicide applications were made on the first study site (Site #1) when KBG seedlings were emerging, but prior to weed emergence. Postemergence applications at Site #1 were made when the KBG was in the 1.5 to 2.5 leaf stage of growth (Table 1). At the second study site (Site #2), a single application was made when KBG was in the 3 to 5 leaf stage, and witchgrass and tumble pigweed were in the 5 to 6 leaf and 3 to 6 inch rosette growth stage, respectively. Weather conditions at the time of application at both sites are summarized in Table 1. All treatments were applied with a hand-held boom, CO_2 pressurized sprayer delivering 16 gallons per acre at 30 psi pressure. Individual plots at both studies were 9 by 30 feet in size, and arranged in a randomized complete block design with 3 replications. Soil at Site #1 was a sandy loam (53.2% sand, 36.6% silt, 10.2% clay, 4.1% organic matter, pH 6.8, CEC of 19.1 meq/100g). Soil at Site #2 was a sandy loam (67.1% sand, 22.6% silt, 10.3% clay, 1.6% organic matter, pH 4.7, CEC of 11.9 meq/100g). Evaluations of percent visible weed control were made on June 26, and July 11, 2008 at both sites, and an additional evaluation was made on July 29, 2008 at Site #2.

Table 1. Weather conditions at time of applications.

	------- Site # 1---------		Site #2
	May 15	June 12	June 19
Kentucky bluegrass	emerging	1.5-2.5 leaf	3-5 leaf
Timing	PRE	POST	POST
Air temp (F)	79	57	75
Relative humidity (%)	22	32	18
Wind velocity (mph)	3	4	2
Soil temp 1 inch (F)	86	52	88

Results and Discussion

No injury to seedling KBG was evident at either study site when observed throughout the growing season. In these studies, neither commercial field was harvested for seed yield, so no yields were taken from the study areas. However, in previous studies conducted by the authors, no crop injury or seed yield reductions have been observed due to mesotrione or flucarbazone applications to KBG (data not shown). Weed control evaluations from Site #1 are summarized in Table 2. In this trial, the 12 oz/a rate of mesotrione represents a 2X rate of application and is not registered for use on KBG. This rate was tested to evaluate potential crop injury and should not be considered to be a recommendation for commercial use. All treatments with mesotrione, either as a preemergence or postemergence application, provided 100% control of henbit at both rating dates, while flucarbazone treatments averaged 52 to 72% henbit control. Flucarbazone applied preemergence, or as a preemergence plus postemergence split application, provided the best control of witchgrass at 73 and 80% control, respectively at the first rating, and 55 and 73% at the second rating date. Mesotrione was less effective with control ranging from 12 to 33%. The Site #1 experimental remained dry and non-irrigated during the establishment period and potentially had a negative impact on witchgrass control from herbicide treatments.

Table 3 summarizes percent visible weed control observed from Site #2. Again, the 12 oz/a rate of mesotrione represents a 2X rate of application and is not registered for use on KBG, but was used to evaluate KBG crop tolerance. No crop injury was observed in this trial at any of the rating dates. This site was irrigated within 24 hours of herbicide application. Witchgrass control averaged 73 to 80% with mesotrione and 53% with flucarbazone-sodium at the first rating date. Mesotrione averaged 73 to 88% control of tumble pigweed, while flucarbazone-sodium provided only 37% control. At the second rating, mesotrione treatments averaged 67 to 87% control of witchgrass, while flucarbazone averaged 62%. Mesotrione controlled tumble pigweed much better (86 to 100%) than did flucarbazone (20%). Witchgrass control was rated again forty days after treatment. Mesotrione averaged 62-80%, while flucarbazone averaged 45%. It appears that the addition of a crop oil concentrate (COC) and liquid nitrogen (Soln 32) may have improved control of witchgrass, slightly (3 to 5%).

From these trials it appears that mesotrione has potential to suppress or control witchgrass during the establishment of KBG. Further investigations should be considered to determine the effect of irrigation timing on the witchgrass control efficacy with these herbicides. It also appears that both mesotrione and flucarbazone have good potential to control henbit and tumble pigweed, both important problem weeds during establishment of KBG seed crops in the Grande Ronde Valley and other locations in the inland Pacific Northwest. Before using either of these herbicides for weed control in Kentucky bluegrass seed production, read and follow complete label information. Particular attention should be paid to crop rotation restrictions, since both of these herbicide materials have considerable soil residual properties.

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Table 2. Witchgrass and henbit control in seedling Kentucky bluegrass (Site #1).

Treatment[1]	Rate	Timing	Witchgrass control		Henbit control	
			6/26/08	7/11/08	6/26/08	7/11/08
	(Product/acre)		---------------------- (%)		----------------------	
Untreated control	--	--	0	0	0	0
mesotrione	6 fl oz	PRE	0	3	100	100
mesotrione	12 fl oz	PRE	0	17	100	100
flucarbazone-sodium	0.6 oz	PRE	73	55	65	52
flucarbazone-sodium/ flucarbazone-sodium + NIS	0.3 oz / 0.3 oz	PRE/POST	80	73	72	62
mesotrione + NIS	3 fl oz	POST	12	33	100	100
mesotrione + NIS	6 fl oz	POST	18	33	100	100
mesotrione + NIS	12 fl oz	POST	27	13	100	100
LSD (0.05)			5	55	8	19

[1] NIS = non-ionic surfactant at 0.25% v/v;

Table 3. Witchgrass and tumble pigweed control in seedling Kentucky bluegrass (Site #2).

Treatment[1]	Rate	Witchgrass control 6/26/08	Witchgrass control 7/11/08	Witchgrass control 7/29/08	Tumble pigweed control 6/26/08	Tumble pigweed control 7/11/08
	(Product/acre)	(%)				
Untreated control	--	0	0	0	0	0
Everest + NIS	0.6 oz	53	62	45	37	20
Callisto + NIS	3 fl oz	77	68	62	78	86
Callisto + NIS	6 fl oz	80	78	75	80	100
Callisto + NIS	12 fl oz	80	87	80	88	100
Callisto + COC	3 fl oz	75	70	65	80	90
Callisto + COC + Soln 32	3 fl oz	73	67	67	80	100
Callisto + COC + Soln 32	6 fl oz	80	83	78	80	100
LSD (0.05)		14	14	13	15	13

[1] NIS = non-ionic surfactant at 0.25% v/v; COC = crop oil concentrate at 1% v/v; Soln 32 at 2.5% v/v.

KENTUCKY BLUEGRASS VARIETY RESPONSE TO PRIMISULFURON

R.P. Affeldt, M.D. Butler and N.K. Lytle

Introduction

Beacon® (primisulfuron) is currently the only registered herbicide that effectively controls rough bluegrass *(Poa trivialis*) and downy brome (*Bromus tectorum*) in seedling Kentucky bluegrass. In commercial seed production, it is conventionally believed that some varieties are extremely sensitive to primisulfuron and that primisulfuron use on sensitive varieties should be completely avoided. Mueller-Warrant et al. (1997) reported differences in varietal sensitivity to primisulfuron, but that research did not report seed yield losses to be severe. Furthermore, many of the varieties previously tested are no longer widely in production. The objective of this research was to further evaluate variety response to primisulfuron, and particularly newer varieties.

Methods and Materials

A field trial was established at the Central Oregon Agricultural Research Center north of Madras, Oregon. The trial consisted of fifteen varieties of Kentucky bluegrass that were chosen for evaluation in a variety trial, which was being conducted in a commercial field at Agency Farms (see "Kentucky Bluegrass Variety Response to No-Burn Residue Management" in this report). The soil was a Madras sandy loam and a soil test prior to seedbed preparation indicated a pH of 7.3 and soil organic matter at 1.6%. Based on the soil test the field was amended with 400 lb/acre of 16-16-16-8 fertilizer. Also, the trial area was treated with 107 lb/acre of metam-sodium (Vapam® 4.26 HL), which was applied through the irrigation system three weeks prior to planting to kill weed seeds in the soil. The trial was planted on August 10, 2007 with rows spacing of 14 and 16 inches every other row. Kentucky bluegrass seeding depth was approximately 0.25 inch; the seeding rate was 5.8 lb/acre for all varieties except 'A01-299', which was seeded at 10 lb/acre because the seed had been harvested in July prior to planting. The trial was sprinkler irrigated and the first irrigation was made on August 13, 2007.

Broadleaf weed control consisted of broadcast applications on September 19, 2007 and again on April 25, 2008 of bromoxynil and MCPA. The few remaining weeds were removed by hand. Another 140 lb/acre of 40-0-0-6 fertilizer was applied April 25, 2008. Fungicide was applied on May 15, 2008 for powdery mildew, consisting of myclobutanil and sulfur.

The trial was arranged as a split-plot design, with 10 x 40 ft main plots and two 10 x 20 ft subplots. Subplots included an untreated check and primisulfuron. Main plots and subplots were randomized within four replicated blocks. The primisulfuron treatment was made as a split-application with 0.018 lb a.i./acre (0.38 oz Beacon®/acre) applied on September 26, 2007 when the Kentucky bluegrass had 1 to 2 tillers, followed by an additional 0.018 lb ai/acre (0.38 oz Beacon®/acre) applied on April 18, 2008 when Kentucky bluegrass was 3 to 6 inches tall. The April 18 primisulfuron application was made just after the first irrigation of the spring. Primisulfuron was applied with a CO_2-pressurized backpack sprayer delivering 20 gal/acre at 40 psi.

Crop injury was determined by making visual evaluations on a percentage scale when Kentucky bluegrass was in a vegetative growth stage on April 18, 2008 and again the Kentucky bluegrass was in a reproductive growth stage on July 3, 2008. Seed yield was measured by harvesting a sample of grass from each plot into burlap sacks when seed moisture for that variety was at 24 to 28%. Harvest dates were as follows:

- July 5, 2008: 'Shamrock' and 'Volt'
- July 7, 2008: 'Atlantis', 'Crest', and 'Merit'
- July 8, 2008: 'Bandera' and 'A00-891'
- July 9, 2008: 'Rhapsody', 'Bordeaux', and 'A01-299'
- July 10, 2008: 'Monte Carlo', 'Valor', and 'A00-1400'
- July 12, 2008: 'Bariris' and 'Zinfandel'

These samples were air-dried and threshed in a Hege plot combine; seed samples were de-bearded and cleaned. Clean seed yield data were analyzed with a paired t-tests comparing primisulfuron to the untreated check using the mixed model in SAS.

Results and Discussion

Primisulfuron injured some varieties more than others and seed yield was reduced compared to the untreated check for six of the fifteen varieties: 'Valor', 'Bariris', 'Monte Carlo', 'A00-891', 'Bandera' and 'Bordeaux' (Table 1). Based on anecdotal information regarding primisulfuron injury to commercial fields of Kentucky bluegrass, yield losses from 80 to 90% may have occurred. The seed yield reductions observed here suggest that other factors are likely to be involved in those severe cases of crop injury.

It is clear that not all varieties were injured, because primisulfuron had no effect on seven of the varieties and actually increased seed yield from 'Atlantis' and 'Shamrock'. We see no clear explanation for this increase. There was very little weed pressure in the trial. The metam-sodium was applied in order to avoid interference from treatment effects on grassy weed competition. Also primisulfuron often reduced lodging as listed in Table 1, but there is no correlation between reduced lodging and reduced seed yield from primisulfuron in this data.

Kentucky bluegrass can be injured from primisulfuron use and some varieties are more susceptible to injury than others. However, in this research most varieties were not injured. The seed yield reductions observed here suggest that other factors are likely to be involved in severe cases of crop injury from primisulfuron. Based on our experience we have the following recommendations to avoid injury to seedling Kentucky bluegrass from primisulfuron.

1. Choose a tolerant variety, if possible.
2. Do not apply the full rate (0.76 oz Beacon®/acre) in one application. Instead split the application as was done in the this trial.
3. In central Oregon, plant Kentucky bluegrass by August 15 to avoid erratic weather conditions that tend to occur in the fall.
4. If possible, avoid applying primisulfuron before or after major changes in daily high temperatures.
5. Only apply primisulfuron once Kentucky bluegrass has reached the 1 to 2 tiller stage.

References

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

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Table 1. Response of newly seeded Kentucky bluegrass to Primisulfuron (Beacon®) herbicide at the Central Oregon Agricultural Research Center, Madras, OR, 2007-2008.[1]

Variety	Vegetative injury[2]	Reduced heading[3]	Lodging[4] Check	Lodging[4] Beacon	Seed yield Check	Seed yield Beacon	Seed yield comparison[5]
	(% Visual)				(lb/acre)		
Atlantis	21	0	78	59	1287	1559	**
Merit	18	3	53	36	1660	1663	NS
Rhapsody	20	5	48	10	1051	992	NS
Valor	23	18	56	2	972	704	**
Bariris	19	4	99	71	827	608	*
Crest	14	15	63	34	1593	1415	NS
Monte Carlo	15	18	38	1	1095	894	*
Shamrock	9	0	79	68	1581	1827	**
A00-891	14	4	81	42	1955	1566	***
A00-1400	13	1	93	44	957	832	NS
Bandera	16	15	28	0	1335	1131	*
Bordeaux	25	9	95	31	1290	979	***
Volt	14	6	79	78	1473	1349	NS
Zinfandel	15	8	40	16	1007	835	NS
A01-299	30	9	78	30	912	898	NS

[1] Primisulfuron (Beacon® 75 DG) was applied at 0.38 oz product/acre on September 26, 2007 when K. bluegrass had 1 to 2 tillers, followed by an additional 0.38 oz product/acre on April 18, 2008, when K. bluegrass was 3 to 6 inches tall. All primisulfuron applications included R-11 non-ionic surfactant at 0.25% v/v.
[2] Injury from primisulfuron compared to an untreated check, evaluated April 18, 2008.
[3] Reduced heading from primisulfuron compared to an untreated check, evaluated July 3, 2008.
[4] Evaluated July 2, 2008.
[5] Comparison made with a paired t-test. NS=Not Significant, * for p=0.1, ** for p=0.05, *** for p=0.01.

KENTUCKY BLUEGRASS VARIETY EVALUATION UNDER NON-THERMAL RESIDUE MANAGEMENT

R.P. Affeldt and N.K. Lytle

Introduction

Recently proposed legislation to eliminate open field burning throughout Oregon has created a sense of urgency among the grass seed industry in central Oregon. The Jefferson County Smoke Management Committee has worked to improve the field burning program in significant ways every year over the last seven years. One major step they have taken has been a ban on all burning within 1/8 mile of US Highways 26 and 97 in Jefferson County. In addition, Affeldt and Weber (2007) conducted large-plot research to re-evaluate alternative residue management practices. Their research showed that with currently available technology there is no suitable replacement for field burning capable of maintaining seed yield in established stands of Kentucky bluegrass.

The current situation consisting of a ban on burning along the highway, a looming statewide ban on burning, and no suitable alternative to burning has created a need for variety performance data for Kentucky bluegrass managed without burning. Kentucky bluegrass variety performance data could be used by growers and seed companies to determine which varieties to grow along the highway. Furthermore, if all burning were banned these data could be used to determine varietal feasibility and the price structure needed to maintain economic viability.

The objective of this research was to evaluate the performance of fifteen Kentucky bluegrass varieties under a non-thermal management system over a three-year period.

Materials and Methods

A trial consisting of large, non-replicated plots was established in a commercial field at Agency Farms north of Madras, Oregon. The soil was a Madras sandy loam and a soil test prior to seedbed preparation indicated a pH of 5.8 and soil organic matter at 1.7%. Based on the soil test the field was amended with 1 ton/acre of lime ($CaCO_3$), 100 lb/acre of potash (K_2O), and 200 lb/acre of 20.5-0-0-24 fertilizer. Each variety was planted on August 7, 2007 in a plot that was roughly 50 x 725 ft, consisting of 20 beds with 2 rows spaced 14 inches apart per bed, with beds spaced 16 inches apart. Kentucky bluegrass seeding depth was approximately 0.25 inch; the seeding rate was 5.8 lb/acre for all varieties except ‘A01-299’, which was seeded at 10 lb/acre because the seed had been harvested in July prior to planting. The plots were randomized but not replicated. Ten beds of ‘Geronimo’ Kentucky bluegrass were planted on the edge of the trial as a border. The trial was furrow irrigated and the first irrigation began the day after planting. After the first irrigation, glyphosate was broadcast on the field to control emerged weeds. One row of ‘Crest’ was missing from the plot and was replanted with a single row seeder on September 6, 2007. Additional weed control consisted of a single broadcast application on October 23, 2007 of bromoxynil, MCPA, and dicamba for broadleaf weed control, hand-hoeing, and a single between-row spray application of the non-selective herbicide paraquat on November 9, 2007. Another 125 lb/acre of 40-0-0-6 fertilizer was applied December 14, 2007. Fungicide was applied on April 2, 2008 for powdery mildew, consisting of myclobutanil and sulfur.

Swathing timing was determined by conducting moisture testing according to methods developed by the International Seed Testing Association. The target seed moisture for swathing was 24 to 28%. Swathing dates were as follows:

- July 4, 2008: ‘Geronimo’ (border), ‘Shamrock’, and ‘Volt’
- July 6, 2008: ‘Crest’, ‘Atlantis’, and ‘Merit’
- July 8, 2008: ‘Bandera’ and ‘A00-891’
- July 9, 2008: ‘Rhapsody’, ‘A00-1400’, ‘Bordeaux’, and ‘A01-299’
- July 10, 2008: ‘Valor’
- July 11, 2008: ‘Bariris’
- July 12, 2008: ‘Monte Carlo’, ‘Zinfandel’

Seed threshing was conducted with an International 403 combine. Each plot was threshed as soon as it was dry. Harvested seed was placed in steel fork-lift totes that were tagged with a lot number and transported to Central Oregon Seeds, Inc. (COSI) for cleaning. Seed cleaning is further discussed below.

Results and Discussion

Variety selection for the trial was established through an advisory committee that consisted of local seed contractors. CHS, COSI and Wilbur-Ellis worked with grass seed breeding companies to select varieties that may have potential under non-thermal production along with other standard varieties. The advisory committee also worked out the overall management strategy for the trial. Agronomic aspects were all done the same for each variety except for the harvest timing, which was done according to maturity as described below. In order to be consistent with actual commercial production practices the committee decided to make each plot as large as possible and forego replicating.

Four plots on one side of the trial had an infestation of downy brome (also known as cheatgrass); these plots were ‘Atlantis’, ‘Bordeaux’, ‘Valor’, and ‘A00-1400’. Beacon® (primisulfuron) is currently the only herbicide that can selectively control downy brome in seedling Kentucky bluegrass, however the advisory committee agreed that primisulfuron should not be used because of the risk of crop injury it poses. Therefore the downy brome was managed with hand-hoeing and between-row spraying. Before the grass began lodging, a visual estimate of the downy brome infestation was made on May 22, 2008 and was determined to be from 20 to 28% for each of these four plots. The rest of the field had very little downy brome infesting it. The fungicide application on April 2 served as preventative step for powdery mildew management. No further development of powdery mildew was observed.

Seed cleaning was completed with commercial equipment at the COSI cleaning facility near Madras. Seed containers were labeled only with a lot number and the cleaning operations were blind, so that COSI personnel handling the seed had no knowledge of variety identity. The percent cleanout, clean seed yield, and pure seed are listed in Table 1 and are ranked by seed yield. Since this was the establishment year there was no effect from not burning post-harvest residues. The ability of these varieties to yield well without burning over the next two years will be the most important part of this research.

In the short-term, the results from this research will be used to determine which varieties can be effectively grown in the phased out area along the Highways 26 and 97. In the long-term, should field burning ever be banned, this research could be used to determine variety placement, crop-rotation length, and price structure needed to maintain economic viability.

References

Affeldt, R. and M. Weber. 2008. Non-thermal residue management in Kentucky bluegrass. Central Oregon Ag. Research Center 2007 Annual Report. Special Report 1084. pp 24-26.

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Table 1. Kentucky bluegrass seed yield from large, non-replicated plots at Agency Farms north of Madras, Oregon, 2007-2008.

Variety	Cleanout	Clean seed yield‡	Pure seed
	(%)	(lb/acre)	(%)
Merit	21	1501	98.25
Shamrock	12	1406	99.26
Crest	17	1399	97.76
Volt	17	1369	94.95
Bandera	15	1364	95.41
A00-891	17	1295	93.24
Atlantis†	25†	1244	98.90
Bordeaux†	29†	1014	94.46
Monte Carlo	19	958	95.31
A01-299	24	918	92.78
Rhapsody	21	873	93.87
Valor†	29†	782	75.04
A00-1400†	38†	752	94.55
Zinfandel	26	740	93.78
Bariris	31	583	94.28

† Indicates plots that had an infestation of downy brome (also known as cheatgrass) that was visually estimated at 20 to 28%.

‡ Seed yield and variety rank were similar in small plots at COARC (data not shown).

FIELD TRIALS IN WESTERN OREGON TO CONTROL SOD WEBWORM IN IRRIGATED BENTGRASS AND UNIRRIGATED TALL FESCUE

G.C. Fisher and A.J. Dreves

Introduction

The sod webworm (SWW), *Chrysoteuchia topiaria* (Zeller) is a familiar fall pest of grass seed, turf and lawns in Oregon. SWW is a persistent, but sporadic pest in perennial ryegrass, tall fescue, bentgrass and orchardgrass. Although a few other webworm species damage grass seed crops in eastern OR, SWW accounts for all damage in western OR grass seed crops. The life history of this single generation per year pest is reviewed in "Sod Webworms of Western Oregon Grass Seed Fields" in the 2007 Seed Production Research publication.

In the last five years, three synthetic pyrethroid insecticides, lambda cyhalothrin (Warrior®), zeta-cypermethrin (Mustang®), and cyfluthrin (Baythroid®) have been labeled for insect and mite control in grass seed crops. Bifenthrin is a fourth that will likely be labeled in 2010. We evaluated three of these products against the industry standard, chlorpyrifos (Lorsban®), for control of the larvae in two field trials conducted in the Willamette Valley, Oregon. A third observation study was performed to control the moth by aerial application of cyfluthrin immediately prior to swathing the grass seed crop.

Study 1: Control of sod webworm larvae in irrigated bentgrass.

Methods and Materials

The purpose of this trial was to compare two synthetic pyrethroid insecticides to chlorpyrifos, Lorsban 4E® insecticide, for control of SWW larvae when applied post-harvest and immediately irrigated into the thatch. This field was located in Linn Co., Oregon and sustained damage from SWW larvae the previous year. Moths were prevalent in the field during June, 2005. Pretreatment sod samples indicated light populations of larvae were present. Plots were 20 ft x 20 ft, replicated 4 times in a randomized block design. The field was irrigated with approximately 2 inches of water within a week of the trial. The treatments were applied with CO_2 powered backpack sprayer in the equivalent of 40 gallons of water per acre on September 5, 2005. One inch of overhead irrigation was applied by wheel line to all treatments within 2 hours of application. On September 12 (7 DAT) and again on October 2 (27 DAT), five 12-in x 12-in squares of turf to a depth of 3 inches deep were removed from each plot; live SWW larvae were counted and recorded. Results are presented in Table 1.

Table 1. Mean number of live sod webworm larvae at 7 and 27 days after treatment.

		Mean no. of live SWW larvae per core[1,2]	
Treatment	Rate	7 DAT	27 DAT
	(lb a.i./a)	(9/12)	(10/2)
Bifenthrin	0.2	0.1 ± 0.1 a	0.1 ± 0.1 a
Lorsban 4E®	2.0	0.3 ± 0.3 a	0.2 ± 0.1 a
Warrior II®	0.1	0.6 ± 0.3 a	0.3 ± 0.1 a
Untreated Check	0	0.9 ± 0.3 a	0.9 ± 0.4 a
		NS[3]	*NS*

[1] Means followed by the same letter within the column do not differ significantly at P=0.05 (Tukey LSD ANOVA analysis).
[2] Five, 12-in x 12-in grass cores were taken for 7 and 21 days after treatment.
[3] *NS* = treatments not significantly different.

Results and Discussion

Even though SWW moths were numerous in this field during the summer, a significant larval infestation did not develop. Numbers of live larvae within the treated plots did not significantly differ from those in the untreated. However, we believe the reduction in live larvae across treated plots compared to numbers of larvae found in the untreated plots are indicative of the performance expected from these insecticides when applied to larger infestations of SWW larvae.

Study 2: Control of sod webworm larvae in unirrigated tall fescue.

Materials and Methods

The purpose of this trial was to compare chlorpyrifos (Lorsban 4E insecticide) to cyfluthrin (Baythroid XL insecticide) for the control of SWW larvae in a multi-year tall fescue field with post-harvest residues chopped back onto the crop annually. This field was heavily infested in 2007. On September 26 and 27, slight rainfall occurred in the south valley, moistening dry soil. A modified randomized complete block design with two replications was established in the south part of the tall fescue field in Linn Co, Oregon. Plots were 250 ft x 90 ft. Two untreated plots were created, measuring 180 ft x 28 ft, and placed between the treated plots. Pretreatment samples consisting of eight 6-inch diameter core samples to a depth of 4 inches were taken on September 26, from the 6 plots. Numbers of live SWW larvae were recorded.

On October 3, Lorsban 4E and Baythroid XL were applied in the equivalent of 18 gallons of water/acre with a 45 ft wide tractor mounted boom. Approximately 0.75 inch of rain fell on this site over the next 72 hours. On October 9, six 8-inch diameter cores were taken in each of the 6 blocks, teased apart and numbers of live sod webworm larvae counted and recorded. Mean numbers of larvae per crown are reported by treatment (Table 2).

Table 2. Control of sod webworm larvae infesting tall fescue.

Treatment	Product rate	Mean no. of live SWW larvae per crown		Percent SWW reduction within treatment	Percent SWW reduction compared to untreated
		Pre-	6 DAT		
	(lb a.i./a)	(9/26/08)	(10/9/08)	(%)	(%)
Baythroid XL	0.02	5.6 ± 0.6 a	2.5 ± 1.0 a	56	42
Lorsban 4E®	1.0	6.1 ± 1.1 a	3.4 ± 0.9 a	44	29
Untreated Check	--	5.6 ± 1.0 a	4.8 ± 2.0 a	15	--
		NS[3]	*NS*		

[1] Means followed by the same letter within the column do not differ significantly at *P*=0.05 (Tukey LSD, ANOVA analysis).
[2] Eight, 6-inch grass cores were taken for pre-treatment counts; six, 8-inch cores were taken for post-treatment counts.
[3] *NS* = treatments not significantly different.

Results and Discussion

Larval control was disappointing. Neither product provided acceptable control (75% or greater of the pre-treatment numbers of larvae). Sod webworm larvae could be found on top of grass crowns at the lower levels of the straw as well as in the soil below the crowns. Post harvest straw residue varied from 1 to 4 inches deep on fescue crowns in all plots. Both products tested are quite insoluble, both adsorb readily to organic matter and neither rehydrate after drying on foliage. We believe the heavy straw load and insufficient rain during application were in part responsible for the mediocre larval control. We believe that control would be improved if: (1) irrigation immediately followed application, (2) post-harvest straw residue was removed, and (3) the target grass had a shallower root system.

Study 3: July control of sod webworm moths in tall fescue using cyfluthrin to reduce fall infestations.

Introduction

The control of SWW larvae in grass seed fields without irrigation and with post-harvest straw chopped back onto the crop is problematic. Prior to its cancellation for use on grass seed crops, Diazinon insecticide was used to control SWW adults prior to peak flight. This practice was used when it became apparent that carbon residue from fields burned more than three years in a row adsorbed Diazinon and made it inactive for larval control. The pyrethroid insecticides recently registered on grass seed crops in Oregon are considered to have an approximate two week residual for insect control and an even longer residual for "repelling" insects from treated foliage.

The purpose of this trial was to evaluate application of a pyrethroid insecticide to a tall fescue seed crop in the summer at approximately 7 to 10 days before peak flight of SWW to kill or repel egg-laying SWW moths that create the larval infestations. This strategy relies on the placement of pheromone traps in fields to detect, trap, record and total numbers of moths caught per trap every 5 days beginning June 1. Numbers of moths caught in traps in a field, coupled with the degree-days that have accumulated since January 1 are used to determine the potential for damage in the fall from larvae as well as proper timing for an insecticide to control the moths.

Previous research related the numbers of SWW moths caught in pheromone traps to subsequent injury by the larvae. In Western Oregon, it has been generally considered that if from 50 to >75 moths are collected in any 5 day period per pheromone trap in a grass seed field within 10 days prior to or at peak SWW flight, then there is potential for larval damage in the fall (Jim Kamm, personal comm.; Glenn Fisher, personal experience). Peak flights for SWW in western Oregon grass seed fields have usually occurred within a few days of 1575 degree-days accumulated from January 1 using a developmental temperature threshold of 42°F (Kamm & McDonough 1982).

Materials and Methods

Three tall fescue seed fields with heavy straw loads were selected for this observation trial because of serious damage sustained in 2007. In 2008, Western Farm Service, Tangent Branch, placed, serviced and monitored the SWW pheromone traps used in these three fields through the early part of the flight season. By late June, pheromone trap moth catches in these fields indicated potential for larval damage in the fall. Therefore, Baythroid XL insecticide (cyfluthrin) at 0.022 lb a.i./a was aerially-applied between July 2 and July 5 using pheromone trap catches and degree-day accumulation to determine timing of application. The extreme south ends of these fields were bordered by trees and a public road. This prevented aerial application to a substantial part of each field. These unsprayed areas served as untreated checks when evaluating fall larval populations in the treated fields. On September 3 (60 days after treatment), six 8-inch diameter crowns were taken from 2 locations within the Baythroid-treated section of each field and from one location in the unsprayed area of each field. Cores were dissected and live larvae (primarily second & third instars) were recorded. Results are presented in Table 3 as mean number of live larvae per crown.

Table 3. Pheromone trap catches and subsequent SWW larval infestations in untreated and treated plots in three established tall fescue fields in Linn Co., Oregon.

Tall fescue field number	Total no. of SWW male moths per pheromone trap by date 6/18/08	6/23/08	6/30/08	Treatment	Mean no. SWW larvae per 8-inch crown [2,3] 60 DAT (9/3/08)
1	8	16	35		
				Untreated	1.4
				Baythroid XL by air[1]	1.9
				Baythroid XL by air	1.7
2	2	10	44		
				Untreated	3.4
				Baythroid XL by air	1.4
				Baythroid XL by air	0.7
3	2	45	67		
				Untreated	4.2
				Baythroid XL by air	0.4
				Baythroid XL by air	0

[1] Baythroid XL applied by air in early July 2008 at 2.8 fl oz/a (0.022 lb a.i./a).
[2] Data was not analyzed with statistics.
[3] Six, 8-inch diameter crowns were sampled for larvae.

Results and Discussion

The larval infestations recorded in the untreated areas of these three fields show a direct relation between numbers of SWW moths caught per pheromone trap and subsequent size of larval infestations. Fields 2 and 3 had pheromone trap catches portending economic larval infestations that did occur in the untreated parts of these fields. An aerial summer spray timed a week to ten days prior to flight peak reduced subsequent larval numbers in the fall below damaging levels (Table 3).

Field 1 had a relatively small flight of moths (35/trap/week) prior to peak flight. The numbers of larvae found in both treated and untreated areas likely arose from eggs deposited by female moths prior to the moth spray.

Conclusion

Control of sod webworm larvae is best accomplished when insecticide applications are made in late August or early September when SWW larvae are small, first through third instars. Insecticides should be applied to pre-irrigated soil and followed immediately with from 1 to 2 inches of overhead irrigation or rain. Control of larvae later than early September in unirrigated, established tall fescue fields with heavy post harvest straw loads is still problematic. This is because: (1) the timing is too late, larvae have already caused substantial damage, (2) insufficient rainfall is available in early September when control timing is optimal, and (3) post-harvest residues in most fields adsorb insecticides before reaching the larvae. Control of SWW adults in these fields can offer an effective alternative to larval control.

References

Kamm, J.A. and L.M. McDonough. 1982. Seasonal flight of the cranberry girdler determined with pheromone traps. New York Entomol. Soc., XC (2): 94-8.

EFFECTS OF PRECIPITATION ON MOLLUSCICIDAL EFFICACY

W.E. Gavin, G.C. Fisher, A.J. Dreves and G.M. Banowetz

Introduction

Control of the gray field slug (GFS), *Derocerus reticulatum* (Mueller), is poor using baited products during cool, wet conditions. By mid- to late-November, soil temperatures generally stabilize to < 8.5 °C at a 5.0 cm depth, and daily to thrice weekly rainfall patterns appear. During establishment of a new stand, growers need to take full advantage of warmer soil temperatures during September and October to reach some critical growth stage in seedling development. To achieve sufficient seedling development in the fall, this small window of opportunity must correspond with sufficient soil moisture. Some years, like the autumn of 2008, this does not occur. When this occurs, growers are placed at a disadvantage later when seedling growth slows, slug populations rapidly increase, and bait product weathering from rainfall or excessive soil moisture is believed to decrease their efficacy (Fisher et. al., personnel communication, and Gavin et. al., 2006). Considerable advances have been made in development of formulations that prolong the effective life of baits in the field. Nonetheless, both attractiveness and toxicity of baits decline rapidly on exposure to moist conditions. Furthermore, extreme environmental conditions can reduce or arrest mollusc activity (Godan, 1983). Bait application should coincide with periods of high mollusc activity, under moist but not excessively wet weather (Barker and Watts, 2002).

A series of field, growth chamber, and greenhouse experiments were conducted to quantify efficacy differences between molluscicides under simulated (greenhouse) and natural (field) rainfall conditions. In-field weathering evaluations were difficult because of the high variance in daily rainfall, temperatures, and animal disturbances. In greenhouse experiments, the products were weathered in arenas using native soil, and placed on benches in a cool greenhouse (10°C day; 6°C night), under natural light conditions. Double pane greenhouse glass was reported to have small quantatative and no qualatative effect on spectral wavelenths, including U.V. (Kamm, et al. 1992).

All data were subjected to analysis of variance (ANOVA) and means were separated using the Fisher Protected (LSD) Test at *P*-value = 0.05. All values were transformed using log transformation (x + .05) to equalize the variance. Original means are presented in tables.

Field experiment methods

Field experiments utilized six formulations of commercial metaldehyde baits that were first exposed to November, western Oregon weather (Table 1) for 0, 3, 5, and 7 days before being placed in the field. Our objective was to determine if "weathering" influenced (1) attractiveness or (2) resulting mortalities through time for a bait product as well as among different products. Weather data were obtained from the Corvallis, Oregon State University AgriMet Weather Station (Lat. 4438, Long. 12311, Elev. 70 meter.; Table 2). The weathered baits were evaluated in a tall fescue field less than a mile east of the Oregon State University research farm. Treatments were replicated six times in a Randomized Controlled Block (RCB) design. Twenty-four treatments were applied by distributing 0.10 grams (3 pellets per treatment, with exception of Metarex totaling 10 pellets) of weathered bait on 15 cm square soil 'paddy' on 14 Nov 2006. The baited paddy was placed in a 30 x 30 cm of soil scraped free of vegetation within each 4.5 x 4.5 meter plot in the morning. Each morning thereafter, between 7:30 and 8:00 a.m., numbers of live, sick, and dead slugs found within each arena were recorded and the slugs were placed in a ventilated plastic bag. This bag remained in the field and was shaded from sun. Bags were inspected for slug mortality at 1, 2, 3, 6 days after treatment. Efficacy of the weathered baits were determined by comparing numbers of slugs attracted to as well as their post-treatment mortalities through time.

Field experimental results and discussion

After baits were placed in the field, they received an additional 3.6 cm of rain, a daily mean temperature of 7.5°C (ranging from 1.5 to 13.6°C, a mean high gust of 24.6 km/h (ranging from 14 49 km/h) with a mean wind of 8 km/h (ranging from 2.8 to 16 km/h) (Table 3). Bait pellets held their form after 7 DAT in the field. Pellets were missing from plots after some treatments and it appeared that slugs and earthworms were responsible.

During the course of this 6 day trial, daily numbers of slugs recorded at any given bait station ranged from 0 to 14 and, averaged ~6 slugs per station. Slug visitation to all baits dropped significantly after 1 day; 64% of the slugs recorded over all plots were reported on the first day after treatment and 91% of the total slugs visiting baits were collected within 2 DAT. In this field trial, the weathered baits of a product attracted just as many slugs as the unweathered bait. In fact there were no statistical differences in numbers of slugs attracted to any of the baits. Although there were statistical differences in observed slug mortality among the weathered baits, the numbers of slugs that died over all treatments was about 33% (Table 4).

Upon examination of slugs stored in plastic bags in the field at 1 DAT, 90% of slugs were not dead, but some appeared "sick" with symptoms of twisting, discoloring and darkened bodies, swollen mantles, extended body, extruding slime, antennae that were shortened or not extended, mouthparts malformed and expanded. Only 64% of slugs died upon completion of trial.

Greenhouse and growth chamber experimental methods
Slugs were collected from the field and maintained in growth chambers (10°C, 8 h daylength) for two weeks before use in experiments. Slugs received lettuce as a food source twice per week. Experiments were conducted in growth chambers maintained at 10/7°C day/night temperatures, with 8 hours of low level light supplied by one 25W incandescent light bulb. Ten gray field slugs (GFS) were placed in a round arena (30 cm diameter x 12 cm deep) covered with a screened lid. Arenas were partially filled with native soil (Dayton/ Woodburn). Sixty perennial ryegrass (*Lolium perenne* L.) seeds were planted in a center row arrangement and grown in the greenhouse until emergence. All seedlings were utilized at 6 d old.

All arenas were randomized on greenhouse benches to provide equal cooling and lighting, rotated every three days, and replicated eight times. Pre-moistened cotton felt pads (3 mm thick) were used in each arena as slug resting and egg-laying sites.

Experimental precipitation was simulated using a mister and domestic tap water. A fine-mist nozzle was fitted to a hose that supplied 20 psi, measured with a pressure reguator, positioned 30 cm above each arena. Five millimeters of water were supplied twice daily for 0, 3, 6, 9, 12 or 15 days. All aging and precipitation applications were performed in the greenhouse in open arenas exposed to sunlight prior to the beginning of slug introduction, and moving to growth chambers.

A single rate of product was calculated for each arena corresponding to field rates. Products and their rates were: Deadline MP®, 16.8 kg/ha, 4 pellets per arena; OR-CAL® blue, 17.3 kg/ha, 4 pellets per arena; MetaRex®, 11.3 kg/ha, 8 pellets per arena: Sluggo® shorts, 11.1 kg/ha, 7 pellets per arena; and Durham 7.5® granular 63 mg per arena. All products simulated field rates used by growers and were obtained from local sources (Crop Protection Service). Slugs were exposed to weathered baits for 7 d and held over for an additional 14 d to determine recovery rates.

Greenhouse results and discussion
Slug Mortality.
After receiving a total of 60 mm of precipitation, all six products killed significantly more slugs than the untreated control by the sixth day (Figure 1).

After nine days, the Durham granular product was partially covered by soil deflected material, thereby reducing its overall efficacy for the remainder of the experiment. Slugs were reduced by 48, 42 and 30% after 0, 3 and 6 days respectiviely. Durham 7.5 killed 18% of the total sum of slugs killed in these experiments, at a cost per acre of $22.50.

Deadline (DMP) reduced slugs from 30 to 22% from day 0 to day 15, respectively, making it the second most weather fast product. All other products outperformed DMP during the first three intervals tested, but DMP provided consistent control for the remainder of the experiment. There were significant differences from the untreated control out to day 15. Deadline MP killed 15% of the total sum of slugs killed in these experiments, at a cost of $16.00 per acre.

MetaRex orange bait was the most weather-fast product tested in these experiments, killing a total sum of 22% of the slugs at a cost of $26.00 per acre. MetaRex provided control that was statistically better than untreated controls out to day 15, reducing slugs by 22%. This product was the smallest bait tested, giving it an advantage of more point sources per unit area than its competitors.

The iron phosphate based bait Sluggo, was the least weather fast bait in these experiments. The softness of this bait noticeably deteriorated after three or four hours. This product consistently killed more slugs (60%) on the first night of baiting than the other products and remained significantly active up to day six (28%). Sluggo killed 18% of the total sum of slugs killed in these experiments, at a cost of $15.00 per acre.

OR-CAL was the third most weather-fast bait tested, killing a range of 42 to 25% of slugs from day 0 out to day 12, respectively. OR-CAL killed 19% of the total sum of slugs in these experiments at a cost of $14.00 per acre, making it the most cost effective product tested.

Seedling Survival
Durham granular protected more ryegrass seedlings in the first six days of this experiment. It appears that abrupt feeding cessation occurs when this product is ingested, even after it has received up to 60 mm of precipitation. This product offers an advantage at protecting crop during a crisis outbreak of the gray field slug during seedling emergence. Fifty-two percent of the seedlings were protected out to day 12 (Figure 2). Durham protected 24% of the total sum of seedlings in these experiments.

Deadline, MetaRex, and OR-CAL baits protected fewer seedlings than Durham during the first six days, but remained active as long as 15 days, after 150 mm of precipitation. Deadline, MetaRex, and OR-CAL protected 24, 22 and 17% of the total sum of seedlings in these experiments, respectively.

Sluggo baits protected the fewest number of seedlings during these experiments, lasting only six days. Sluggo protected 13% of the total sum of seedlings in these experiments.

Egg Reduction.
Reducing the recruitment of additional slugs in a field can serve as an important tool for integrated pest management strategies. All products reduced the number of eggs laid after 3 days of exposure (Figure 3). Only Deadline and OR-CAL reduced eggs after six days of exposure. No products reduced eggs past six days of exposure. During cool, wet conditions absent of active precipitation events, we have shown a sub-

stantial reduction in egg production from these products (Gavin et al., 2006).

Conclusion

Precipitation events influence slug activity and overall product performance. Both field and simulated indoor experiments have shown no significant differences *between* product efficacy when weathered for 0, 3, 6, 9, 12 or 15 days. Both MetaRex and Deadline MP demonstrated their weather fastness out to 15 days, and OR-CAL out to 12 days, when compared to the untreated control. Sluggo was the least weather-fast product tested, observing physical structural breakdown in as little as four hours. Our highest level of slug mortality (60%) occurred on the first day of application with Sluggo. The effectiveness of Durham was hampered by soil deflected material which covered the product.

Durham granulars protected more seedlings during the 0, 3 and 6 day aging experiment, however, MetaRex, OR-CAL, and Deadline MP protected seedlings out to 15 days. It may be cost effective to apply Durham granular during initial seedling emergence when slug populations are high and precipitation is low.

All products reduced egg production after three days of exposure, only Deadline and OR-CAL baits reduced eggs after 6 days of exposure. Reducing eggs during active rain periods with these products will remain challenging.

Acknowledgements

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Literature

Barker, G.M, C. Watts, 2002. Management of the invasive alien snail Cantareus aspersus on conservation land. Doc Science Internal Series, 31. Department of Conservation, Wellington, New Zealand.

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

W.E. Gavin, G.M. Banowetz, S.M. Griffith, G.W. Mueller-Warrant, G.W. Whittaker. 2007. Effects of baits and bait alternatives on slug mortality, egg production, and seedling survival. *In* W.C. Young III (ed.), Seed Production Research, Oregon State Univ., Ext/CrS 127, 3/08 pp. 12-17.

D. Godan. 1983: *In* Pest slugs and snails: Biology and control. 2nd edn. Springer-Verlag, Berlin, Heidelberg, NewYork.

J.A. Kamm, Fairchild, C.E., W.E. Gavin, and T.M. Cooper. 1992. Influence of celestial light on visual and olfactory behavior of seed chalcids (Hymenoptera: Eurytomidae). Journal of Insect Beharior, vol. 5, no. 2., 273-287.

Table 1. Descriptions of slug control formulations tested.

Product	Formulation	Manufacturer
Deadline MP	4%, metaldehyde slug bait	Amvac, Los Angeles, CA, USA
Durham 7.5	7.5%, metaldehyde, granular	Amvac, Los Angeles, CA, USA
MetaRex orange	4%, metaldehyde, slug bait	De Sangosse SA, Pont Du Casse, France
Sluggo	1 %, iron phosphate, slug bait	Lawn and Garden Products, Inc., Fresno, CA, USA
Wecon O	4%, metaldehyde slug bait	OR-CAL, Junction City, OR, USA
Wecon AY	4%, metaldehyde slug bait	OR-CAL, Junction City, OR, USA
Metaldehyde 4	4%, metaldehyde slug bait	
Wilco Blue 3.25 (= OR-CAL blue)	3.25%, metaldehyde slug bait	OR-CAL, Junction City, OR, USA

Table 2. Daily weather experienced during field trials.

Date	Min. temp	Max temp.	Mean temp.	Precip.	Humidity	Wind mean	Wind gust
	----------------------(°F)------------------------			(inch)	(%)	(km/h)	(km/h)
11/7/06*[1]	48.3	62.9	58.0	2.4	92.2	11.1	35.3
11/8/06	44.9	52.1	48.4	0.2	91.4	7.6	28.9
11/9/06	43.0	52.7	47.1	0.1	86.9	7.4	29.3
11/10/09	42.8	52.6	46.9	1.1	78.9	12.7	51.5
11/11/09	41.3	52.3	45.2	0.4	89.0	6.7	23.6
11/12/09	41.3	53.6	44.8	0.5	84.5	15.8	57.9
11/13/09	42.3	53.2	49.2	0.1	83.5	10.1	51.1
11/14/06*[2]	34.8	54.6	45.4	0.0	83.8	4.6	20.1
11/15/06	47.2	56.5	50.8	0.5	78.4	15.3	49.0
11/16/06	37.6	55.0	44.6	0.0	91.6	3.5	17.3
11/17/06	35.0	48.8	40.4	0.0	95.8	2.9	14.5
11/18/06	39.4	44.2	41.9	0.0	94.5	5.4	22.2
11/19/06	40.5	52.1	46.4	0.9	96.5	5.0	18.7
11/20/06	43.3	57.3	49.6	0.1	87.5	6.6	30.7
11/21/06	43.1	50.4	46.6	1.4	84.9	12.1	52.9

*[1] Weathering of baits began on 11/7/2006.
*[2] All weathered baits were placed in the field on 11/14/2006.

Table 3. Accumulated mean weather during field trials.

	Total prec.	Wind gust	Mean air temp.	Relative humidity
	(in.)	(km/h)	(°C)	(%)
7 days	4.7	39.6	9.1	86.6
5 days	4.1	33.8	9.5	87.6
3 days	2.6	31.2	10.6	90.2
0 days	--	--		--

Table 4. Field trial comparisons of slug deaths from six products that were weathered for 0, 3, 5 and 7 days.

Product	Days Exposed	1 DAT (15 Nov)	2 DAT (16 Nov)	3 DAT (17 Nov)	6 DAT Total Slugs (20 Nov)	6 DAT Mean Slug Mortality (20 Nov)
Wecon O	7 days	3.5	0.83	0.33	4.7	1.7 abcdef[1]
Wecon O	5 days	3	1.3	1	5.3	1.8 abcde
Wecon O	3 days	2.7	1.8	0.33	4.8	1.7 abcdef
Wecon O	0 days	3.8	2	0.83	6.7	2.3 abcde
Wecon AY	7 days	4.7	1.7	0.33	6.7	3.8 a
Wecon AY	5 days	2.5	1.7	0.67	4.8	3.0 ab
Wecon AY	3 days	3.5	1.7	1.2	6.3	3.0 ab
Wecon AY	0 days	2	1.7	0.33	4	2.5 abcd
Deadline® M-Ps™	7 days	4.7	0.83	0.33	5.8	3.2 a
Deadline® M-Ps™	5 days	2.7	1.3	0.33	4.5	1.8 bcdef
Deadline® M-Ps™	3 days	2.7	1.5	0.33	4.5	0.33 fg
Deadline® M-Ps™	0 days	2.8	2.2	1.33	6.3	2. 3abcde
Metarex 4%	7 days	4.3	1.7	0.5	6.5	2. 8ab
Metarex 4%	5 days	4.7	1.5	0.83	7	3.3 a
Metarex 4%	3 days	3.8	1.7	0.5	6	1.8 abc
Metarex 4%	0 days	4	3.3	0.33	7.7	3.0 ab
Metaldehyde 4	7 days	3.8	0.67	0	4.5	0.83 def
Metaldehyde 4	5 days	3.5	1.7	0	5.2	0 f
Metaldehyde 4	3 days	3.8	0.67	0.5	5	0.67 def
Metaldehyde 4	0 days	3.5	1	0.33	4.8	1.0 cdef
Wilco Blue 3.25	7 days	3	1	0.17	4.2	0.83 def
Wilco Blue 3.25	5 days	3.3	2.3	0.5	6.2	0.50 ef
Wilco Blue 3.25	3 days	4.3	0.83	0.5	5.6	1.8 bcdef
Wilco Blue 3.25	0 days	3.7	2	0.67	6.3	0.33 f
	F	0.66	1.07	1.21	0.61	4.11
	P	0.87	0.39	0.25	0.91	<0.0001

[1] Means (original) followed by the same letter are not significantly different ($P = 0.05$; Fisher LSD).

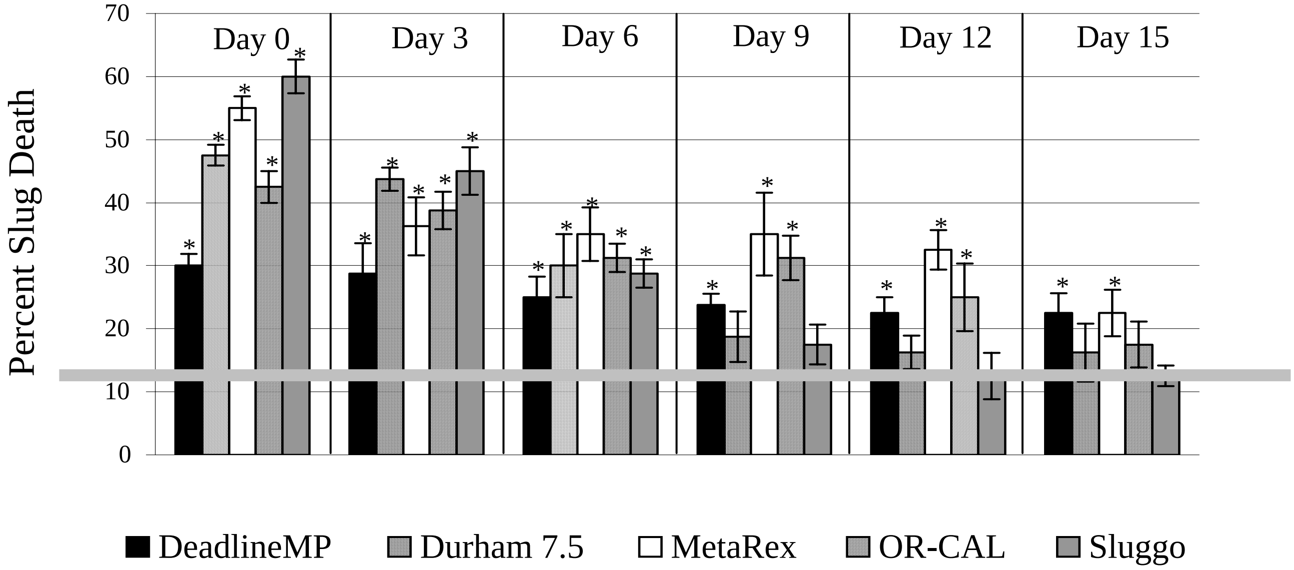

Figure 1. Average means comparison of weathered products affecting slug mortality by *product age x untreated control*. Gray line represents average mean slug death in the untreated control. [1]

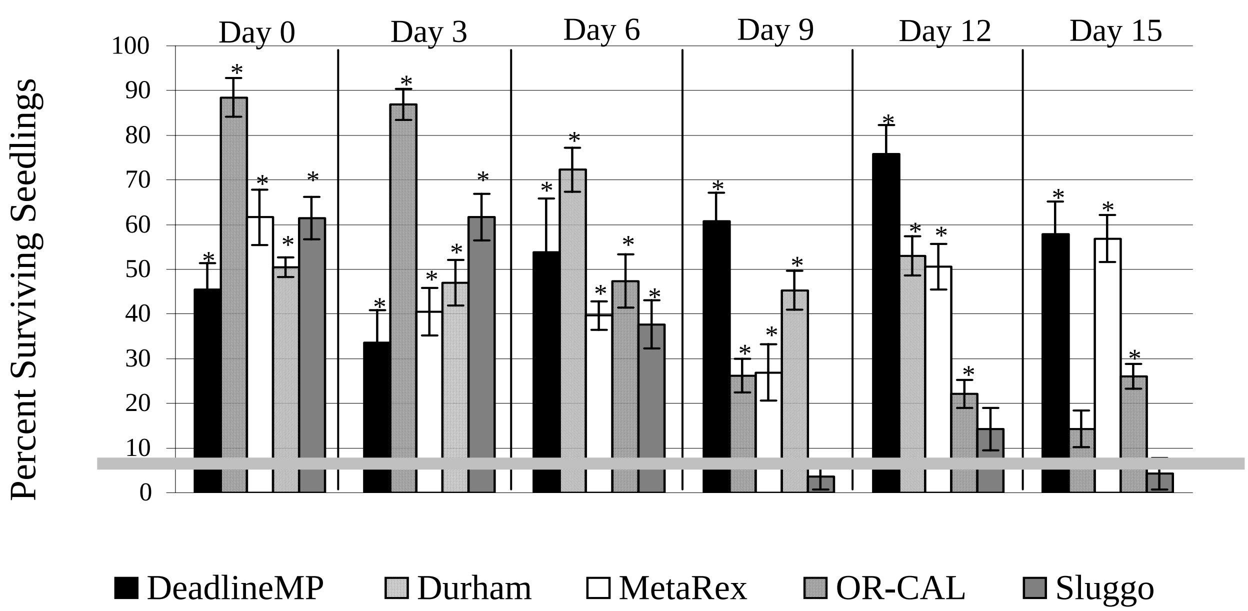

Figure 2. Average means comparison of weathered products affecting seedling survival by *product age x untreated control*. Gray line represents average mean seedling survival in the untreated control. [1]

[1] * $P = 0.05$; Fisher LSD

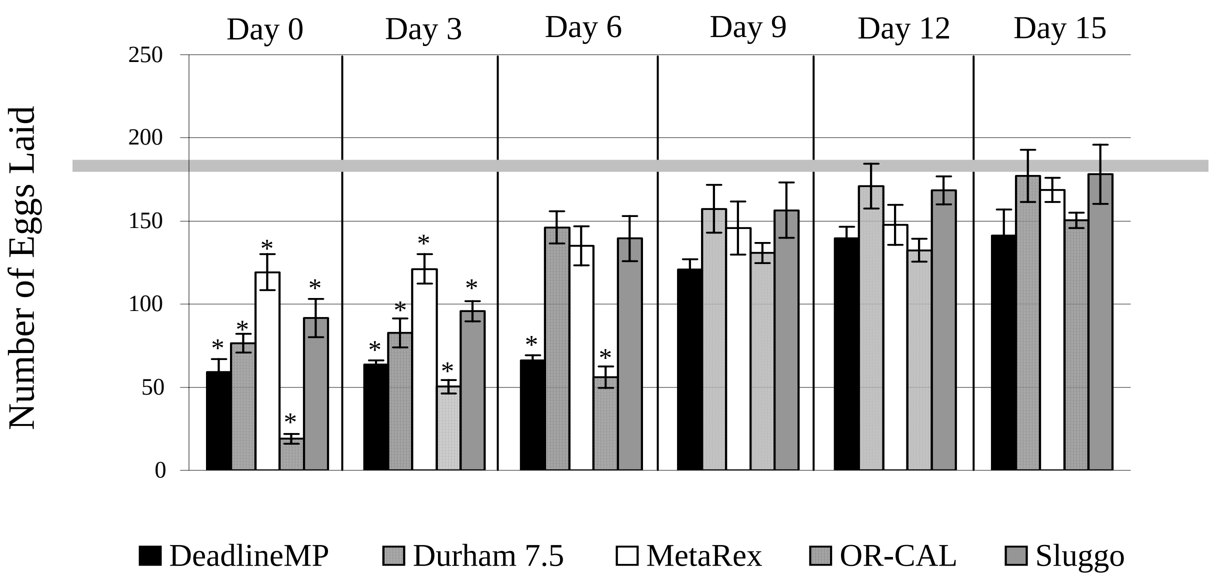

Figure 3. Average means comparison of weathered products reducing egg production by *product age x untreated control*. Gray line represents average mean number of eggs laid in the untreated control. [1]

[1] * P = 0.05; Fisher LSD

EFFECT OF GRAZING SHEEP ON GRAY FIELD SLUG POPULATIONS IN WHITE CLOVER SEED FIELDS

A.J. Dreves and G.C. Fisher

Introduction

The gray field slug (GFS), *Deroceras reticulatum,* is among the most important pests in western Oregon grass seed and rotational crops.

White clover grown for seed is one of the rotational crops in grass seed systems in the Willamette Valley. In addition to providing a seed crop, white clover fixes nitrogen for future crops, is a valuable forage for sheep grazing and plays an important role in honey production. It grows rapidly, has a shallow root system, and spreads via stolons. It grows best during cool, moist weather on well-drained, fertile soils with a pH between 6 and 7. However, populations of the GFS build to extremely high levels over the life of a clover stand in the Willamette Valley, making it quite difficult to establish a grass seed crop into clover with minimum-tillage or no-till practices.

Growers have observed that with extreme grazing of clover immediately prior to seeding perennial ryegrass, slug pressure and seedling losses greatly diminish. Jones (1992) reported that "mob sheep grazing" of clover prior to seeding a grass pasture results in better seedling survival than if clover is not grazed with sheep. Similar results have been reported from New Zealand by Barker (1991) and Clear Hill and Silverton (1996). Sheep probably reduce slug levels by treading on slugs and slug eggs, and incidentally consuming them while grazing.

The study objective consists of developing preliminary quantitative information on the immediate effect of grazing white clover with sheep versus no grazing on population densities of GFS.

Methods

This study was conducted in a third year, unirrigated white clover field grown in Linn Co., Oregon. In October 2007, slug population densities in white clover were compared between plots grazed with sheep during the summer after clover seed harvest and plots where sheep were excluded. We determined slug densities in the two treatments immediately after sheep removal and prior to direct seeding of perennial ryegrass (PRG) in the fall.

In summer 2007, treatments (grazed with sheep and not grazed) were arranged in a randomized complete block design with three replications. Each plot measured 50 x 50 feet. An electric fence excluded the sheep from the no-graze plots. Four 19 x 19 inch "slug blankets" provided by Liphatec Co., were randomly placed in each plot to obtain relative densities of slugs between treatments. Slug blankets were first dunked in a 5-gal bucket of water, placed in the plots and securely fastened with metal stakes over the soil and low-growing foliage. The black perforated side of the blanket (where slugs gather) was placed face down with the silver reflective lining face up. On October 29, four days after placement of the blankets (4 DAT), stakes were removed and the blankets were turned over for slug counts. After approximately one minute of search time, total numbers of slugs on the blankets and on the soil and foliage were recorded. The majority of slugs in all plots were found on the blankets, but some were found on the clover foliage and soil. Data was analyzed using ANOVA (SAS Institute 9.1), means were log-transformed and separated using Tukey's studentized range test. Original means are presented in Table 1. Mean temperature ranged from 37.5 to 59.3°F with a total precipitation of 0.06 inches over the trial period.

Table 1. Mean numbers of GFS under Liphatec slug blankets in white clover plots either grazed by sheep or ungrazed, 2007.

Field Management	Mean no. of slugs per blanket [1,2] 10/29/07 (4 DAT) Reps (1,2 & 3)	Reps 2&3 [3]
Sheep-Grazed	19.2 ± 3.9 b	10.3 ± 1.1 b
No-Sheep	29.0 ± 2.6 a	25.9 ± 3.4 a
% Slug Reduction	34 to 60% less	
P-value	= 0.0543*	< 0.0006**

[1] Each plot contained 4 blankets per plot, totaling 12 blankets.
[2] Means were separated using Tukey's studentized range (HSD) test. Means followed by different letters are significantly different.
[3] Removed data from replication 1. It was uncertain why this plot received very little grazing pressure compared to replications 2 and 3.

Results

Approximately 100-300 sheep were grazed for three to four weeks on this 80 acre field prior to assessing the density of slug populations. Fewer slugs were found under blankets in grazed plots than in ungrazed plots, but this difference was marginal ($p < 0.0543$) (Table 1). However, it was observed that after the sheep were removed, block 1 had an amount of foliage equal to the foliage in the plots without sheep. It was obvious the sheep avoided and did not feed as much in this area of the field. When data from replicate 1 were removed, there was a highly significant difference in slug densities between plots with and without sheep ($p < 0.0006$) (Table 1). There were approximately 2.5 times fewer GFS in the plots grazed by sheep. This preliminary study indicates that grazing sheep may be an effective method for reducing slug populations in a white clover field immediately before direct seeding to PRG. Future research should attempt to quantify animal units per acre and duration of grazing needed to reduce GFS populations below levels that prevent PRG seedling establishment.

References

Jones, L. 1992. Preliminary trials using a white clover (*Trifolium repens* L.) understory to supply the nitrogen requirements of a cereal crop. Grass and Forage Science, 47 (4), pp. 366 -374.

Barker, G.M. 1991. Biology of slugs (Agriolimacidae and Arionidae: Mollusca) in New Zealand hill country pastures. Oecologia, 85 (4), pp. 581-595.

Clear Hill, B.H. and J. Silvertown. 1997. Higher-order interaction between mollusks and sheet affecting seedling numbers in grassland. Acta Ecologica,18 (5), pp. 587-596.

FALL EVALUATION OF MOLLUSCIDES FOR CONTROL OF SLUGS IN THIRD YEAR WHITE CLOVER DIRECT SEEDED TO PERENNIAL RYEGRASS

G.C. Fisher and A.J. Dreves

Introduction
Reduction or elimination of open field burning, adoption of no-till farming practices, and greatly increased levels of organic matter in western Oregon's grass seed producing areas have increased food, habitat and moisture essential for increasing populations of certain pests like slugs. White clover fields in the Willamette Valley have among the largest populations of slugs encountered in any of western Oregon's crops.

The objective of the following two trials was: to evaluate bait, granule and liquid products applied in the fall for control of the gray field slug (GFS), *Deroceras reticulatum* (Mueller), and the brown banded slug (BBS), *Arion circumscriptus*.

Materials and Methods
Two replicated field trials, denoted as Trial 1 and Trial 2, were initiated in the fall of 2007. The trials were located in Linn County, Oregon in a heavily infested 3-year old, 4 acre white clover field that had been sprayed with glyphosate herbicide in late September and no-till seeded to perennial ryegrass (PRG) in mid-October. The clover was bordered on the south and east by forested and weedy areas.

Trial 1. The first trial was initiated on September18, 2007. Plots measured 35 ft x 35 ft in a randomized block design with three replications. Eight treatments were applied on 3 different dates: September 19, October 2 and October 9. Liquid products (Lorsban 4E®, WECO Foli-Gro, Slugfest®) were delivered in the equivalent of 30 gal/a of water with a CO_2 powered backpack sprayer operating at 30 psi using a 4-nozzle (8002 flat fan) hand held boom that covered a 6.5 ft swath. Granules and pellet baits (MetaRex, Sluggo®, Durham 3.5, WECO 4 blue bait) were applied with a hand held, rotary bait spreader. Slug population densities were high, averaging 33 (13 to 75) slugs per blanket. Average slug weight (n = 100) was 0.16g when trial began. A few clutches of eggs were observed at this time. Precipitation and mean temperatures were obtained from Corvallis AgriMet weather station (CORVALLIS OR_ST_UNIV; Lat: 4438; Long:12311; Elev: 230 ft) to draw a parallel with slug activity and product efficacy.

Control was determined by comparing numbers of live GFS observed under either 1 or 2 Liphatec® slug blankets (19 in x 19 in; moistened and either placed over bare soil or over low-growing clover) per plot before and after application of treatments. Live slugs were not always removed from under the blankets after each evaluation, which is noted in the tables. Control between treatments would be inferred from reduction in numbers of slugs observed prior to and after application of treatments. Pre-treatment counts of slugs per plot were taken on September 19. Post-treatment evaluations were made on September 22 (3 DAT), September 25 (6 DAT) and October 1 (12 DAT) (Table 1).

Numbers of slugs under blankets remained high after the first application of treatments. Therefore new treatments with higher rates were re-applied to plots in hopes of optimizing slug kill. Pre-treatment counts before second application of treatments were taken on October 2. Post-treatment evaluations were made on October 5 (3 DAT) and October 9 (7 DAT) (Table 2). Pre-treatment counts before third application of treatments were taken on October 9. Post-treatment counts were made on October 10 (1 DAT), October 29 (20 DAT), November 1 (23 DAT) and November 30 (52 DAT) (Table 3). The mean number of slugs per blanket is presented in Table 1, 2 and 3.

All data were subjected to analysis of variance (ANOVA) and means were separated using the Tukey's studentized range (HSD) test at *P*-value = 0.05. All values were transformed using log transformation (x + .01) to equalize the variance. Original means are presented in tables.

Trial 2. The second trial was located in the southwest area of the same clover field. Six treatments were applied as described in Trial 1 on each of two application dates, October 2 and October 9. Plots measured 50 ft x 50 ft in a randomized block design with three replications.

Control in this trial was evaluated by using two different methods: open bait stations and Liphatec® slug blankets. Prior to application #1, relative populations of slugs were determined in each plot using 3 bait stations (6 in x 12 in bare arena) randomly placed in the interior of each plot. Each station received 5 Deadline mini-pellets®, placed at dusk the day prior (October 1 and October 8) to taking slug counts. Numbers of slugs within the arena were observed, recorded and removed early the next morning. A post-treatment count was taken on October 9 (7 DAT) (Table 4).

Liphatec slug blankets were used to determine relative control among the treatments in this experiment after application #2. Pre-treatment numbers of slugs were taken on October 9 using two slug blankets placed over low-growing vegetation the day prior; and post-treatment counts on October 10 (1 DAT) using two blankets placed over bare ground the day prior. Slugs were not removed from under blankets after the evaluation. Baits were re-applied to plots late in the afternoon of October 9. Only slug blankets over foliage were left in plots for post-treatment evaluation on October 29 (19 DAT). These slugs were removed, blankets left in place and slugs recorded again on November 1 (slugs not removed) and again on November 30. Slug numbers per blanket were recorded in Table 5.

Because pellet size and type affects numbers of pellets/ft^2 when applied at a give rate, the number of pellets per square foot was recorded at different times over the course of these two trials. These data are presented in Table 6.

Results

Table 1. Treatment effect on control of slugs, measured by slug counts under slug blankets, in white clover from mid to late September 2007.

9-19-07 (application #1) Trial 1 Treatment, rate/a	Mean no. of slugs per blanket[1] Pre- 9-19-07[2]	3 DAT 9-22-07	6 DAT 9-25-07	12 DAT 10-1-07
MetaRex, 10 lb	28.7 a	35.0 ab	31.5 a	15.3 b
Sluggo, 10 lb	36.3 a	48.7 ab	35.0 a	10.3 b
MetaRex, 5 lb + Sluggo, 5 lb	24.3 a	37.3 ab	36.0 a	13.5 b
MetaRex, 10 lb + Lorsban 4E, 1 qt	26.3 a	32.2 b	37.3 a	21.7 ab
Slugfest, 1.5 qt	39.0 a	52.8 ab	57.3 a	28.7 ab
Slugfest, 1.5 qt + Sluggo, 5 lb	38.0 a	62.0 a	66.7 a	16.7 b
Slugfest, 1.5 qt + Durham 3.5, 10 lb	36.3 a	36.0 ab	38.7 a	20.0 ab
UTC	34.3 a	53.0 ab	54.0 a	33.7 a
	NS[3]	$P<0.037$	*NS*	$P<0.018$

[1]Means were separated using Tukey's studentized range (HSD) test at $P=0.05$. Means with same letter are not significantly different.
[2]Slugs were not removed from blanket in plots after evaluation on September 19; an accumulative count was recorded.
[3]*NS*=treatments within column not significantly different.

Table 2. Treatment effect on control of slugs, measured by slug counts under slug blankets, in white clover during early October 2007.

10-2-07 (application #2) Trial 1 Treatment, rate/a	Mean no. of slugs per blanket[1] Pre- 10-2-07	3 DAT 10-5-07[2]	7 DAT 10-9-07[3]
MetaRex, 20 lb	20.7 a	34.0 a	43.0 b
Sluggo, 20 lb	13.3 a	47.3 a	63.3 ab
MetaRex, 10 lb + Sluggo, 10 lb	25.3 a	44.7 a	68.0 ab
MetaRex, 10 lb + Sluggo, 5 lb	18.3 a	39.7 a	61.0 ab
Durham 3.5, 20 lb	23.7 a	41.7 a	64.5 ab
Durham, 20 lb + Sluggo, 5 lb	24.3 a	50.2 a	70.3 a
WECO Foli-Gro, 2 qt	28.0 a	49.3 a	59.5 ab
UTC	31.0 a	45.0 a	57.8 ab
	NS[4]	*NS*	$P<0.05$

[1] Means were separated using Tukey's studentized range (HSD) test at $P = 0.05$. Means with same letter are not significantly different.
[2] All treatments received an additional slugfest treatment by grower on October 5. Application 2 was applied on October 2 after pre-evaluation. Slugs were not removed from blanket in plots after evaluation on October 2; an accumulative slug count of 3 days was recorded on October 5.
[3] Blankets were placed on October 8 for a 1 day evaluation taken on October 9, 2007.
[4] *NS* = treatments within column not significantly different.

Table 3. Treatment effect on control of slugs, measured by slug counts under slug blankets, in white clover from mid October to end of November 2007.

10-9-07 (application #3) Trial 1	Mean no. of slugs per blanket[1]				
Treatment, rate/a	Pre 10-9-07[2]	1 DAT 10-10-07	20 DAT 10-29-07[3]	23 DAT 11-1-07	52DAT 11-30-07[3]
MetaRex, 20 lb	43.0 b	34.0 a	10.0 a	9.3 a	14.0 a
Sluggo, 20 lb	63.3 ab	48.3 a	28.3 a	12.0 a	23.3 a
MetaRex, 10 lb + Sluggo, 10 lb	68.0 ab	34.3 a	13.5 a	10.7 a	25.0 a
MetaRex, 10 lb + Sluggo, 5 lb	61.0 ab	36.0 a	19.3 a	8.0 a	17.3 a
Durham 3.5, 20 lb	64.5 ab	33.3 a	19.5 a	8.0 a	22.9 a
Durham 3.5, 20lb + Sluggo, 5 lb	70.3 a	35.3 a	15.9 a	6.3 a	14.7 a
WECO Foli-Gro, 2 qt	59.5 ab	51.3 a	18.0 a	5.3 a	19.3 a
UTC	57.8 ab	47.7 a	22.7 a	7.3 a	18.0 a
	$P<0.05$	*NS*[4]	*NS*	*NS*	*NS*

[1] Means were separated using Tukey's studentized range (HSD) test at $P = 0.05$. Means with same letter are not significantly different.
[2] Two blankets were placed over foliage on October 8, and slug counts were taken on October 9. Counts based on average per blanket. Treatments were applied on October 9 after pre-evaluation.
[3] Slugs were not removed from blankets in plots after evaluation on October 10 and November 1; an accumulative slug count was taken 20 and 52 days after treatment, respectively.
[4] *NS* = treatments in same column not significantly different.

Table 4. Treatment effect on control of slugs, measured by slug counts recorded at open bait stations, in white clover during early October 2007.

10-2-07 (application #1) Trial 2 Treatment, rate/a	Mean no. of slugs recorded at overnight bait stations[1] Pre- 10-2-07[2,3,4]	 7 DAT 10-9-07[3,4]
Sluggo, 20 lb	19.1 a	9.4 b
MetaRex, 13 lb	17.4 a	15.8 ab
WECO Blue Bait, 10 lb + Sluggo, 10 lb	13.2 a	18.3 ab
Durham 3.5g, 10 lb + Sluggo, 10 lb	13.9 a	16.7 ab
WECO Blue Bait, 20 lb	15.9 a	17.6 ab
UTC	17.3 a	32.3 a
	NS	$P < 0.003$

[1] Means were separated using Tukey's studentized range (HSD) test at $P = 0.05$. Means with same letter are not significantly different.
[2] Treatments were applied on October 2 after pre-treatment counts.
[3] Three open bait stations were established in each plot with 5 Metarex pellets on October 1 and October 8. Slugs were counted each morning on October 2 and October 9.
[4] *NS* = Treatments within column not significantly different.

Table 5. Treatment effect on control of slugs, measured by slug counts under slug blankets, in white clover from mid October to end of November 2007.

10-9-07 (application #2) Trial 2	Mean no. of slugs per blanket[1]				
Treatment, rate/a	Pre 10-9-07[2]	1 DAT 10-10-07	20 DAT 10-29-07[3]	23 DAT 11-1-07	52DAT 11-30-07[3]
Sluggo, 20 lb	26.7 a	23.7 a	9.0 a	1.5 a	8.3 a
MetaRex, 13 lb	23.3 a	23.7 a	11.2 a	4.7 a	12.7 a
WECO Blue Bait, 10 lb + Sluggo, 10 lb	15.3 a	24.7 a	11.5 a	4.8 a	13.3 a
Durham 3.5g, 10 lb + Sluggo, 10 lb	15.0 a	25.5 a	8.3 a	5.3 a	14.0 a
WECO Blue Bait, 20 lb	12.0 a	23.3 a	11.0 a	3.2 a	11.0 a
UTC	19.7 a	24.7 a	14.2 a	4.2 a	10.0 a
	NS[4]	*NS*	*NS*	*NS*	*NS*

[1] Means were separated using Tukey's studentized range (HSD) test at $P = 0.05$. Means with same letter are not significantly different.
[2] Blankets were placed in plots on October 8, for a pre-treatment count taken 1 day later, October 9.
[3] Applications were applied on October 9 after pre-treatment counts.
[4] *NS* = Treatments within columns are not significantly different.

Table 6. Number of pellets per ft^2 remaining in treated plots at different time intervals from application.

DATE	Trial ID	Treatments, rate/a	DAT	Pellet granules/ft^2
9/25/07	Trial 1; application 1	Metarex,10 lb	6 DAT	3.1
		Metarex, 10 lb + Lorsban, 1.5 qt	6 DAT	3.9
		Sluggo, 10 lb	6 DAT	1.6
10/2/07	Trial 1; application 2	Metarex 20	7 DAT	2.0
		Metarex, 20 lb + Lorsban, 1.5 qt	7 DAT	1.9
		Sluggo, 10 lb	7 DAT	0.1
10/10/07	Trial 1; application 3	Meterex, 20 lb	1 DAT	3.3
		Sluggo, 20 lb	1 DAT	0
		Metarex, 10 lb + Sluggo, 10 lb	1 DAT	2.2
		Metarex, 10 lb + Sluggo, 5 lb	1 DAT	1.6
		Durham 3.5, 20 lb* + Sluggo, 5 lb	1 DAT	0
		WECO, 20 lb	1 DAT	2.5
10/9/07	Trial 2; application 2	WECO, 20 lb	1 DAT	4.9
		Sluggo, 20 lb	1 DAT	0.1
		Metarex, 13 lb	1 DAT	4.4
		WECO, 20 + Sluggo, 10 lb	1 DAT	1.9
		Durham 3.5, 10 lb* + Sluggo, 10 lb	1 DAT	0

*Note: It was not possible to see numbers of remaining Durham granules in plots.

Results and Discussion

It became apparent early in the study that economic control of the huge population of slugs in this clover field might not be achievable, even with multiple applications of baits, sprays and granules. In fact, the grower was unable to establish PRG in this field even with two consecutive fall seedings and multiple applications of slug bait. We believe that the overwhelmingly large population of slugs, immigration from bordering forest and weedy landscape, and copious amounts of post harvest residue on the soil surface in this field were responsible for stand failure. We recorded the numbers of bait pellets remaining in some of the plots at different times from day of application. The Sluggo® pellets were rapidly consumed and disappeared from plots at a faster rate than the metaldehyde pellets, sometimes as rapidly as 24 hours in both trials!

Even though we were unable to bring slug populations down to acceptable levels at these two trial sites, we did see statistical differences in slug control among treatments on different dates (see below). Unfavorable weather (cold temperature, high winds, and heavy rains) between evaluation periods such led to less slug feeding, movement and activity across plots which also affected treatment results. In addition, the rain most likely affected the baits' performance over time. Interestingly, only four percent of the slugs recorded in Trial 1 were *Arion circumscriptus***,** yet twenty-five percent of the slugs recorded in Trial 2 located about 100 yards southwest of Trial 1 were *A. circumscriptus*. We did not detect differences in bait preference or control observed between species.

As far as the usefulness of the slug sampling methods, we came to the conclusion that it is best to remove slugs from blankets every three-four days, and then move blankets to new locations within plots between evaluations. Otherwise slugs seem to desire the warm blanket and food supply under the blanket and were quite content to remain there. Possibly these slugs under blankets were less exposed to treatments in plots by not traveling at night. The bait station method was adequate, however bait disappeared quickly and live and sick slugs did not always remain in arena for counting if weather was unfavorable.

No-till and direct seeding systems of crop establishment can be problematic if slugs are present. Even with multiple applications of baits, sprays and granules before and after seeding PRG, the population of GFS at our study site was not able to be reduced to levels that allowed seedling PRG establishment.

Trial 1

Pretreatment numbers of slugs ranged from 3 to 30 slugs (mean 17 slugs) under each of 7 slug blankets placed over bare ground and left in the field for 3 days in this white clover field seeded to PRG. Numbers increased under blankets left in same location by 32% and 47% (average of 25 and 33 slugs/blanket) after 4 and 5 days, respectively.

<u>Three separate bait applications</u> (not necessarily the same treatments and rates as the previous treatments) were made to the plots in Trial 1.

On October 1, twelve days after the first application of products was made, plots treated with Metarex at 10 lb/a, Sluggo at 10 lb/a, MetaRex at 5 lb/a + Sluggo at 5 lb/a, and Slugfest at 1.5 qt/a had significantly fewer slugs than the untreated plots. However, a 50 to 67% reduction in slugs from the untreated (33 slugs/blanket) was insufficient for economic control (Table 1).

On October 2, a second application was made to the plots. Some treatments remained the same but were doubled in rate. Other treatments were changed as shown in Table 2. One week later, populations in the UTC had nearly doubled, from an average 31 to 58 slugs/blanket. At 7 DAT, plots treated with Metarex at 20lb/a were the only treatment (43 slugs/blanket) with statistically fewer slugs/blanket than the UTC (58 slugs/blanket) (Table 2).

On October 9, a third application was made to the plots in Trial 1. From October 9 through November 30 slug populations in the untreated diminished progressively from 58 slugs/blanket to 18 slugs. This trend follows previous observations that indicate the numbers of slugs recovered, irrespective of sampling method, steadily decrease in untreated plots or fields beginning sometime in mid-October through November. Interestingly, none of these treatments significantly reduced slug populations relative to the untreated check over 4 sampling periods from October 10 through November 30 (Table 3). It appears that fall slug control is best accomplished with late September and mid-October applications of products. This is because slug populations as measured by various sampling methods naturally and slowly decline through November, even without product application.

Trial 2

Trial 2 was established on October 2 along the southwest edge of the same field that housed Trial 1. Bait stations were used to quantify relative slug populations prior to the first application of products in this experiment. As when slug blankets are used for monitoring slug numbers, reductions in post-treatment numbers of overnight slug visits to bait stations in the different plots relative to pre-treatment numbers in the same plots and relative to numbers in the untreated plots are used as indices of control.

Slug populations in the untreated nearly doubled (17 slugs/bait station to 32) from October 2 to October 10 (8 DAT). Sluggo-treated plots at 20 lb/a were the only plots to have a significant reduction in slugs (9 slugs/bait station) compared to the untreated (32 slugs/bait station) (Table 4).

On October 10, these plots were re-randomized and assigned different treatments. Slug blankets provided data in regard to treatment efficacy. As in Trial 1, from October 10 (25 slugs/blanket) through November 30 (10 slugs/blanket) slug populations in the untreated progressively diminished. The temperature, heavy rains discouraged slug activity. Of equal interest is that, as in Trial 1, none of the treatments applied on this date significantly reduced slug populations relative to the untreated check over the same four sampling periods from October 10 through November 30 (Table 5).

Disappearance of slug bait

We counted and recorded numbers of bait pellets remaining in some of the plots at varying time intervals after application. Lorsban 4E was applied as an adjunct chemical to reduce earth-worm predation on the Metarex pellets in one of the plots of Trial 1. However, earthworm activity at this time was minimal and pellet numbers remained approximately the same for the two treatments.

Sluggo (iron phosphate) pellets disappeared more rapidly than metaldehyde bait pellets in our plots. This was presumably due to greater rates of consumption per slug of iron phosphate bait compared to metaldehyde bait. Occasionally we could find no pellets in the Sluggo plots after only 1 day after treatment (Table 6).

CONTROL OF THE GRAY FIELD SLUG DURING ANNUAL RYEGRASS ESTABLISHMENT

W.E. Gavin, G.D. Hoffman and G.M. Banowetz

Introduction

A variety of molluscicidal compounds have been evaluated as active ingredients in baits for slug control (DeFrancesco and Fisher, 1999; Fisher et al., 1995; Henderson and Triebskorn, 2002). Under the relatively uniform conditions of agricultural fields, the level of control with a single baiting operation is rarely above 70%, and typically in the range of 10–60% (e.g., Godan, 1983; Barker et al., 1991). The level of control in more complex, spatially varied ecosystems can be expected to be substantially less (i.e., after canopy closure or dense plant crown habitat). A number of factors influence the efficacy of molluscicide bait treatments (Barker and Watts, 2002; Gavin, et al., 2006). Environmental conditions, in particular soil moisture and soil and air temperature, interact with both crop seedling and slug emergence during the early autumn season. In years of a dry early autumn like 2008, the crop and the slugs emerged at the same time, making it very difficult to save crop in fields with moderate to high slug populations. As a result, multiple, properly timed applications of molluscicides are required.

We conducted trials to determine how product type and ad-mixtures of products could reduce slug populations during establishment of annual ryegrass (*Lolium multiflorum* Lam.) in the autumn of 2007 and 2008. Our goal was to identify an approach to establish grasses in low-to-high slug populated fields at the lowest possible cost to growers.

This project has been supported in part by a grant awarded to Hoffman and Gavin (agreement no. C36-0031, OSU Agricultural Research Foundation, Alternatives to Field Burning), with the remaining of the cost offset by the USDA ARS in Corvallis, Oregon.

Field methods

Product type, formulation, and manufacturers or distributors are shown in Table 1. All products were calculated per plot size by weight and adjusted to standard field rates as shown in Table 2. Dry products were applied using a hand operated spin spreader (Solo®, model 421S) by walking a grid pattern in two directions to assure uniform coverage. Liquid applications were applied using an 18 litre back pack sprayer (Solo® , model L435) fitted with an 1.8m wide boom, Tee-Jet® 80-02 (model XR8002) nozzles, and delivered at 20 p.s.i.

Plot size measured 12 m x 12 m layed out in a randomized block design configuration. Two 0.5 x 1.0 dm wetted slug mat traps (Draza Slug Activity Monitors, Bayer AG) were spaced out in each plot and examined at two to four day intervals. All captured slugs were removed and mats re-charged with water on each visit. Slugs were identified and weighed (mg) in the laboratory. Ninety-nine percent of the slugs were gray field slugs, *Derocerus reticulatum*, with an occasional marsh slug, *D. laeve*.

Field trials reported in this paper were conducted in the autumns of 2007 and 2008 (Table 2). Precipitation, and air and 5.0cm deep soil temperature data were obtained from Oregon Climate Service, Hyslop Field Station, in Corvallis, Oregon. Application events are highlighted in gray.

All data were subjected to analysis of variance (ANOVA) and means were separated using the Fisher Protected (LSD) Test at p-value = 0.05. When necessary means were transformed, typically using the square root, to equalize variances. Original means are presented in tables.

Discussion of results

Harrisburg 2007 Site

Two weeks following initial application (24 Oct 2007), slug numbers in plots treated with both levels of Deadline MP (6.1 kg/ha; 21.1 kg/ha) and Durham (21.1 kg/ha) treatments, were significantly lower than those recorded in the untreated control (UTC) plots (Figure 1). The effectiveness of the lowest rate of Deadline was unexpected. Little vegetative growth, and a clean, smooth soil surface were present at the time of this early application, suggesting a high level and ease of bait 'discovery'.

Fewer slugs were present after treating with Sluggo (21.1 kg/ha) compared to the UTC, although the differences were not statistically significant. The iron phosphate in Sluggo takes longer than metaldehyde to kill slugs which may account for the lower effect.

Liquid SlugFest AWF had little effect on slug populations in this test. Small seedling size and the amount of exposed earth may have reduced the effectiveness of this product. Application recommendations suggest applying to green standing crop.

After the second application of materials, only Durham following Sluggo (program code 5) resulted in a significant decline in slug numbers from the UTC. In an additional test, Durham was applied just prior to a precipitation event (50 mm) and failed to reduce slugs. Rain deflected soil material covering this product has been shown to have negative effects on its efficacy (Gavin et al., 2008).

Hwy 34 2008 Site

There were no differences in slug numbers among the treatment plots before the first application (P= 0.7488). The UTC slug population were 10.4 slugs per trap out of the range of 9.2

to 13.2 slugs for the 5 entries. This relatively low population of slugs in the UTC prior to any slug control measures may partly explain why we found no differences between the UTC and the four slug control treatments after the first and second slug control application periods (Figure 2). On day seven after the first application there was no significant differences between the treated and UTC groups (*P*= 0.3722). Eight days following the second slug control application there were still no difference between the treatments and the UTC (*P*= 0.6185). Thirteen days following the third application, treatment 2 contained significantly fewer slugs than the UTC. Treatments 1 and 4 were significantly different at the *P*= 0.0610 level (Figure 2).

<u>Columbus 2008 Site</u>

Prior to the first application there were no differences in slug numbers between the treatment plots (*P*= 0.5819) and UTC. Ten days after the first application (just prior the second application) there was no difference in any of the treatments compared to the UTC (*P*= 0.0821). The application of Durham (treatment 3) reduced slug populations the most (Figure 3). Ten days after the second application, treatments 1 and 2 had significantly fewer slugs than the UTC. Treatments 4 and 5 were significantly lower than the UTC at a *P*= 0.0600 level. Eight days after the third application all the slug control treatments contained fewer slugs than the UTC. Freezing temperatures on subsequent days ended slug activity and the experiment.

Conclusions

During early establishment of ryegrass under bare soil conditions, Deadline MP or OR-CAL baits at low or moderate rates reduced slugs significantly. As grasses grow and make bait 'discovery' more difficult, control may be more problematic.

Durham granulars significantly reduced slugs at three sites in 2007 and 2008 unless followed by heavy rains. Heavy rains increased soil deflected material which covered this product. At the Hwy 34 site, Durham was applied once or twice to two of the three successful programs. OR-CAL followed by and included with Sluggo, was also successful at this site.

Our initial single applications at the Hwy 34 and Columbus sites failed to reduce slugs, but all second and third applications significantly reduced slug numbers. Both of these fields experienced very high populations of the gray field slug. Despite our attempts to reduce slug numbers at the 2008 sites, no crop was established.

SlugFest AWF should be applied to as much green standing material as possible. Our attempts at early seedling establishment with this product failed to reduce slug numbers.

No attempt was made to quantify differences between admixture or single product treatments. Decisions were made based on weather fastness of the product, regulatory guidelines, and soil surface conditions.

In fields following white clover under no-till management, slug populations can build up to very high populations, making it impossible to establish a crop. No sheep grazing occurred at any of the three sites in this study. A winter fallow and slug control program followed by an early spring planting, may be a grower's best option under these conditions. Figure 4 summarizes the effect of the treatments at the Columbus and Hwy 34 sites. The accumulated number of 'Slug Days' was calculated similar to the way in which growing degree-days are calculated. This value estimates the total activity of the slugs in each treatment over the entire course of the application periods. At Columbus, treatments 3, 4 and 5 were significantly lower than the UTC. At Hwy 34 there was no difference between the UTC and any of the slug control treatments.

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Literature

G.M. Barker, R.P. Pottinger, J.M. Lloyd, P.J. Addison, A.C. Firth, and A.P. Stewart. 1991. A novel bait formulation of slug and snail control. *Proceedings of the New Zealand Weed and Pest Conference, 44, 195-200.*

G.M. Barker, and C. Watts, 2002. Management of the invasive alien snail *Cantareus aspersus* on conservation land. *In* DOC Science Internal Series, 31. Department of Conservation, Wellington, New Zealand.

J.T. DeFrancisco and G.C. Fisher. 2000. Control of the gray garden slug with baits. *In* W.C. Young III (ed.), Seed Production Research, Oregon State Univ., Ext/CrS 114, 4/00. pp. 34-35.

G.C. Fisher, J.T. DeFrancesco, and R.N. Horton. 1996. Managing slugs in grasses grown for seed. *In* W.C. Young III (ed.), Seed Production Research, Oregon State Univ., Ext/CrS 106, 3/96. pp. 25-27.

D. Godan. 1983. *In* Pest slugs and snails: Biology and control. 2nd Edition, Springer-Verlag, Berlin, Heidelberg, New York.

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

W.E. Gavin, G. Fisher, A.J. Dreves, and G.M. Banowetz. 2009. Effects of precipitation on molluscicidal efficacy. *In*

W.C. Young III (ed.), Seed Production Research, Oregon State Univ., Ext/CrS 128, 3/09. pp. 55-61.

I. Henderson and R. Triebskorn. 2002. Chemical conrol of terrestrial gastropods. *In* Molluscs As Crop Pests, CABI Publishing, pp. 1-32.

Table 1. Product, formulations, and manufacturers used in field experiments in 2007 and 2008.

Product	Formulation	Manufacturer
Deadline MP	4% metaldehyde, bait powder	AMVAC, Los Angeles, CA USA
Durham 7.5	7.5% metaldehyde, granular	AMVAC, Los Angeles, CA USA
MetaRex	4% metaldehyde, bait powder	De Sangosse SA, Pont Du Casse, France
OR-CAL blue	3.25% metaldehyde, bait powder	OC-CAL, Junction City, OR USA
SlugFest AWF	25% metaldehyde, liquid	OC-CAL, Junction City, OR USA
Sluggo	1% iron phosphate, bait product	W. Neudorff, GmbH KG, D-31860, Emmerthal, Germany

Table 2. Description and code of programs plus cost (February, 2009 prices) used at three research sites in 2007 and 2008.

Program Code	1st Application	2nd Application	3rd Application	2/10/09 Cost/A
Harrisburg, 2007, 2 km south, ryegrass following white clover (*Trifolium repens* L.)				
1	Deadline MP 6.1 kg/ha	Deadline MP 6.1 kg/ha	na	$16.00
2	Deadline MP 6.1 kg/ha	Durham 11.1 kg/ha	na	$30.50
3	Deadline MP 21.1 kg/ha	Durham 6.1 kg/ha	na	$43.25
4	Sluggo 21.1 kg/ha	Durham 11.1 kg/ha	na	$52.50
5	Durham 21.1 kg/ha	Sluggo 11.1 kg/ha	na	$60.00
6	SlugFest 4.2 L/ha	Sluggo 11.1 kg/ha	na	$31.50
7	No treatment	Deadline MP 11.1 kg/ha	na	$16.00
8	UTC	UTC	na	$0.00
Old Hwy 34, 2008, at Columbus Drive, ryegrass following white clover (*Trifolium repens* L.)				
1	Durham 13.6 kg/ha	Sluggo 13.6 kg/ha	Durham 13.6 kg/ha + Sluggo 8 Kg/ha	$84.00
2	OR-Cal 13.6 kg/ha	Sluggo 13.6 kg/ha	OR-CAL 8 kg/ha + Sluggo 8 kg/ha	$52.20
3	Sluggo 13.6 kg/ha	MetaRex 9.1 kg/ha	Sluggo 8 kg/ha + MetaRex 4.5 kg/ha	$58.20
4	Durham 13.6 kg/ha	Sluggo 13.6 kg/ha	Durham 13.6 kg/ha + SlugFest 4.2 L/ha	$88.50
5	UTC	UTC	UTC	$0.00
Columbus, 2008, Columbus Drive at old Hwy 34, ryegrass following white clover (*Trifolium repens* L.)				
1	OR-CAL 8 kg/ha	Sluggo 8 kg/ha	SlugFest 4.2 L/ha + Phor-Ti-Phy 22.5 L/ha	$50.10
2	MetaRex 9.1 kg/ha	Sluggo 8 kg/ha + SlugFest 4.2 L/ha	MetaRex 9.1 kg/ha	$64.10
3	Durham 13.6 kg/ha	Durham 13.5 kg/ha + Sluggo 8 kg/ha	Durham 13.6 kg/ha	$87.00
4	Sluggo 13.6 kg/ha	Sluggo 8 kg/ha + MetaRex 4.5 kg/ha	Sluggo 8 kg/ha + SlugFest 4.2L/ha	$62.90
5	OR-Cal 13.6 kg/ha	OR-Cal 8 kg/ha + Durham 13.6 kg/ha	OR-CAL 8 kg/ha + Sluggo 8 kg/ha	$69.60
6	UTC	UTC	UTC	$0.00

Table 3. Field trials reported in this paper were conducted in the autumns of 2007 and 2008. Precipitation, and air and 5.0cm deep soil temperature data were obtained from Oregon Climate Service, Hyslop Field Station, in Corvallis, Oregon. Application events are highlighted in gray.

2007 Lane Co.

	2007 Day	Air temp.	Soil temp at 5.0 cm Soil *t*	Prec.
		--(mean °C)--		(mm)
October	19	13.9	13.1	22.4
	20	10.8	12.8	11.2
	21	10.0	11.7	8.1
	22	9.2	12.8	0.0
	23	11.9	13.9	0.3
	24	13.3	14.4	0.3
	25	9.2	10.8	0.8
	26	8.6	8.6	0.3
	27	10.6	8.6	0.0
	28	8.3	9.4	0.0
1st application	29	8.3	9.7	0.0
	30	8.6	9.4	0.5
	31	6.4	8.9	0.3
November				
	1	5.8	9.2	0.3
	2	6.7	8.6	0.0
	3	5.3	7.8	0.0
	4	7.5	8.3	0.0
	5	8.6	9.7	0.5
	6	8.3	9.4	0.0
	7	8.1	11.4	0.3
	8	6.4	9.4	0.3
2nd application	9	8.3	10.8	0.5
	10	11.1	11.4	11.2
	11	8.9	11.4	1.3
	12	9.7	10.3	2.3
	13	6.4	8.1	3.8
	14	6.7	9.2	0.3
	15	6.7	7.5	0.3
	16	12.5	10.3	3.0
	17	11.9	11.7	19.3
	18	10.8	11.7	9.1
	19	5.8	8.3	35.6
3rd application	20	5.6	8.6	4.6
	21	4.7	6.4	0.3
	22	5.6	5.3	0.0
	23	4.4	5.0	0.0
	24	2.8	4.4	0.0
	25	0.3	3.9	0.0
	26	1.4	3.9	0.0
	27	2.8	3.1	9.4
	28	5.3	5.6	2.8
	29	4.4	4.4	4.8
	30	4.2	4.4	0.5

2008 Linn Co.

	2008 Day	Air temp.	Soil temp at 5.0 cm Soil *t*	Prec.
		--(mean °C)--		(mm)
November	4	8.9	20.1	10.8
	5	7.8	8.1	10.0
	6	10.0	16.5	9.7
	7	13.6	1.3	12.8
	8	13.9	0.3	15.0
	9	11.9	7.1	13.1
	10	10.8	1.3	11.9
	11	10.6	8.9	12.2
	12	11.9	11.4	11.9
	13	13.3	17.0	14.2
1st application	14	8.1	0.3	11.4
	15	6.9	0.3	10.3
	16	7.5	0.3	10.6
	17	5.6	0.3	9.4
	18	10.0	0.3	11.7
	19	9.7	0.0	11.4
	20	11.1	2.8	11.1
	21	5.8	6.4	8.6
2nd application	22	4.7	1.5	8.1
	23	6.1	0.5	9.2
	24	4.7	0.3	9.2
	25	3.3	0.3	7.8
	26	3.9	0.3	6.9
	27	5.6	0.0	6.9
	28	3.3	0.0	6.1
	29	10.0	0.0	10.3
	30	11.9	0.3	12.5
December				
3rd application	1	8.6	0.3	10.6
	2	9.4	6.4	10.3
	3	9.4	0.3	10.8
	4	5.6	0.0	8.6
	5	4.2	0.0	6.1
	6	3.9	0.0	6.1
	7	6.1	0.3	6.1
	8	5.0	0.5	6.1
	9	-1.1	0.0	0.0
	10	2.5	0.0	5.3
	11	5.6	0.0	7.5
	12	4.4	0.3	6.1

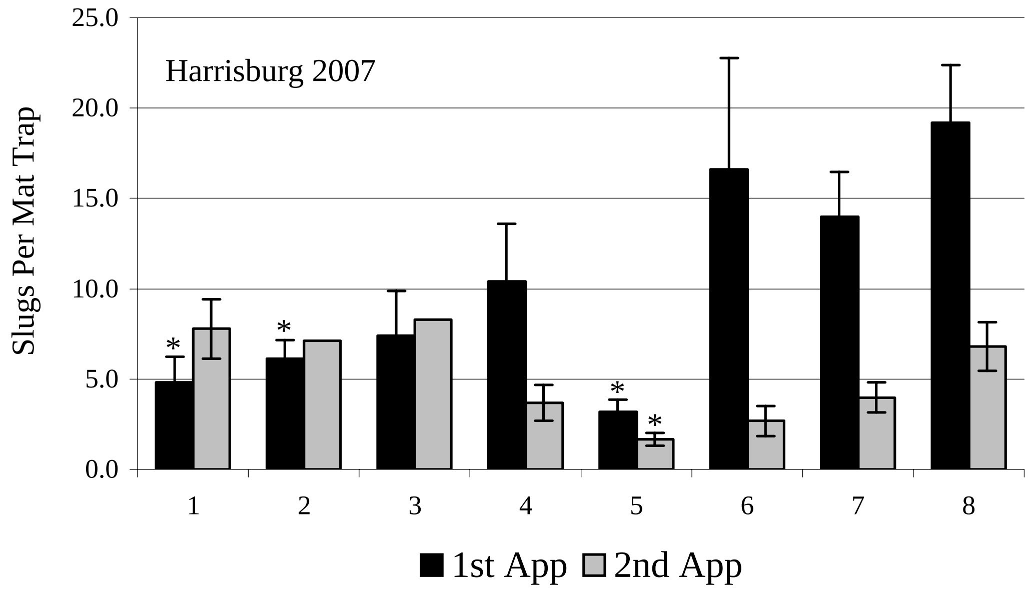

Figure 1. The effect of seven treatments (1-7) and untreated control (8) on slug numbers in 2007 at the Harrisburg site.[1]

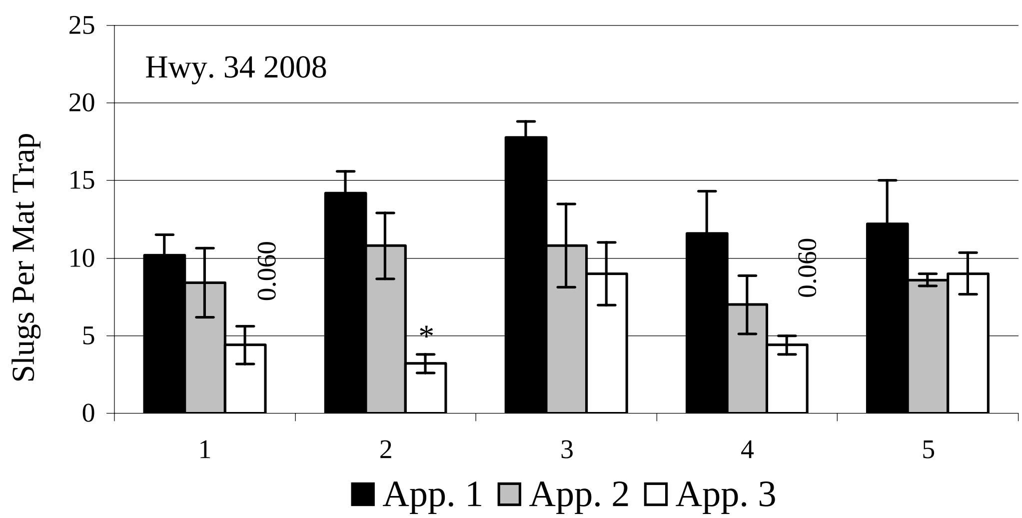

Figure 2. The effect of four treatments (1-4) and an untreated control on slug numbers in 2008 at the Hwy 34 site.[1]

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[1] (P = 0.05; Fisher LSD), refer to table 2 for program and application codes

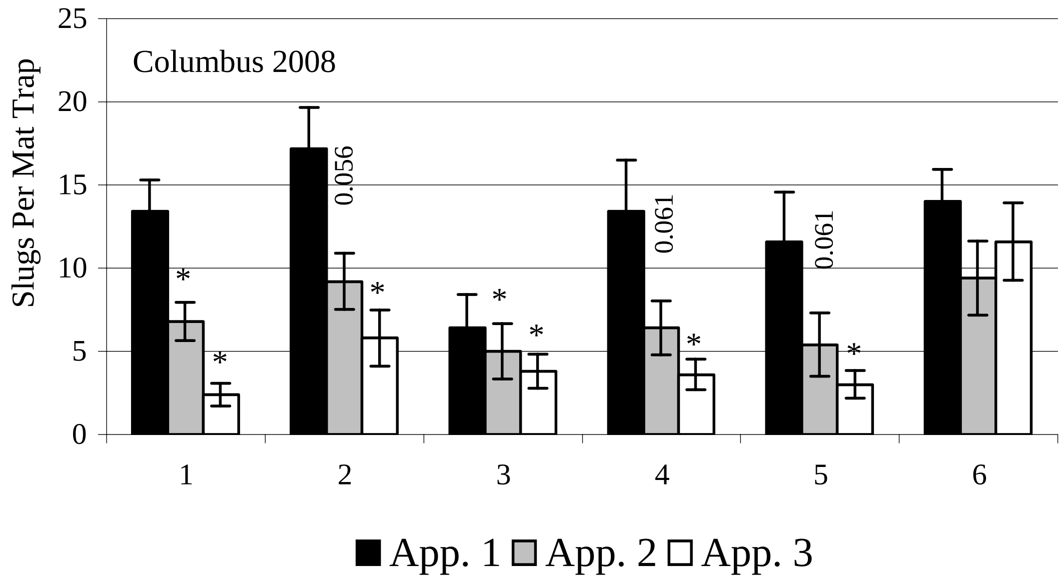

Figure 3. The effect of five treatments (1-5) and an untreated control on slug numbers in 2008 at the Columbus site.[1]

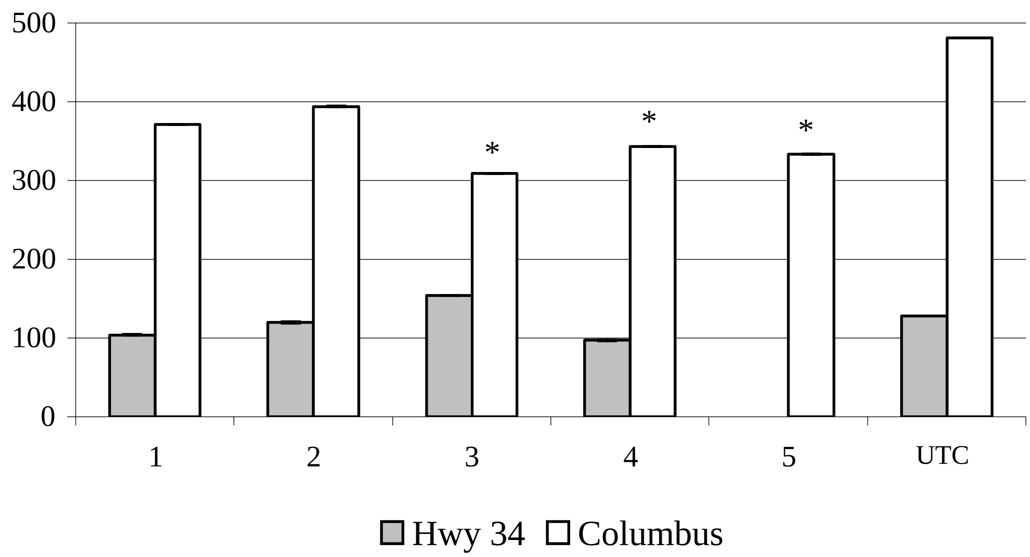

Figure 4. Overall effects of the slug control programs in 2008 at the Hwy 34 and Columbus sites. Programs 3, 4 and 5 were significantly different than the untreated control. Refer to table 2 for the treatment applied to these fields.

[1] (*P* = 0.05; Fisher LSD), refer to table 2 for program and application codes

SHORT-TERM EFFECTS OF CHLORPYRIFOS AND OTHER PESTICIDES ON EARTHWORM NUMBERS

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

Introduction

The aim of this study was to investigate the effects of chlorpyrifos (O,O-diethyl-O-(3,5,6-trichloro-2-pyridyl)) phosphorothioate insecticide and two herbicides, paraquat dichloride (1.1'-dimethyl-4,4'-dipyridinium dichloride), and MCPA amine (Dimethylamine salt of 2-methyl-4-chlorophenoxyacetic acid), on springtime activity of the earthworm *Lumbricus terrestris* L.

Chlorpyrifos is generally used on grasses grown for seed to control billbugs (*Sphenophorus venatus confluens*) and cutworms (various species), and on other crops for crane fly larvae (*Tipula* spp.), garden symphyllans (*Scutigerella immaculate*), and wireworms (*Agriotes* spp.) (Fisher et al., 2001; Rao et al., 2000; Berry and Robinson, 1974). This compound is a cost effective and proven successful means of controlling these species.

During the course of these field trials an application of two herbicides, paraquat and MCPA amine, were applied to the field to reduce green biomass of the crop and rid the field of unwanted weed species. This admixture was applied by the grower and an over spray of chlorpyrifos was applied by the authors.

The indirect impact of controlling the target species may also adversely affect non-target species such as earthworms. Earthworms reduce thatch (in turf grasses), remove crop residue, improve water infiltration and aeration through their burrows, and play an important role in the nutrient cycle.

Although many toxicity studies have been conducted, the fact remains that only a few pesticides in use have been tested against relatively few earthworm species both in laboratory tests and under field conditions (Eijasackers, 2004). The short half-life of chlorpyrifos in the soil (Richardson and Gangollil, 1993) offers some disadvantages to growers trying to control target species, but may reduce the impact of this compound on non-target species.

Methods

A white clover (*Trifolium repens* L.) field located in central Linn county, Oregon that had been in production using no-till production practices for three years was identified as our study site. In the spring of 2006, an admixture of Gramoxone® Extra, MCPA amine, and Lorsban® 4E, was applied to the field to remove the white clover stand. The chlorpyrifos was added to study the combined effect on earthworms. Untreated areas of the field were set aside as a control for this study. The application of the herbicides failed to remove the crop and the clover field was left in for an additional year of production. In 2007, a replicated dosage experiment was set up in the same field using only chlorpyrifos.

Test methods followed standard protocols (H. Kula, 1992) with plots measuring 10m x 10m replicated four times, in a randomized block design. No buffer between plots was necessary since sampling was done near the center of each plot. Sampling was done at 0, 1, 3, 7, 11 and 18 days after treatment, with a follow-up at 30 days. Two soil cores per plot were dug with a spade shovel, measuring 30cm x 30cm and 20cm deep. Earthworms were immediately hand sorted, identified, and counted in the field. Tests were conducted in April of 2006 and April and May of 2007 when populations of earthworms were at their highest. Rainfall was necessary following application to transport the chlorpyrifos into the soil to be effective as a control (Table 1).

Spray applications were applied using a calabrated ATV mounted 3m spray boom, at 4.8 km/h, 50 cm nozzle spacing (80-02 TeeJet, 100 mesh screens), at 20 psi, delivering 154 L/ha.

All data were subjected to analysis of variance (ANOVA) and means were separated using the Fisher Protected (LSD) Test at *P*-value = 0.05. All values were transformed using log transformation (x + .05) to equalize the variance. Original means are presented in tables.

Results and Discussion

Time had an influence on the effect of both the admixture in 2006 and chlorpyrifos alone in 2007, on earthworm numbers. The admixture had an immediate effect on the following day, reducing the net activity density by 54%, recovering to 23% by day 3, and 9% by the seventh day (Figure 1). By day eleven through the final 30-day sampling date, there were no significant differences between plots receiving the admixture and the untreated control.

In 2007, the three highest rates, 1.1, 1.75 and 2.3 L/ha, had an immediate but temporary effect on earthworm numbers (Figure 2). The greatest reduction was observed by day 3 at the 1.2 and 1.8 L/ha concentrations (31 and 41% respectively), while the 2.3 L/ha had reduced the numbers to the greatest extent by the seventh day sampling date (42%). These effects dissipated with time after 12 days, when populations recovered to untreated control levels.

Rainfall may have played an important role in the results of these tests, however, percent soil moisture remained relatively constant at 32% and 27% in 2006 and 2007, respectively (data not shown). Field conditions were typical of spring application timing for the grower.

Most importantly, no surface mortality or dermal lesions on the earthworms, were observed in either year or treatments. All treatments completely recovered to functional untreated control levels by the end of the 30-day sampling period (Table 2).

Conclusions

Studies have shown that medium to high rates of the insecticide chlorpyrifos (OP) can cause mortality, dermal lesions, and reductions in activity of the common nightcrawler *Lumbricus terrestris.* During the course of this study, no reduction in activity density was observed 18 and 30 days following treatment. Temporal rate-dependent reductions in activity were observed during the first week following application. These data suggest that real-time field condition applications of both chlorpyrifos alone and in combination with paraquat and MCPA amine, have only temporal effects on these important non-target species.

Acknowledgements

We thank Mark Macpherson for the use of his fields and Curt Dannen, Bob Schroeder and Bob Spinney at Crop Production Services, for products and helpful suggestions.

Literature

B. Axelsson, D. Gärdefors, U. Lohm,T. Persson, and O. Tenow, 1971. Reliability of estimating standing crop of earthworms by hand sorting. *Pedobiologia 11, 338–340.*

R.E. Berry and R.R. Robinson. 1974. Biology and control of the garden symphylan. *Oregeon State University Extension Service, Extension Circular 845, pp. 1-11.*

Y. Capowiez and A. Berard. 2006. Assessment of the effects of imidacloprid on the behavior of two earthworm species (*Aporrectodea nocturna* and *Allolobophora icterica*) using 2D terraria. *Ecotoxicology and Environmental Safety 64, pp. 198-206.*

C.A. Edwards. 1980. Interactions between agricultural practice and earthworms. *In* Soil biology as related to land use practices. *Proc. VII international colloquium of soil zoology, pp. 3-11.*

C.A. Edwards. 1992. Testing effects of chemicals on earthworms: the advantages and limitations of field tests, *In Ecotoxicology of earthworms*. Ed. Greig-Smith, Becker, Edwards,and Heimbach, Intercept Ltd, Hants, UD., pp. 75-83.

H. Eijsackers. 2004. Earthworms in environmental research. *In* Earthworm Ecology, 2nd ed. Clive A. Edwards (ed.), pp. 321-342.

G.C. Fisher, J.T. DeFrancesca, and S.U. Rao. 2001. Evaluation of insecticides for control of western orchardgrass billbug. *In* W.C. Young III (ed.), Seed Production Research, Oregon State Univ., Ext/CrS 121, 4/02.

C. Kula. 1992. Measuring effects of pesticides on earthworms in the field: test design and sampling methods. *In Ecotoxicology of earthworms.* Ed. Greig-Smith, Becker, Edwards,and Heimbach, Intercept Ltd, Hants, UD., pp. 90-99.

A.M. Langan, E.M. Shaw. 2006. Responses of the earthworm *Lumbricus terrestris* to iron phosphate and metaldehyde slug pellet formulations. *Applied soil ecology*.

D.A. Potter, M.C. Buxton, C.T. Redmond, C.G. Patterson, and A.J. Powell. 1990. Toxicity of pesticides to earthworms (Oligochaeta: Lumbricidae) and effect on thatch degradation in Kentucky Bluegrass Turf. *J. Econical Entomology, 83, pp. 2362-2369.*

M.L. Richardson and S. Gangollil (Eds.). 1993. The dictionary of substances and their effects, *vol. 2C. Royal Society of Chemistry, London, U.K.*

S.U. Rao, G.C. Fisher, and L.A. Royce. 2000. Crane flies and emerging pest complex in grass seed fields. *In* W.C. Young III (ed.), Seed Production Research, Oregon State Univ., Ext/CrS 115, 4/01.

O. Schmidt. 2001. Time-limited soil sorting for long-term monitoring of earthworm populations. *Pedobiologia, 45, pp. 69-83*

J.A. Springett. 1981. A new method for extracting earthworms from soil cores, with a comparison of four commonly used methods for estimating earthworm populations. *Pedobiologia 21, 217–222.*

A.R. Thompson. 1971. Effects of nine insecticides on the numbers and biomass of earthworms in pasture. *Bul. Environ. Contam. Toxicol. 5, pp. 577-586.*

Table 1. Weather data for April 2006 and April-May 2007 during field trials. Shaded area represents sampling day. Day 0 equals pre-treatment density of earthworms. Soil moisture remained relatively stable at 32% and 27% for 2006 and 2007 respectively.

April 2006

Treat. Day	Day	Mean air °C	Mean soil °C	Precip. mm
0	1	10.0	13.3	4.1
1	2	9.4	11.9	2.5
	3	9.7	11.4	1.8
3	4	8.1	11.1	0.0
	5	10.0	12.5	0.0
	6	9.4	12.8	0.3
	7	10.6	12.8	0.0
7	8	13.9	14.2	3.8
	9	10.6	14.2	0.3
	10	9.7	14.2	3.8
	11	10.8	15.3	7.1
11	12	11.9	16.1	7.6
	13	12.8	17.5	0.3
	14	2.8	0.8	11.9
	15	8.1	11.7	7.1
	16	5.8	8.6	19.1
	17	7.2	11.9	1.0
	18	6.1	11.4	2.0
18	19	9.7	13.9	0.0
	20	12.5	16.1	0.0
	21	13.1	16.4	1.0
	22	8.6	13.1	0.0
	23	11.1	12.2	0.0
	24	13.6	13.9	0.0
	25	12.5	16.4	0.0
	26	11.9	16.1	0.0
	27	10.6	15.8	0.0
	28	14.4	17.5	0.0
	29	16.1	20.6	0.0
29	30	10.0	16.7	0.0

April-May 2007

Treat Day	Day	Mean air °C	Mean soil °C	Precip. mm
	1	6.1	10.0	1.5
	2	6.4	10.8	0.3
	3	6.1	10.0	0.0
	4	7.2	9.4	0.0
	5	10.8	13.9	0.0
	6	14.2	14.7	0.0
0	7	17.5	16.9	1.3
1	8	10.0	14.2	4.1
	9	10.3	11.4	11.7
3	10	8.3	12.8	2.0
	11	10.3	14.2	0.3
	12	9.4	12.2	2.8
	13	7.2	11.9	1.5
7	14	12.8	14.2	8.1
	15	7.5	12.5	0.0
	16	7.8	13.6	0.0
	17	7.2	10.3	3.8
11	18	7.5	11.9	2.5
	19	5.3	11.4	1.3
	20	6.7	13.6	0.0
	21	11.7	14.2	1.5
	22	8.3	10.6	6.6
	23	8.6	13.6	1.5
	24	12.5	16.1	0.0
18	25	10.8	14.7	0.0
	26	9.2	13.9	0.0
	27	11.9	15.8	0.0
	28	15.8	18.6	0.0
	29	12.8	18.1	0.0
	30	10.6	16.7	0.0
May-07	1	11.9	16.1	0.8
	2	11.7	14.7	10.7
	3	8.3	13.1	9.7
	4	9.2	15.0	8.9
	5	7.2	14.4	1.8
	6	8.6	15.8	0.0
30	7	14.7	18.9	0.0

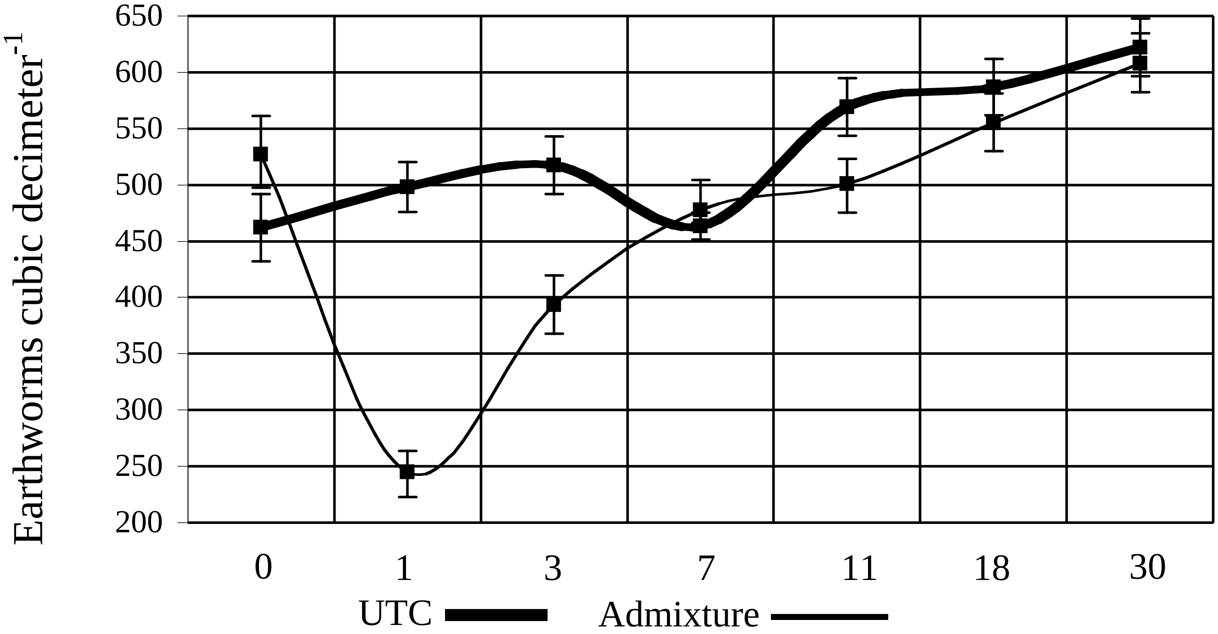

Figure 1. Effects of Gramoxone® Extra (2.3 L/ha) + MCPA amine (0.58 L/ha) + Lorsban® 4E (2.3 L/ha) as an admixture on earthworm density, April 2006.

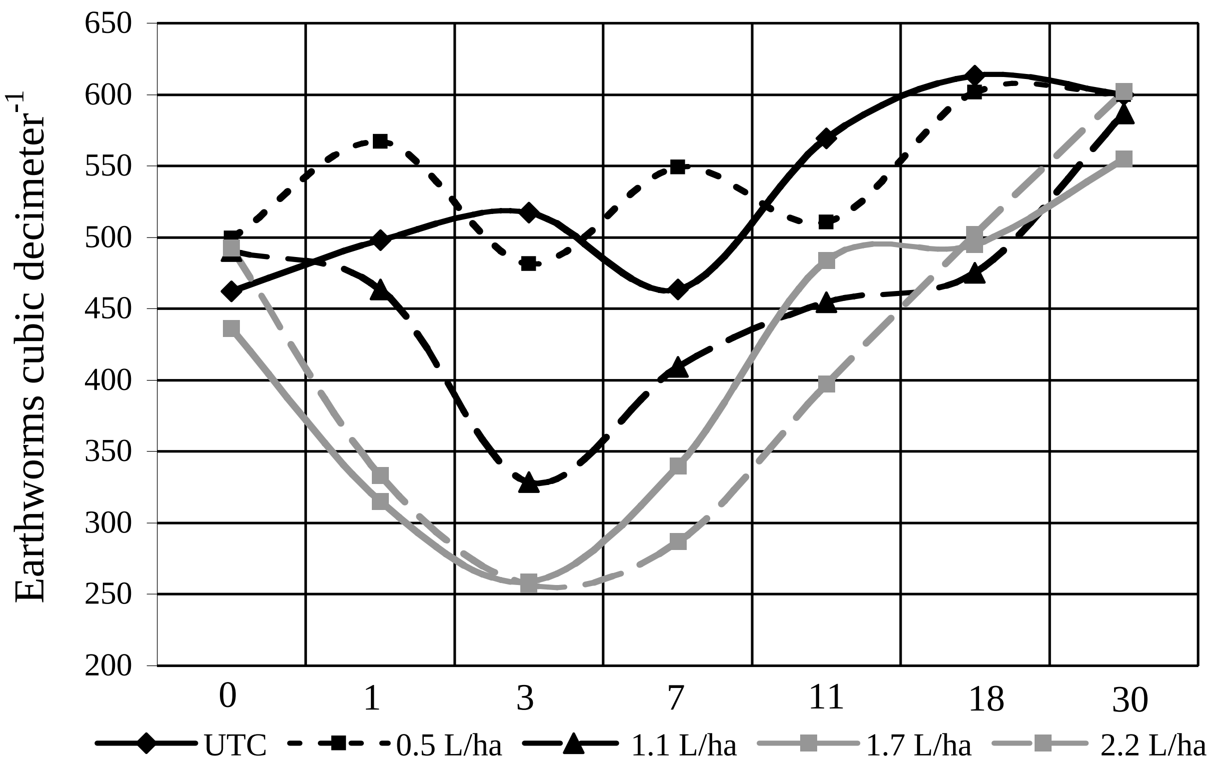

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Figure 2. Effect of four rates of Lorsban® 4E on earthworm density abundance, April-May 2007. Samples were taken on days 0, 1, 3, 7, 11, 18, and 30. There were no significant differences between treatments by the end of 30 days.

Table 2. A comparison of the mean number of earthworms sampled after applying four rates of Lorsban® 4E.

Treatment	Days after treatment	Earth worm density	SEM[1]	*P*-value[2]
		(no./dm^2)		
UTC	0	462	29.934	NS
	1	498	22.160	NS
	3	518	25.588	NS
	7	464	11.906	NS
	11	569	25.555	NS
	18	613	20.428	NS
	30	600	22.160	NS
0.5 L/ha	0	500	39.316	NS
	1	567	48.047	NS
	3	482	66.289	NS
	7	549	16.016	NS
	11	511	35.122	NS
	18	602	29.106	NS
	30	600	22.160	NS
1.1 L/ha	0	491	39.658	NS
	1	464	45.965	NS
	3	329	38.272	*
	7	410	35.338	NS
	11	455	28.102	NS
	18	475	22.125	NS
	30	587	22.160	NS
1.7 L/ha	0	436	39.658	NS
	1	315	45.965	*
	3	259	38.272	*
	7	340	35.338	*
	11	484	28.102	NS
	18	495	27.421	NS
	30	555	22.160	NS
2.2 L/ha	0	493	39.658	NS
	1	333	45.965	*
	3	257	38.272	*
	7	287	35.338	*
	11	397	28.102	NS
	18	502	27.346	NS
	30	602	22.160	NS

[1]SEM = standard error of the mean
[2]NS = not significant at 0.05 probability level
* = significant at the 0.05 probability level

NATIVE BUMBLE BEE ABUNDANCE AND FORAGING BEHAVIOR IN RED CLOVER SEED PRODUCTION FIELDS OF THE WILLAMETTE VALLEY

K.M. Skyrm, S. Rao and W.P. Stephen

Introduction

Red clover (*Trifolium pratense*) is an important forage legume grown for seed in the Willamette Valley of western Oregon. A critical factor in the production of red clover is pollination. Given the self-incompatibility of flowers, plants rely on cross pollination for adequate seed set (Smith, Taylor and Bowley, 1985). Bees serve as the primary pollinating agents in red clover. Traditionally, growers have rented honey bees for pollination by incorporating 1-2 hives per acre. However, given the increasing difficulties in hive management attributed to parasites and diseases, honey bees have declined significantly in abundance, resulting in low availability and consequently increased costs to growers (Winfree et al., 2007). Furthermore, honey bees were found to be inefficient pollinators of red clover when compared to alternative bee species such as bumble bees (Rao and Stephen, 2006; Rao et al., 2007). Bumble bees exhibit a stronger preference for red clover over alternative flowering species as they visit 2-3 times more flowers per day than honey bees (Holm, 1966). In a recent cage study conducted by Rao et al. (2007) in a red clover field, bumble bees produced seed set comparable to that of honey bees.

Growers of the Willamette Valley have expressed interest in evaluating bumble bees as alternative pollinators in red clover. Since bumble bees are commercially unavailable in Oregon, growers must rely on feral populations of bumble bees for pollination. Unfortunately, the abundance and foraging behavior of the majority of feral bumble bee species is unknown in the Pacific Northwest (Stephen, 1957). These data are vital to evaluating feral pollinators as viable alternative pollinators for red clover seed production.

This study is centered on the dominant endemic bumble bee of the region, *Bombus vosnesenskii* (Radoszkowski), especially on its foraging behavior. An attempt is made to pair these behavioral observations with those of the honey bee, *Apis mellifera*, its principal competitor in red clover fields. The objectives of this study were: (1) to compare and contrast the numbers and pollen foraging behaviors of *B. vosnesenskii* with that of the honey bee, *A. mellifera* throughout the bloom period of red clover, and (2) to examine the pollen collecting foraging behavior of *B. vosnesenskii*, as a function of colony size.

Methods

Abundance. Bee estimates were taken in two red clover seed production fields in Polk County. To compare the abundance of *B. vosnesenskii* foragers with *A. mellifera*, surveys were taken during July and August. Visual counts of 2 minute duration were taken at 8 a.m. and 6 p.m. during sunny, dry weather along a 16.4 ft longitudinal grid, 6.6 ft wide. All honey bee and bumble bee species observed on red clover flowers were noted as well as those bees with pollen loads. Bumble bees were all endemic and honey bees were from introduced hives. A total of 2,080 counts were taken over 9 days. A Student's paired t-test was utilized to compare the abundance of bee species throughout bloom.

Colony Foraging Behavior. *B. vosnesenskii* colonies were obtained from a propagator and established within wooden nest boxes (10.0 x 8.5 x 7.5 inches). Colonies were classified by size based on the number of foragers within the colony. Small colonies consisted of 7-29 foragers whereas large colonies had 39-127 foragers. Bees were marked on the thoracic dorsum with distinctive colored tags (The Bee Works, Ontario, Canada) (Figure 1). Colonies were placed on a three-tiered shelf 3.3 ft from the field margin (Figure 2). The entrance of each colony was monitored daily in the morning (8 am to 12 am) and afternoon (4 p.m. to 8 p.m.) to determine the number of workers entering and leaving the nest box and the incidence of pollen loads. Of the 1,244 foraging trips, 363 were for pollen, during the160 hours of observation made during July. Only the data from two large colonies and two small colonies are presented in this report.

Figure 1. A marked nest of *B. vosnesenskii* bumble bees.

Figure 2. The three-tiered shelf setup of nest boxes for evaluating the foraging behavior of bumble bees situated within a red clover field.

Results

Abundance. Both *A. mellifera* and *B. vosnesenskii* foragers were present throughout red clover bloom (Figure 3). The abundance of honey bees varied from 0.24 to 6.11 bees per count (mean = 1.14, median = 0.24) whereas bumble bee abundance varied from 0.36 to 18.77 individuals per count (mean = 3.28, median = 0.79). The peak abundance for honey bees was on July 7, while the peak abundance for bumble bees occurred on August 12. For bees observed carrying pollen, honey bee abundance was highest on July 7, while bumble bee abundance was highest on August 9. Beginning on July 18, honey bee abundance began to decline while bumble bee abundance increased. A similar trend was observed for individuals carrying pollen. Statistically, there were differences between the abundance of bee species during early and late bloom but not during mid bloom. Honey bee abundance was highest during early bloom ($P = 0.05$) whereas bumble bee abundance was highest during late bloom ($P = 0.01$) (Figure 3). During late bloom, the abundance of bumble bees carrying pollen was greater than honey bees ($P = 0.03$) (Figure 4).

Colony Foraging Behavior. In small colonies the proportion of bees foraging for pollen varied from 0% to 67% whereas large colonies had 13% to 100% pollen foragers. Both groups of colonies "switched" in pollen foraging behavior with the time of day throughout July. In small colonies a higher proportion of pollen foragers switched from afternoon to morning time periods as the season progressed (Figure 5). The highest proportion of pollen foragers (67%) among small colonies occurred on July 15 during the morning. Small colonies ceased pollen collection on July 28. Large colonies also exhibited a behavioral switch as a larger proportion of individuals shifted to foraging for pollen from morning to afternoon time periods (Figure 6). However, unlike small colonies, large colonies possessed active pollen foragers throughout the month of July, as the highest proportion of individuals foraging for pollen (100%) occurred on July 26 in the afternoon.

Discussion

Red clover depends on bee pollinators for adequate seed set. However, declines in honey bee availability and increased costs of hive rental have resulted in a search for alternative pollinators for red clover. Past studies have indicated the greater efficiency of bumble bees as red clover pollinators. Information regarding the abundance and foraging behavior of many of these species is unknown and is critical for their evaluation as alternative pollinators.

The results of this study indicate that *B. vosnesenskii* is not only abundant in red clover fields throughout the season but that during late season their numbers are greater than that of the commonly utilized honey bee. Furthermore, the pollen foraging behavior of *B. vosnesenskii* colonies seems to differ based on the colony size and time of day.

The abundance of bee foragers in this study was gathered from observations made in two non-randomly chosen red clover fields. Based on these observations, it seems producers of red clover seed should consider feral bumble bee populations for pollination.

Future work will include seasonal comparisons of the pollen foraging behavior of bumble bees compared to that of honey bees by analyzing pollen samples collected from foragers in the field and at the nest site. Lab bioassays will also be conducted to determine if bumble bees indeed choose red clover over alternative plant species.

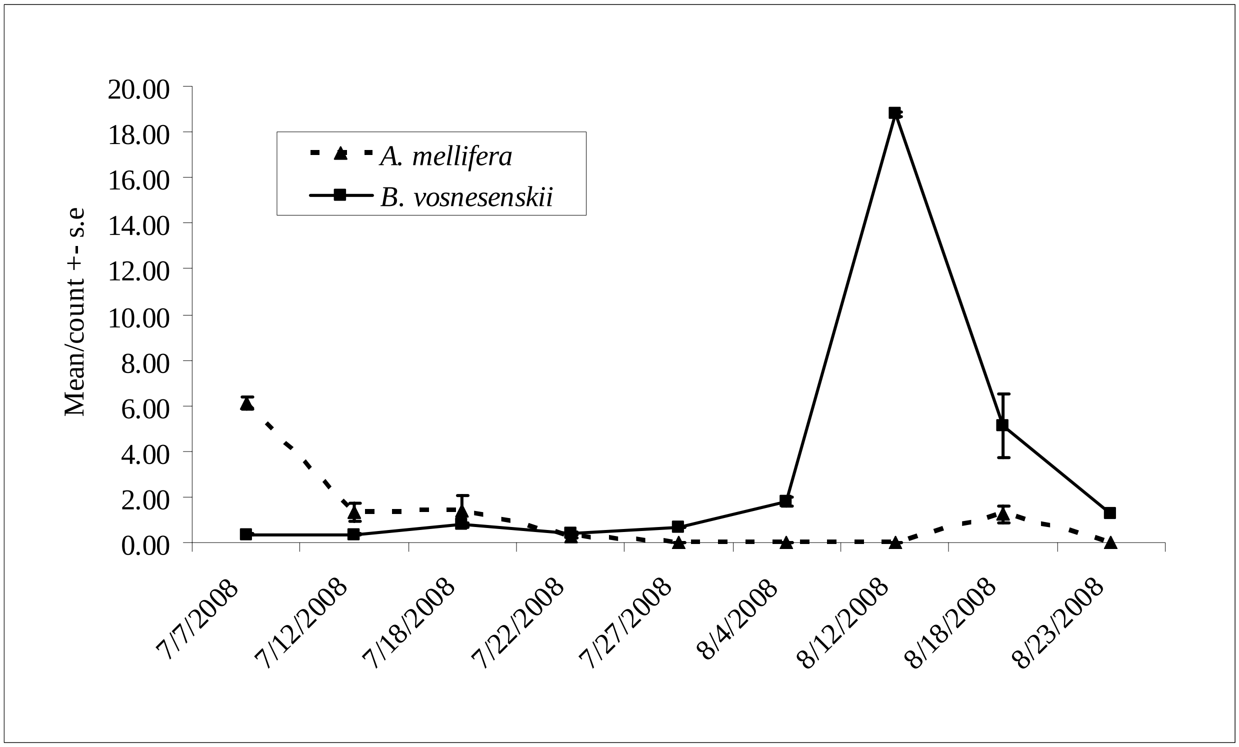

Figure 3. Abundance of bumble bees and honey bees (mean per 2 minute count) in two red clover seed production fields in Polk County, Oregon. No counts were made for honey bees on July 27, August 4, August 12 or August 23.

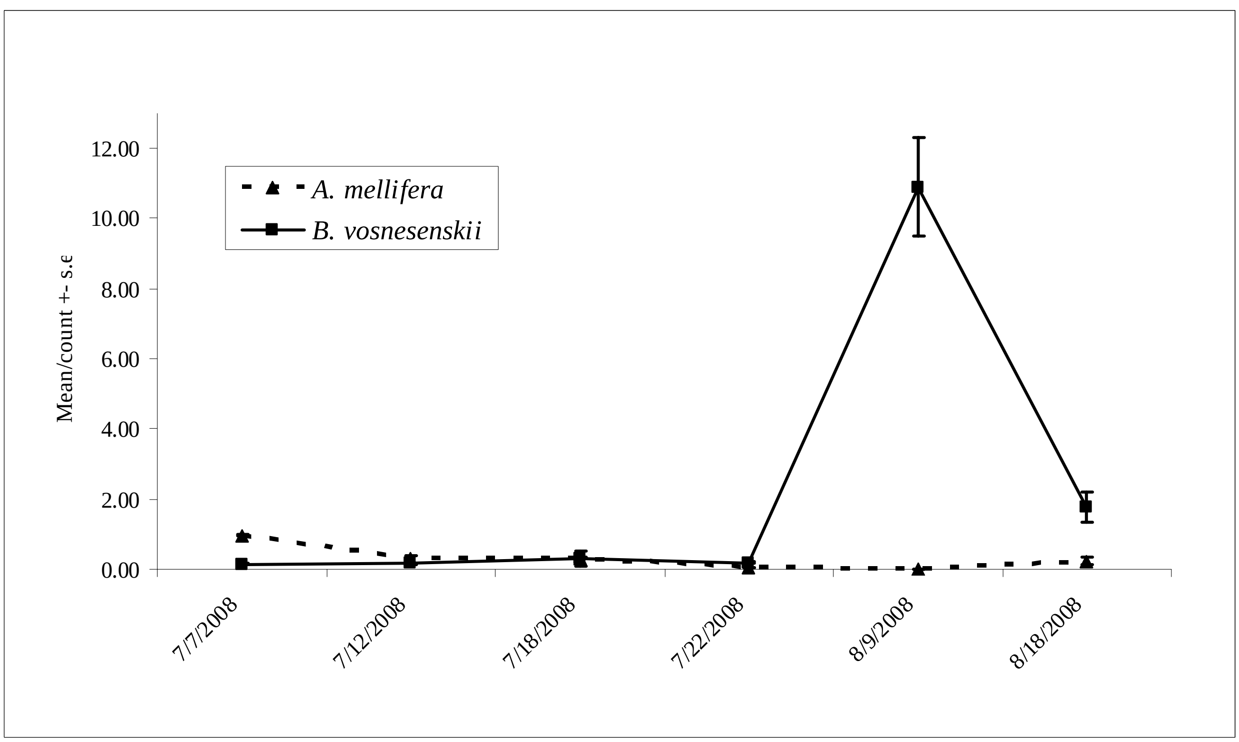

Figure 4. Abundance of bumble bees and honey bees (mean per 2 minute count) observed carrying pollen in two red clover seed production fields in Polk County, Oregon. No counts were made for honey bees on August 9.

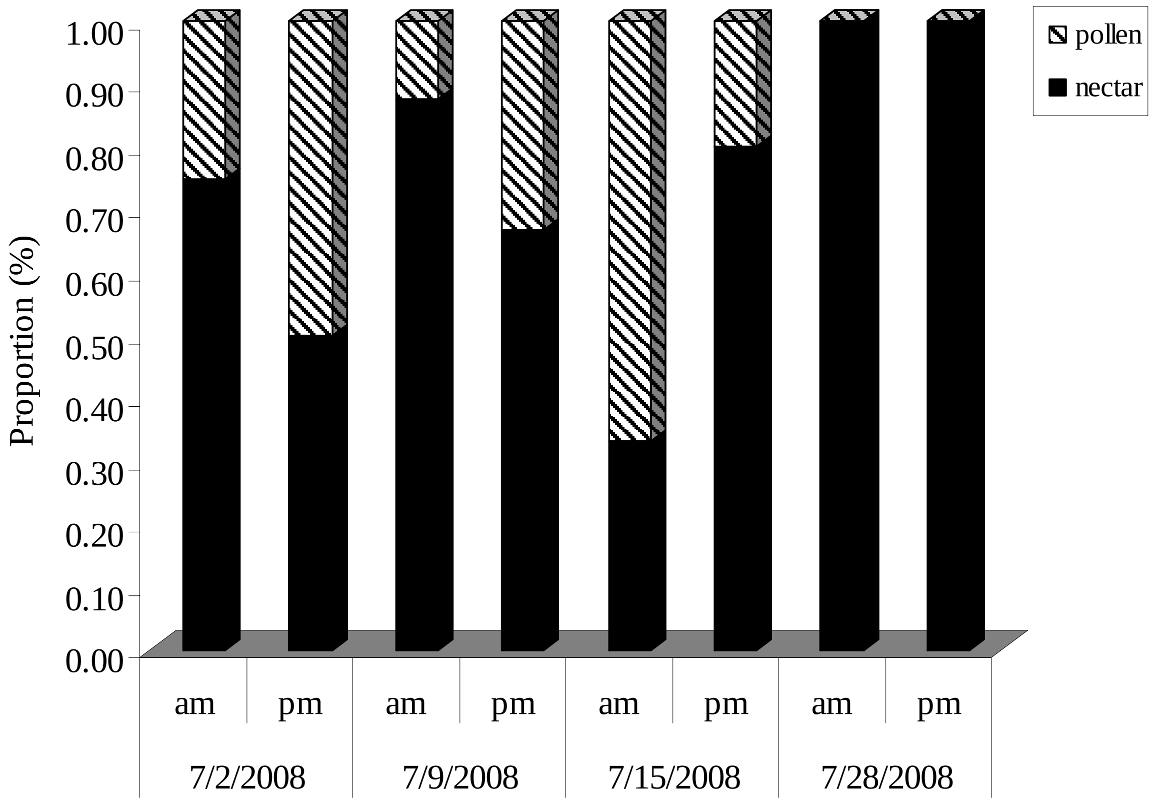

Figure 5. The proportion of individual bumble bees foraging for pollen and nectar from small *B. vosnesenskii* colonies (N=2) during the month of July. Pollen foragers were characterized by the presence of pollen loads. Nectar foragers were those which did not have visible pollen loads.

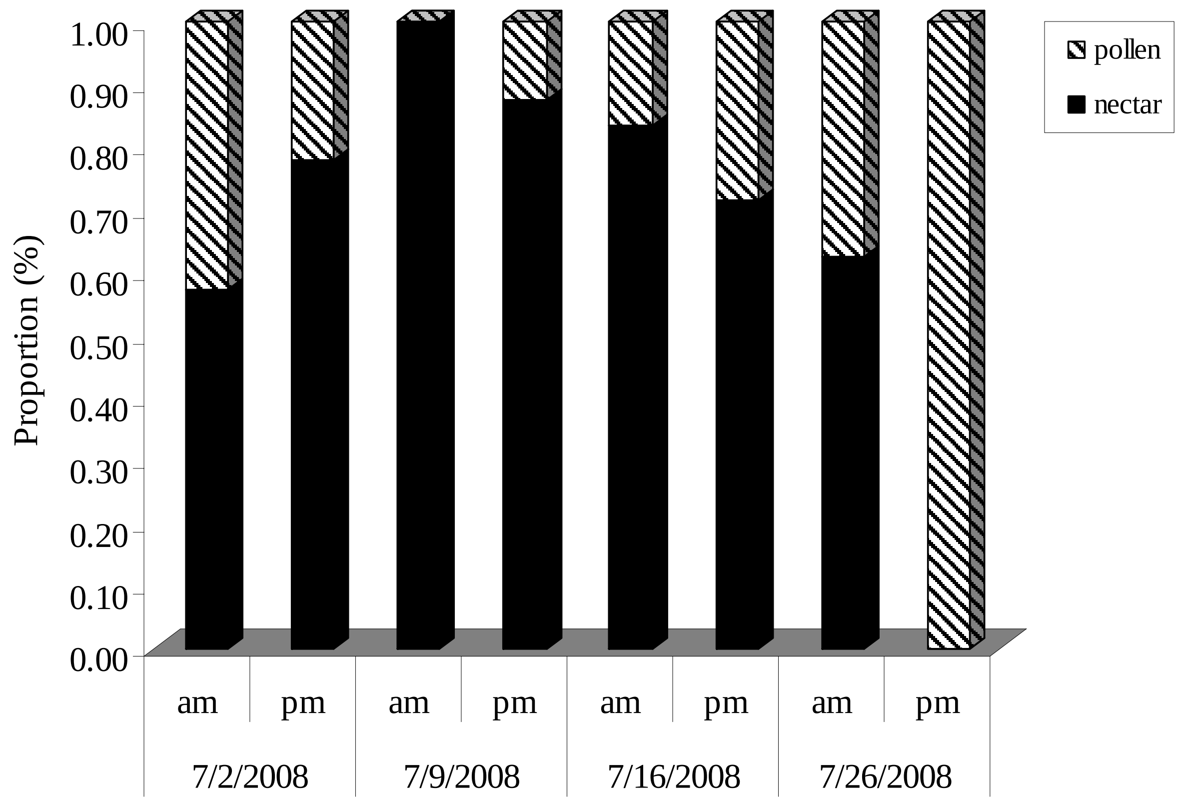

Figure 6. The proportion of individual bees foraging for pollen and nectar from large colonies of *B. vosnesenskii* (N=2) during the month of July. Pollen foragers were characterized by the presence of pollen loads. Nectar foragers were those which did not have visible pollen loads.

References

Holm, S.N. 1966. The utilization and management of bumble bees for red clover and alfalfa production. Annual Review of Entomology, 11: 155-182.

Rao, S. and Stephen, W.P. 2006. Native bee pollinators in clover seed production. *In* Young, W.C., Ed., Seed Production Research, Oregon State University Publication 126: 44-46.

Rao, S., Stephen, W.P. and Bergh, J. 2007. Comparison of red clover pollination by commercial and native bees in seed production fields in the Willamette Valley. *In* Young, W.C., Ed., Seed Production Research, Oregon State University Publication 127: 59-62.

Smith, R.R., Taylor, N.L., and Bowley, S.R. 1985. Red clover. *In* Taylor, N.L., Ed., Clover Science and Technology, Agronomy Monograph No. 25: 457-501.

Stephen, W.P. 1957. Bumble bees of Western America. OSU Technical Bulletin 40. 162 pp.

Winfree, R., Williams, N.M., Dushoff, J., and Kremen, C. 2007. Native bees provide insurance against ongoing honey bee losses. Ecology Letters, 10: 1-9.

AN ATTEMPT TO SYNCHRONIZE BUMBLE BEE FLIGHT TIMES WITH PEAK BLOOM IN RED CLOVER

W.P. Stephen and S. Rao

Researchers and seed producers have for many years been frustrated by the difficulty in achieving an adequate seed yield in red clover. The poor seed yields have been attributed, in part, to rejection of red clover by honey bees because their short tongues are unable to reach the nectar in the deep floral tubes. In an earlier study (Rao et al., 2008), we documented that honey bees are capable of pollinating red clover under cage conditions. However, even though honey bees pollinate the crop, their performance is affected by the presence of competing foraging resources in the vicinity (Peterson et al., 1960). Currently, there are no known tactics for retaining honey bee workers in red clover fields in which the hives are placed instead of foraging on other bloom in the area.

Alternative bee pollinators in Oregon include the social bumble bees and a diversity of solitary bees. Bumble bees (*Bombus* spp.), in particular, are considered to be excellent pollinators of red clover. There are eight species of bumble bees in western Oregon (Stephen, 1957), six of which are abundant in summer when red clover is in bloom (Rao and Stephen, 2007). Five of these are long-tongued, and likely to contribute to red clover pollination. These include *B. appositus* and *B. californicus*, *B. griseocollis, B. nevadensis* and *B. vosnesenskii.*

The impact of naturally occurring bumble bees on red clover seed production is dependent not just on the species and their abundance but also on synchrony with bloom. All bumble bees overwinter as fertilized queens. They emerge in the spring, seek out floral sources for nourishment, and look for sites in which to establish their nest (often old mouse or vole nests). When the first brood emerges in about 4-6 weeks, the queens remain in the nest and the workers perform all other duties including collection of pollen for nourishment of colony members. Once a colony is established, it grows steadily as long as adequate foraging resources are available. Thus, is a sense, pollination is a by-product of colony growth in bumble bees.

In western Oregon, we have observed bumble bee queens and workers foraging in blueberries in spring. The abundance of blueberry pollen enables them to build their colonies. Unfortunately, when blueberry bloom ends, foraging resources in the area are limited. When faced with food shortages, workers in bumble bee colonies remove developing brood, sacrificing their brood in order to save the colony. The result is a steep decline in foraging bumble bees in early summer (Figure 1.) Populations do build up again in late summer. However, due to the decline in early summer, there is a lag in bumble bee abundance relative to red clover bloom in western Oregon.

We speculated that, if a plentiful forage source is available during June, bumble bee colony development will be stimulated, and populations will be high at the time of peak bloom in red clover. To test this we examined bumble bee abundance in red clover fields which varied in bloom to determine if the presence of early bloom would result in synchronization of bumble bee foraging with peak red clover bloom.

Methods

Sites: The study was conducted in red clover seed production fields in Polk county in western Oregon. Two growers, both with fields of approximately 30-40 acres, cooperated in this study. One grower cut his field leaving a 16 ft strip of clover at the edge of his field (Field A). A second grower left his entire field uncut (Field B). Two other fields (Field C and D) were both cut in early June and both bloomed by July 7, 2008.

Sampling: Blue vane traps used in earlier studies (Stephen and Rao, 2005; Rao et al., 2008) were used to estimate bumble bee abundance. Two traps were set out on each of the four fields on June 14, 2008. Traps were left in place for 48 hours, after which they were collected, and the contents frozen and identified. Sampling was conducted every 1-2 weeks in each field until late August.

Results and Discussion

In all four fields bumble bee abundance was low in June and July (Figure 2). Subsequently, in Fields A, C and D, populations rose rapidly and peaked in mid-August before dropping during the last sampling period. There was little difference in bumble bee abundance between these three fields. In contrast, in Field B, no dramatic increase in bumblebee was observed and the populations dropped by mid-August.

The study documented that maintenance of a border of uncut red clover in Field A did not result in drawing bumble bees to the field. It is possible that the strip of uncut red clover was too small to act as a major forage source. On the other hand, Field B had an abundance of red clover in bloom in July, and should have attracted bumble bees in the area. Field location may have had an impact as Field B was surrounded by agricultural fields, and it is possible that searching bees were drawn to native landscapes rather than the open farmland area around Field B.

The low abundance of bumble bees in red clover fields in July is intriguing. It is possible that bumble bees prefer some other food source during this period. Alternatively competition with honey bees could influence foraging by bumble bees. Earlier studies have documented negative impacts on reproductive success (Thomson, 2004) and size of workers (Goulson and Sparrow, 2008) of bumble bees in areas of high honey bee density. Foraging behavior could also be affected by competition with honey bees. In a study conducted in Minnesota, Peterson et al. (1960) reported that bumble bees tended to be more abundant in fields located > 1.0 mile away from apiaries (honey bee colonies). In another study, Butler (1941) observed that bumble bees were more abundant when nectar concentration was lower than that of other plants which drew the honey bees out of red clover.

Further research is needed to determine the basis for the early low abundance of bumble bees in red clover fields in Oregon. If food preference is the factor, research could be directed towards determining what flowers draw bumble bees away from red clover. If competition is a factor, naturally occurring bumble bees and other native pollinators may be adequate for red clover seed production in Oregon without the addition of honey bee hives. An area-wide study, required for such an evaluation, would be beneficial as it could lead to a savings in production costs especially with the recent increase in the price of honey bee hive rentals resulting from the colony collapse disorder.

References

Butler, C.G. 1941. A study of the frequency with which honeybees visit red clover (*Trifolium pretense*) together with an examination of the environmental conditions. Ann. Appl. Biol. 28: 125-134.

Goulson, D., and K.R. Sparrow. 2008. Evidence for competition between honeybees and bumblebees; effects on bumblebee worker size J. Insect Conserv. Doi: 10.1007/s10841-008-9140-y.

Peterson, A.G., B. Furgala, and F.G. Holdaway. 1960. Pollination of red clover in Minnesota. J. Econ. Entomol. 53: 546-550.

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

Rao, S., W.P. Stephen, and J. Bergh. 2008. Comparison of red clover pollination by commercial and native bees in seed production fields in the Willamette Valley. *In* W.C. Young, III (ed.), Seed Production Research, Oregon State University Publication 127: 59-62.

Stephen, W.P. 1957. Bumble Bees of Western America. Oregon State College, Agricultural Experiment Station, Technical Bulletin 40, 163 pp.

Stephen, W.P., and S. Rao. 2005. Unscented Traps for Non-*Apis* Bees (Hymenoptera: Apoidea). J. Kans. Entomol. Soc. 78: 373-380.

Thomson, D. 2004. Competitive interactions between the invasive European honey bee and native bumble bees. Ecology 85: 458-470.

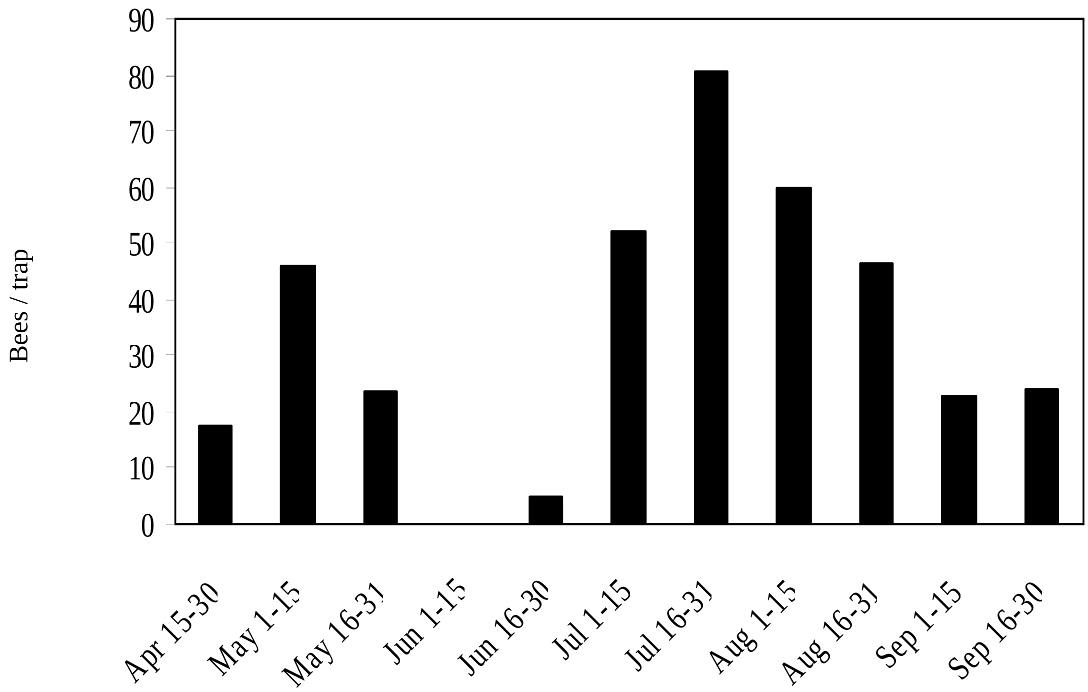

Figure 1. Mean number of bumble bees trapped in blue vane traps placed in blueberry and red clover fields in the Willamette Valley between 2005 and 2008.

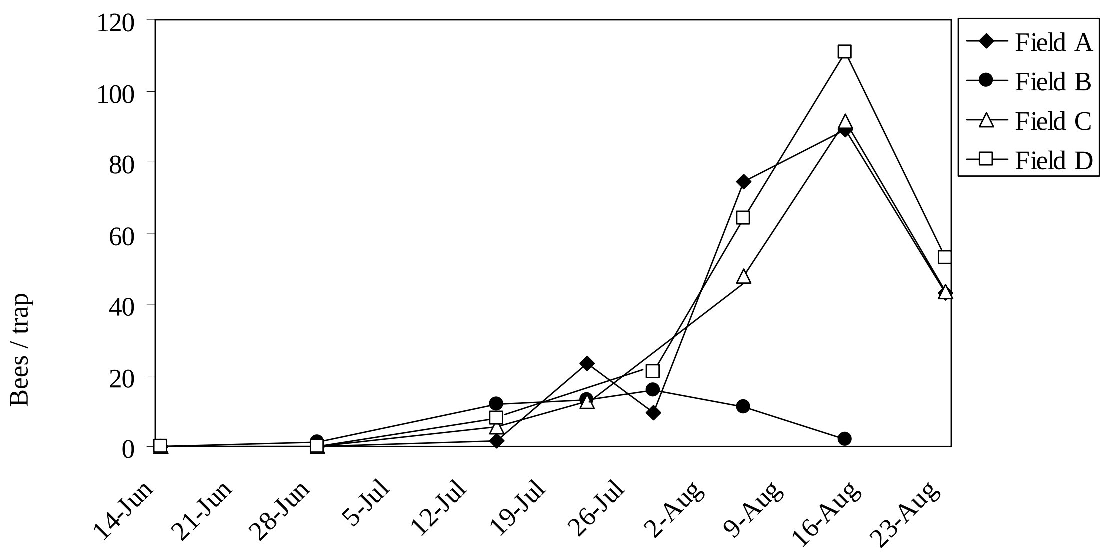

Figure 2. Mean number of bumblebees trapped in blue vane traps in four red clover fields. Field A = Field with 5 m border of uncut clover; Field B = Entire field uncut; Field C, D = Field cut in early June.

EVALUATION OF FIFTEEN KENTUCKY BLUEGRASS VARIETIES FOR TOLERANCE TO POWDERY MILDEW, 2008

M.D. Butler, R.P. Affeldt, L.L. Samsel and N.K. Lytle

New fungicide products have been regularly evaluated for control of powdery mildew in Kentucky bluegrass *(Poa pratensis)* seed production fields in central Oregon since 1998. Products have included the historic industry standard Bayleton® (triadimefon), along with Tilt® (triadimefon), Tilt (propiconazole) plus Bravo® (cholorothalonil), new products such as Laredo® (myclobutanil), Folicur® (tebuconazole), Quadras® (azoxystrobin) and Quilt® (azoxystrobin+ propiconazole), and alternative materials like Microthiol® (sulfur) and stylet oil. The objective of this project is to determine susceptibility of 15 varieties being grown without open field burning for residue management, and the influence of stand age of disease severity. This is the first year of a three year study.

This research was conducted at the Central Oregon Agricultural Research Center (COARC) near Madras. A split plot design was used, with plots 10 ft x 60 ft main plots and three 10 ft x 20 ft subplots. Subplots were randomized and included Palisade® (trinexapac-ethyl), Beacon® (primisulfuron) and an untreated check. Main plots were replicated four times in a randomized complete block design. The untreated single plots within the split plots were used for this project.

Plots were evaluated using a rating scale of 0 (no mildew present) to 5 (total leaf coverage) on May 14, 2008. The following day the entire plot area was treated with Laredo at 12 oz/acre plus Microthiol at 5 lb/acre. Powdery mildew ratings (Table 1) ranged from less than 1.0 for 'A00-891', 'Valor', 'Monte Carlo', 'Rhapsody' and 'Zinfandel' to 2.6 for 'Atlantis' and 2.8 for 'Merit'. This may be due in part to plant growth characteristics in addition to natural plant tolerance. 'Atlantis' and 'Merit' are larger plants with more rank growth, creating an environment conducive to disease development.

Table 1. Tolerance of Kentucky bluegrass varieties grown for seed to powdery mildew *(Erysiphe graminis)* near Madras, OR evaluated on May 14, 2008.

	Powdery mildew	
Variety	Ratings (0-5)	Significance
A00-891	0.3[1]	a[2]
Valor	0.6	ab
Monte Carlo	0.7	ab
Rhapsody	0.7	ab
Zinfandel	0.8	ab
Bordeaux	1.0	bc
A00-1400	1.0	bc
Bandera	1.5	cd
Bariris	1.8	de
Crest	1.8	de
Shamrock	2.1	def
Volt	2.3	efg
A01-299	2.3	efg
Atlantis	2.6	fg
Merit	2.8	g

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

SOD WEBWORM MANAGEMENT SYSTEM FOR KENTUCKY BLUEGRASS SEED PRODUCTION IN CENTRAL OREGON, 2008

M.D. Butler, L.L. Samsel, G.C. Fisher and R.E. Berry

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. No billbugs (*Sphenophorus venatus confluens*) were collected in 2003-2004, while 22 were collected during 2004-2005. At that time sod webworms were considered an emerging pest that could have a financial impact on Kentucky bluegrass fields in central Oregon.

More recently the project has focused on sod webworm populations and distribution during the 2005, 2006 and 2008 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 correlation between moth and larval populations. The objective of this research is to determine if pheromone traps can be used as an indicator of which fields will have high populations of larvae in the fall, when control measures are applicable. The number of cutworms collected in pheromone traps has been tracked as well.

Four pheromone traps were placed in each of the four quadrants of 11 commercial Kentucky bluegrass seed production fields in early May. Fields with potential for insect problems in the Madras and Culver areas were chosen for the project this season. Contents of the traps were collected approximately weekly from May 12 to July 21, with the number of sod webworm and cutworm moths noted. Traps were removed prior to harvest operations, and the resulting data provided to the appropriate fieldman for follow-up with growers.

All fields with significant numbers of sod webworm moths were treated in the fall, making them unsuitable for follow-up sod sampling. Instead the project focused this fall on problem fields indentified by cooperating fieldmen. Eight sod samples per field were collected from four fields and processed using Berlese funnels.

The overall peak flight of sod webworm moths was from July 1 to July 20 (Table 1). This is comparable to previous years. During peak flight the total number of sod webworm moths collected per field per week from the four traps were near 170. The total number of sod webworm moths collected per field varied from 27 to 1253. These numbers are considered relatively low compared to the Willamette Valley.

Cutworm moths attracted to the traps were tracked as well (Table 2). Peak numbers were collected during June 18 through July 20, with the number collected per field per week during this time near 25. The total number of cutworms collected per field varied from 47 to 265. The number of cutworms collected is considered relatively low compared to other growing regions. Their lifecycle appears to be similar to that of sod webworm.

Four problem fields were the focus of this project during the fall of 2008. Sod samples collected at Location 1 on October 19 indicated infestations of cutworms and aphids, with some sod webworms, billbugs, springtails and rove beetles. Samples collected at Location 2 on October 28 revealed a large number of billbugs, a variety of mites, aphids and early stages of springtails. This despite insecticide applications directed at the perceived problem. At Location 3 sod samples collected on October 19 showed an infestation of winter grain mites, aphids, some cutworms and a few sod webworm. Samples collected on October 19 at Location 4 revealed infestations of winter grain mites and aphids, some cutworms, billbugs and sod webworms and a large number of springtails.

Following are some informal observations. Fieldmen and growers indicate that higher numbers of larvae are often found under windrows where there is greater protection and higher moisture levels. It is felt that field dry down following harvest, followed by open field burning makes a relatively inhospitable environment for emerging larvae. Some years the presence of moths during the summer is followed by few to no larvae in the fall. This seems to occur at the same time both in central Oregon and the Willamette Valley. This observation would seem to indicate the cause may be a regional weather event, such as exceptionally hot, dry weather following harvest.

Table 1. Sod webworm moths collected per field using pheromone traps from May 7 to July 21, 2008 near Madras, Oregon.

Field	Sod webworm moths									
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Total
1	2	1	0	6	17	1	---	---	---	27
2	6	2	0	0	1	21	82	339	91	542
3	16	4	2	0	3	9	15	62	55	166
4	2	3	0	0	3	15	52	114	249	438
5	3	5	4	1	1	10	13	41	42	120
6	2	2	---	0	10	13	50	73	49	199
7	1	---	14	1	9	29	146	243	95	538
8	---	---	---	---	1	6	126	228	46	407
9	7	7	2	1	7	84	82	446	617	1253
10	4	0	0	0	---	2	63	171	128	368
11	2	5	2	4	---	7	24	131	73	248
Total	45	29	24	13	52	197	653	1848	1445	

Table 2. Cutworm moths collected per field using pheromone traps from May 7 to July 21, 2008 near Madras, Oregon.

Field	Cutworm moths									
	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Total
1	2	0	1	18	24	2	---	---	---	47
2	2	0	1	0	0	13	15	11	7	49
3	3	2	2	11	23	20	30	29	12	132
4	14	3	3	5	12	30	35	34	42	178
5	1	3	3	5	4	20	28	37	39	140
6	2	36	---	34	13	31	40	71	38	265
7	2	---	1	1	18	37	42	18	15	134
8	---	---	---	---	9	20	33	1	18	81
9	3	4	3	1	20	2	9	0	9	51
10	4	1	1	1	---	8	27	0	30	72
11	6	0	0	13	---	19	34	7	52	131
Total	39	49	15	89	123	202	293	208	262	

WINTER GRAIN MITE CONTROL IN KENTUCKY BLUEGRASS GROWN FOR SEED IN CENTRAL OREGON, 2008

M.D. Butler, W.D. Scott, L.L. Samsel and J.L. Carroll

The winter grain mite has long been considered the major insect pest for Kentucky bluegrass seed production in central Oregon. Other pests include sod webworm *(Chrysoteuchia topiaria)*, cutworm *(Protagrotis obscura)* and most recently billbugs *(Sphenophorus venatus confluens)*. The product of choice for control of winter grain mites has been dimethoate. The objective of this project is to evaluate new and alternative materials for efficacy compared to this industry standard.

The trial was conducted in cooperation with S & L Farms in a commercial Kentucky bluegrass seed field on the Agency Plains north of Madras, Oregon. Insecticides that were compared with the industry standard dimethoate, included Lorsban® (chlorpyrifos), Baythroid® (beta-cyfluthrin), and Oberon® (spiromesifen). Plots were 10 ft by 25 ft replicated 4 times in a randomized complete block design. Treatments were applied November 7, 2008 using a CO_2-pressurized hand-held boom sprayer outfitted with TeeJet 8002 nozzles on a 9-ft boom operated at 40 psi and applying 20 gal/acre water.

Mite counts were made using eight 2-inch crown and soil core samples per plot. Samples were stored under refrigeration while waiting processing in Berlese funnels. Insects were collected into jars and identified using a dissecting microscope. Precounts were taken prior to application on November 3 and following application on November 12, 17, 24 and December 1, 2008. Dimethoate was applied to clean up the entire plot area on January 2, 2009.

None of the insecticides provided significantly greater control of winter grain mites than the industry standard, dimethoate (Table 1). Although the winter grain mite population was relatively modest at the time of insecticide application, the performance of Oberon was not significantly different from the untreated plots.

Table 1. Winter grain mite control following insecticide applications on November 7, 2008 in Kentucky bluegrass grown for seed near Madras, Oregon.

	Product	Mites per plot				
Treatment	per/acre	Pre Count	Nov 12	Nov 17	Nov 24	Dec 1
Dimethoate[1]	0.67 pt	3.50	1.50	1.00	0.25 a[2]	1.25 ab
Lorsban	0.5 pt	6.25	0.50	0.50	0.25 a	0.25 ab
Baythroid	28 fl oz	2.50	2.00	0.75	0.00 a	0.00 a
Oberon	8 fl oz	5.00	8.75	3.50	8.75 c	4.00 ab
Oberon	12 fl oz	6.25	3.25	5.75	3.25 bc	3.25 ab
Untreated	-----	5.25	6.75	5.50	4.75 ab	5.00 b
		NS	NS	NS		

[1]Dimethoate = dimethoate, Lorsban = chlorpyrifos, Baythroid = beta-cyfluthrin, Oberon = spiromesifen,
[2]Mean separation with LSD at $P \leq 0.05$.

EVALUATION OF PALISADE ON FIFTEEN KENTUCKY BLUEGRASS VARIETIES GROWN FOR SEED IN CENTRAL OREGON, 2008

M.D. Butler, R.P. Affeldt, L.L. Samsel and N.K. Lytle

Research to evaluate Palisade® (trinexapac-ethyl) on Kentucky bluegrass *(Poa pratensis)* was conducted in commercial seed fields of ‘Merit’ or ‘Geronimo’ from 1999 to 2003. Yields were increased by 31 to 36 percent four of the five years when Palisade was applied at 22 oz/acre from the second node (Feekes 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 out grow the effect of earlier Palisade applications. No differences between treatments in weight per 1,000 seed were observed, and percent germination was not adversely affected.

This research was conducted at the Central Oregon Agricultural Research Center (COARC) near Madras. A split plot design was used, with plots 10 ft x 60 ft main plots and three 10 ft x 20 ft subplots. Subplots were randomized and included Palisade, Beacon® (primisulfuron) and an untreated check. Main plots were replicated four times in a randomized complete block design. Palisade was applied at 24 oz/acre on May 14 when most varieties were in the boot stage. The exceptions were the early maturing varieties ‘Volt’ and ‘Shamrock’ where the heads were starting to appear.

Application was 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 on June 20 and percent lodging was estimated on July 2. A research-sized swather was used to harvest a 40-inch by 17-foot portion of each Kentucky bluegrass plot as varieties matured from July 5 to July 10. Samples were placed in large burlap bags and hung in the equipment shed to dry, then combined by hand-feeding the samples into a stationery Hege small-plot combine. Seed samples were transported to the Hyslop Crop Science Research Farm near Corvallis where they were debearded, run through a small scale clipper cleaner and clean seed weight determined.

Seed yield (Table 1) was significantly increased for 7 varieties by as much as 35 percent for ‘A01-299’ and 32 percent for ‘Atlantis’. Yield was decreased by 18 percent for ‘A00-891’, while there was no significant change for 7 varieties. Lodging was significantly reduced for 14 of the fifteen varieties, with ‘Bariris’ showing no change. Results were mixed concerning plant height, with 11 varieties shorter by as much as 15 percent following Palisade application and 4 varieties taller by as much as 6 percent. These mixed results are likely due to the plants outgrowing the effect of Palisade by the time height measurements were taken.

Table 1. Effect of Palisade growth regulator on seed yield, lodging and plant height for fifteen Kentucky bluegrass varieties, Madras, Oregon, 2008.

	Clean seed yield (lb/a)				Lodging (%)		Plant height (in)	
Variety	Check	Palisade	% Check	Signif. [1]	Check	Palisade	Check	Palisade
Atlantis	1287	1696	132	***	78	36	29.00	30.25
Merit	1660	1860	112	*	53	3	26.75	23.75
Rhapsody	1051	1040	99	NS	48	0	25.25	22.25
Valor	972	1029	106	NS	56	0	23.75	20.25
Bariris	827	1066	129	**	100	92	27.00	28.50
Crest	1593	1664	104	NS	63	7	26.50	25.25
Monte Carlo	1095	1015	93	NS	37	0	26.00	22.25
Shamrock	1581	2031	128	***	79	46	29.25	27.25
A00-891	1955	1595	82	***	81	23	25.25	24.00
A00-1400	957	1235	129	**	93	60	24.75	25.25
Bandera	1335	1299	97	NS	28	1	26.75	24.25
Bordeaux	1290	1527	118	**	95	21	26.25	27.00
Volt	1473	1457	99	NS	79	43	26.75	26.50
Zinfandel	1007	1006	100	NS	40	0	25.00	22.50
A01-299	912	1228	135	***	78	21	27.25	27.00

[1] Comparison with paired t-test: NS = non-significant, * for P=0.10, ** for P=.05, *** for P=0.01

EVALUATION OF SIMULATED HAIL DAMAGE TO KENTUCKY BLUEGRASS SEED PRODUCTION IN CENTRAL OREGON, 2008

M.D. Butler, M.E. Zarnstorff and L.L. Samsel

Kentucky bluegrass seed production has historically been an integral part of agriculture in central Oregon. In recent years there has been a decline in acreage due to reduction in price from an oversupply, but more recently acreage has rebounded. The objective of this project is to determine the impact from timing and severity of hail damage on seed production of Kentucky bluegrass. This information will assist the National Crop Insurance Service in developing methodology to evaluate hail damage on Kentucky bluegrass.

This is the second year of a multiple year evaluation on the effect of simulated hail damage on Kentucky bluegrass seed production. The study was conducted in a commercial third-year field of 'Monte Carlo' with H & T Farms near Culver, Oregon. Plots were 5 ft by 15 ft, with 3-ft alleyways, replicated four times in a randomized complete block design.

Variables established for this study included three treatment timings and three levels of damage. Damage treatments were inflicted at the boot stage, at head emergence, and during seed fill. Severity of damage inflicted was targeted at 33, 67, and 100 percent compared to undamaged plots.

A Jari mower was used to cut three-foot alleys across the front and back of each block of plots. Treatments were made on May 20, June 13, and July 1 using a weed eater with plastic blades held on edge at a 45 degree angle or perpendicular to the ground for the 100 percent treatment. The target amount of foliage or seed heads removed was one-third of the growth, two-thirds of the growth, or removal of all plant material above 1-2 inches. A research-sized swather was used to harvest a 40-inch by 12-ft portion of each Kentucky bluegrass plot on July 15, the date commercial harvest of the field was begun. Samples were placed in large burlap bags and hung in the three-sided equipment shed at the Central Oregon Agricultural Research Center to dry. When samples were dry they were combined using a stationary Hege, with seed samples processed using a debearder follow by a Clipper cleaner.

The data (Table 1) are very similar to those collected last year. The same treatments caused similar reductions in yield with nearly the same comparative ranking of treatments to last year. This gives confidence in the results across two varieties, stand age and growing season.

It is clear that damage at head emergence resulted in the greatest reduction in yield. Treatments that applied 33 or 67 percent damage at head emergence had a significantly greater effect on seed yield than other treatment timings. It appears that Kentucky bluegrass is particularly susceptible to damage at head emergence.

One hundred percent damage at the boot stage allowed the plant to recover only 41 percent of the yield for the untreated plots. Damage later in plant development at head emergence or seed fill eliminates any yield potential. Lesser damage of 33 and 67 percent inflicted at seed fill appears to cause less reduction in seed yield than the same damage at the boot stage. This is despite heavier than intended damage inflicted at seed fill.

Table 1. Simulated hail damage on Kentucky bluegrass grown for seed with damage inflicted at the boot stage, head emergence and seed filling prior to harvest on July 15, 2007.

Hail damage		Seed yield		
Damage (%)	Growth stage	Pounds/acre		% Untreated
Untreated	---	821	a[1]	100
33	Seed fill	622	b	76
33	Boot	568	b	69
67	Seed fill	453	c	55
100	Boot	338	d	41
67	Boot	335	d	41
33	Heads emerged	186	e	23
67	Heads emerged	67	f	8
100	Heads emerged	0	f	0
100	Seed fill	0	f	0

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

INSECTS FOUND IN GRASS SEED FIELDS IN THE LOWER COLUMBIA BASIN

S.I. Rondon

Grass seed crops are adapted to Columbia Basin area's soils and climate, and fit well when grown in rotation with other irrigated crops of regional importance such as sweet corn, potatoes and onions. The use of center pivot irrigation systems, low soil organic matter, sandy soils, and differing climate, however, can produce problems specific to the region during grass production. Problems with pest management, specifically arthropods (insects, mites), can be acute since many of the pest control strategies developed for more traditional grass seed production areas are inappropriate or ineffective for Columbia Basin conditions. While research the past several years has contributed greatly to the understanding of insect issues, there is still much to learn related to the best control methods under conditions found in the Columbia Basin. The objectives of this research are to continuously survey arthropod pests and beneficials in the area, to evaluate the role of emerging or new emerging pests such as sawfly incidence in the lower Columbia Basin and to disseminate information on arthropod control to the industry.

Materials and Methods.

A survey of arthropod pests in seed grass crops was conducted during from 2006-2008 (see http://cropandsoil.oregonstate.edu/seed-ext/Pub/2007/18-Rondon.pdf) . Six commercial Kentucky bluegrass fields were included in the 2006 and 2007 survey; three fields were included in 2008. Fields were split in replicated plots. Pitfall traps, sweep net and sod samples were taken in each section of each field. Six pitfall traps replicated four times were placed at each location to collect insects that were moving in the field. Ten sweeps replicated four times were taken in each field. Six sod samples 1 ft in diameter by 4 inches deep replicated four times were collected at each location. In all years, arthropods were collected from the traps weekly. In 2008 a handful of species were selected based on their high number, and their role in the grass ecosystem was investigated the following year. Preliminary research showed that millions of springtails can be present in the grass crop. Growers have indicated their concern regarding those high numbers and the potential effect springtails may have moving diseases in their crops. It remains unanswered if the presence of springtails relates to disease incidence such as ergot or if springtails can cause secondary damage. Only pit fall trap data will be presented on this article.

Results

Table 1 shows the average number of arthropods per Order per week (2006-08). The most abundant groups were: springtails, mites, spiders, flies, and various families of beetles. Springtails (Order Collembola) are part of the community of decomposers that break down and recycle organic wastes. Springtails can be identified because they "hop" by snapping their furcula ('tail') against the substrate; they may propel themselves up to 20 cm in the air. The two species identified in eastern Oregon were *Isotoma* and *Sinella*. Information regarding both species is limited. Due to their large numbers in the area, growers are concerned. Springtails have been observed "jumping" all over grass leaves. However, their role in the grass ecosystem is still unclear. Although it is unlikely that they are causing damage to grass plants or are having a detrimental effect on yield; we speculate that they can potentially move disease spores, but this hypothesis needs further investigation.

Spiders (Order Arachnida) are well represented in the grass system with the two families Lycosidae and Linyphiidae being the most abundant. Both families are beneficial. It is rarely useful to apply pesticides to control or eliminate spider infestations.

Six different families of beetles (Order Coleoptera) were found during our survey. One of the most predominant is the rove beetles (Family Staphilinidae) which occurs in a variety of habitats. Some species are considered beneficial since they feed on insect pests.

Sawflies (Hymenoptera: Cephidae) (Figure 1) are important re-emerging feeding insect pest of wheat and other cereals, but they are also found on a broad range of grass hosts. They attack native and many common exotic species of grass such as smooth bromegrass (*Bromus inermis*), timothy (*Phleum pratense*), and quackgrass (*Agropyron repens*). Currently, it is not clear which species of sawflies we have in the region, thus we are in the process of collecting and identifying sawflies in the lower Columbia Basin. Also, damage in the region will be estimated during the following growing season. An extensive mailing list of Columbia Basin grass growers, field representatives, financiers, seed industry representatives, and ag-chemical company representatives has been established and will be updated and used to notify important pest alerts.

Literature Review

Fisher G,S., S. Rao, M. Mellbye and G. Gingrich. 2002. Grass Seed Pests. *In* PNW Insect Management Handbook 2002, OSU, Corvallis, OR.

Seed Production Research Reports. OSU Extension. http://cropandsoil.oregonstate.edu/seed-ext/Pub/research_rept.html

Shetlar D.J. 1991. The Ohio State University Extension Fact Sheet Entomology 1991 Kenny Road Columbus, Ohio 43210-1090 “Billbugs in Turfgrass” HYG-2502-91

Walenta, D.L., S. Rao, C.R. McNeal, B.M. Quebbeman, and G.C. Fisher. 2004. *Sphenophorus* spp., A Complex Billbug Community Infesting Kentucky Bluegrass Seed Fields in the Grande Ronde Valley of Northeastern Oregon. Dept. of CSS Ext/CrS 124. p. 53-56.

Figure 1. Sawfly larva (top) and adult (bottom).

Table 1. Average number of individuals per Order per week collected with pit fall traps in Kentucky bluegrass in Hermiston OR, 2006 and 2007.

Order	Common name	Average no. of individuals/week 2006	2007	2008
Acari	Mites	60	163	218
Arachnida	Spiders	75	605	325
Collembola	Springtails	36748	13485	28654
Orthoptera	Grasshoppers	16	4	5
Thysanopetera	Thrips	3	13	8
Hemiptera	True bugs	74	37	41
Homoptera	Leafhoppers	102	120	112
Coleoptera	Beetles	133	858	658
Diptera	Flies	224	229	234
Hymenoptera	Wasps	2	2	2

QUEST FOR BILLBUG MANAGEMENT TOOLS IN GRASS SEED IN EASTERN OREGON: PRELIMINARY FINDINGS

S.I. Rondon and D.L. Walenta

Billbugs can be one of the most common pests of grass seed production in the Grande Ronde Valley (GRV) region in northeastern Oregon and include three species: the bluegrass billbug (*Sphenophorus parvulus*), Denver billbug (*S. cicatristriatus*), and *S. sayii.* Billbugs have been associated with increased losses to Kentucky bluegrass seed production fields in the region, which may be attributed to increased frequency of billbug infestations, changing production practices, cancellation of key pesticides and interactions with other grass seed pests.

General background

Billbugs are an important pest due to their lifecycle and feeding habits. Billbugs are beetles with a hard shelled body that does not absorb pesticides easily. Since billbugs feed at night and hide in the soil during the day it is difficult to target their most vulnerable stage. This insect has four different stages: egg, larva, pupa and adult (Figure 1). Billbugs overwinter as adults in the soil or under other forms of cover.

Figure 1. Denver billbug adult (above) and immature stage (below).

Billbugs attack nearly all cultivated and wild grasses and do the most damage as larvae; they can destroy large sections of grass if not controlled. Some common signs of billbug damage in turf are large brown spots that do not regenerate and sawdust-like frass may be present at the soil surface from larval feeding. Billbug feeding may also cause heads to bleach and straw to fall when feeding on small grains. Feeding damage in grass seed production fields often results in reduced seed yield and, over time, a decline in stand vigor. Weaker stands are more susceptible to additional stresses such as other pest infestations and environmental conditions.

Scouting billbugs

Scouting is best accomplished by monitoring pitfall traps and inspection of grass crowns. Due to the billbug's nocturnal feeding habits, a trap consisting of a sub-surface container will catch bugs anytime of day. Plant examination can be accomplished by digging up grass crowns with roots to a depth of approximately 3 to 4 inches soil to inspect for grubs and feeding damage or visibly inspecting for adults. Adult billbugs may also be collected from sod samples that are placed in Berlesse funnels when monitoring for larval pests, such as the obscure cutworm, but may require additional physical examination to locate billbug larva. Although thresholds have not been established for any billbug species in northeastern Oregon, treatment is usually sought when damage reaches 5% to 10% of crowns damaged or when sod sampling efforts indicate billbug populations ranging from 1 to 3 per sq ft. (Walenta, personal communication).

Controlling billbugs

Several insecticides have been evaluated for billbug control and efforts have resulted in a special use permit for Capture® 2EC (active ingredient bifenthrin) on the Western orchardgrass billbug only in western Oregon. (Note: bifenthrin is currently in the IR-4 program). A succession of insecticides beginning with the chlorinated hydrocarbons (Aldrin, Dieldrin), followed by diazinon 14G and most recently Lorsban® 4E, have been the most cost effective means of controlling billbugs in orchardgrass grown for seed. The application is timed so that most of the overwintered beetles are in the field and actively feeding but before females begin to deposit eggs (early May). Clorpyrifos is the only currently registered insecticide for billbug control in northeastern Oregon; however, it has not provided consistent control due to the critical need for adequate rainfall and/or irrigation to move the insecticide into the crown and soil where the pests reside.

Current research

Preliminary research on the biology of the GRV billbug complex is being conducted in northeastern Oregon, however, additional research is needed to further determine phenology of each billbug species; to identify softer, more species-specific insecticides (as alternative to organophosphates); and to develop other biological, cultural and mechanical means of control.

Biology of billbugs

Several experiments are being conducted at the Oregon State University Hermiston Agricultural Research and Extension Center Entomology laboratory. Billbugs larvae were collected in the GRV on October 10 2008. Since larvae identification keys for billbugs are not available in the literature, we reared each billbug collected in Solo cups (4cm diameter X 4cm high). Each solo cup contained sterilized soil and a small grass seed plant, which was replaced once every month or more often if needed. Grass plants were watered every other day. Four trays containing 30 solo cups each with one billbug per cup were arranged in a complete randomized block. Each solo cup was checked every other day from October 10 until all larvae pupated. Daily observations will be made and the number of days from instar to instar will be recorded. Instars will be distinguished by the presence of cast exuvia. Once adults emerged we will be able to separate them by morph-species. After adults emerge, one female and one male will be paired (n = 20) in 30 ml plastic cups for 48 h to facilitate mating. Gender will be determined by examining the last abdominal sclerite with a dissecting microscope. After 48 h, females will be isolated in 15 X 15 X 10 cm plastic cups to determine viability of eggs (% eclosion), survival (larva to adult), numbers of egg masses, and numbers of eggs per mass produced by each female. A small grass plant and soil will served as an oviposition substrate. Longevity of adults will also be measured. The experiment will be repeated at least three times. The data will be presented as average (± SE) over the three experiments.

Field monitoring and entomopathogenic nematodes for billbug management

A commercial Kentucky bluegrass field infested with billbug was selected to monitor billbug populations in the fall 2007 (sod samples) and in the spring 2008 (pitfall traps) in the GRV. Sod samples were collected (1 sample/treatment/replication) on 5 October 2007 to determine insect pest population levels overwintering at the site. The samples were examined to determine the number of billbug (larvae, nymphs, and/or adults) and other soil inhibiting insect pests from the 0-2 and 2-4 inch sections of the soil profile (Table 1). Overall, insect pest numbers were low but consisted primarily of an evenly mixed population of billbug and cutworm (*Protagrotis obscura* L.) larva which were concentrated in the 0-2 inch depth zone (Figure 2).

Figure 2. *Protagrotis* adult (top) and larva (bottom).

Table 1. Fall 2007 (early October) Kentucky bluegrass insect pest total density (sod/soil sample)

Rep	Sample Depth	Denver billbug Larva	Denver billbug Nymph	Denver billbug Adult	Glassy cutworm larva
		(no. 6 sod samples)			
	(inch)				
1	0 – 2	1	0	1	1
2	0 – 2	2	0	0	1
3	0 – 2	1	0	1	4
4	0 – 2	1	0	0	1
	Avg.	1.3	0	0.5	1.7
1	2 – 4	1	0	0	0
2	2 – 4	0	0	0	1
3	2 – 4	0	0	0	0
4	2 – 4	0	0	0	0
	Avg.	0.3	0	0	0.3

Pitfall traps were installed (1 trap/treatment/replication) on 12 May 2008 and monitored on a weekly basis until 11 July 2008. Total number of adult billbugs collected per week was 0, 3, 3, 2, 4, 5, 1, 1 and 1, respectively, from 28 pitfall traps in the trial. Peak adult billbug activity occurred 13 June and 20 June. In anticipation of increased adult activity, treatments were delayed until July 1 in order to evaluate the efficacy of two species of entomopathogenic nematodes

(*Steinernema carpocapsae* and *Heterorhabditis bacteriophora*) and two selected insecticides. However, differences in efficacy were not possible due to low populations of adult billbugs.

Observations from billbug infested fields have revealed a range of crop re-growth vigor after seed harvest. We have seen fields that don't green up properly in the fall, but these fields that look poor in the fall, apparently yield normally the next year. In other cases, fall re-growth looks normal, however, damage areas appear the following spring. Efforts to monitor billbug populations should employ both sod/soil sampling and pitfall trapping techniques, yet, it is unknown how many sod samples or pitfall traps are required to accurately determine infestation-levels within a field. In addition, a critical question remains about the extent of economic damage each billbug species causes to grasses grown for seed in the GRV. Future plans are to investigate the impact of various billbug larvae densities on grass seed yield.

GERMINATION ARREST FACTOR (GAF): A NATURALLY OCCURRING HERBICIDE THAT TARGETS GRASSY WEEDS

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Introduction

Weed control in production agriculture and in recreational and professional turfs continues to be a challenge to producers and turf managers. Controlling grassy weeds like annual bluegrass (ABG, *Poa annua*) is a particular problem in grass seed production where the presence of ABG seeds in commercial seed lots reduces the quality and market value of the product in international markets.

We identified isolates of soil bacteria, mostly *Pseudomonas* spp., which were originally isolated by Dr. Lloyd Elliott (USDA/ARS, retired) that produced a substance that irreversibly arrested the germination of ABG seeds, and those of other grasses. Because of the particular effect of this compound on grassy weed germination, we called it Germination Arrest Factor (GAF). The biological properties and development of a bioassay system to quantify GAF are described here.

Methods

Preparation of bacterial culture filtrates

Bacterial strains were inoculated into Wheaton bottles containing Fe-containing PMS medium. The bottles were placed on a rotary shake (200 rpm) and maintained at 27 °C for seven days .

Cultures were centrifuged at 3000 g for 15 min, the supernatants were collected and filtered through a 0.22 µ Millipore GP Express Steritop Bacteriological Filter. These supernatants, representing filtrates of bacterial cultures, were then stored at 4 °C until used in bioassays.

Sources of seeds

ABG seeds were obtained from 1996 mid-Willamette Valley grass seed screenings from DLF-International Seeds, Inc. (Halsey, OR) and C and R Farm (Tangent, OR). Seeds of other *Poa* species and wheat were provided by the Oregon State University (OSU) Seed Testing Laboratory. Seeds of other grasses were obtained from OSU, USDA, and other local sources. Seeds of dicot species were obtained from local garden supply stores with the exception of tobacco seeds which were grown in the greenhouse.

Standard Poa bioassay for GAF activity

Culture filtrates and other solutions to be tested for GAF activity were distributed into wells of sterile 48-well microplates along with sterile bacteriological media (PMS) or water as control solutions. Each well received three surface-sterilized ABG seeds, and three replicate wells were used per trial (a total of nine seeds). Plates were sealed with Parafilm® and incubated in a growth chamber at 20 °C, which provided a photoperiod of 8 hr followed by 16 hr of darkness. Seed germination was scored after 7 days on a scale of 0-4, 4 representing complete, normal germination (i.e., no GAF activity) and 0 representing no visible sign of germination.

Effects of GAF on seed germination

Surface sterilized seeds of other grasses and dicots were placed into appropriately sized sterile microplates along with culture fluids, control fluids, or other solutions to determine whether GAF affected germination. Approaches for surface sterilization, germination, and the standard assay for GAF activity are described in Banowetz et al. (2008).

Results and Discussion

Treatment of ABG seeds with culture filtrate from GAF-producing strains of *Pseudomonas* arrested the germination of these seeds at a stage immediately after the emergence of the plumule and coleorhizae and before these structures had exceeded the length of the seed (corresponding to a germination score of 1) The arrest of ABG germination appeared to be irreversible in our trials, but if GAF was applied to seedlings after germination occurred, plant development proceeded, although at a reduced rate (data not shown).

Figure 1 shows that uninhibited (i.e., normal) germination of ABG seeds occurred in seeds exposed to water, sterile bacteriological medium (PMS), and culture fluid from a strain of *Pseudomonas* (Pf-5) that does not produce GAF while complete arrest of germination occurred in seeds exposed to culture fluids from five GAF-producing isolates. GAF also inhibited the germination of the seeds of most other grasses (Table 1). The eight *Poa* species that we tested were sensitive to GAF. Many of the grasses whose seed germination was arrested, including ABG, downy brome, rattail fescue, and jointed goatgrass, are serious weed pests in agricultural production. In general, dicot seeds were less affected by exposure to GAF.

The fact that GAF inhibited germination of grasses grown for seed suggests that in addition to control of grassy weeds, GAF may have utility in preventing the growth of volunteer seeds in subsequent crop years. The degree of species specificity that we observed, combined with the stage-specific action of GAF suggest that this naturally occurring herbicide may have potential as a pre-emergence herbicide. An agent like GAF that does not affect post-germination plant growth would likely have utility in controlling grassy weeds like ABG in grass seed production fields. GAF also may have utility in controlling germination of grassy weeds in established turf settings, including golf courses, parks, and residential lawns. However, GAF applications in field tests are needed to evaluate its practical use. These trials must await the development of approaches to produce the amounts of GAF necessary to conduct the trials.

References

Banowetz, G.M., M.D. Azevedo, D.J. Armstrong, A.B. Halgren, and D.I. Mills. 2008. Germination-arrest factor (GAF): Biological properties of a novel, naturally-occurring herbicide produced by selected isolates of rhizosphere bacteria. Biological Control 46:380-390.

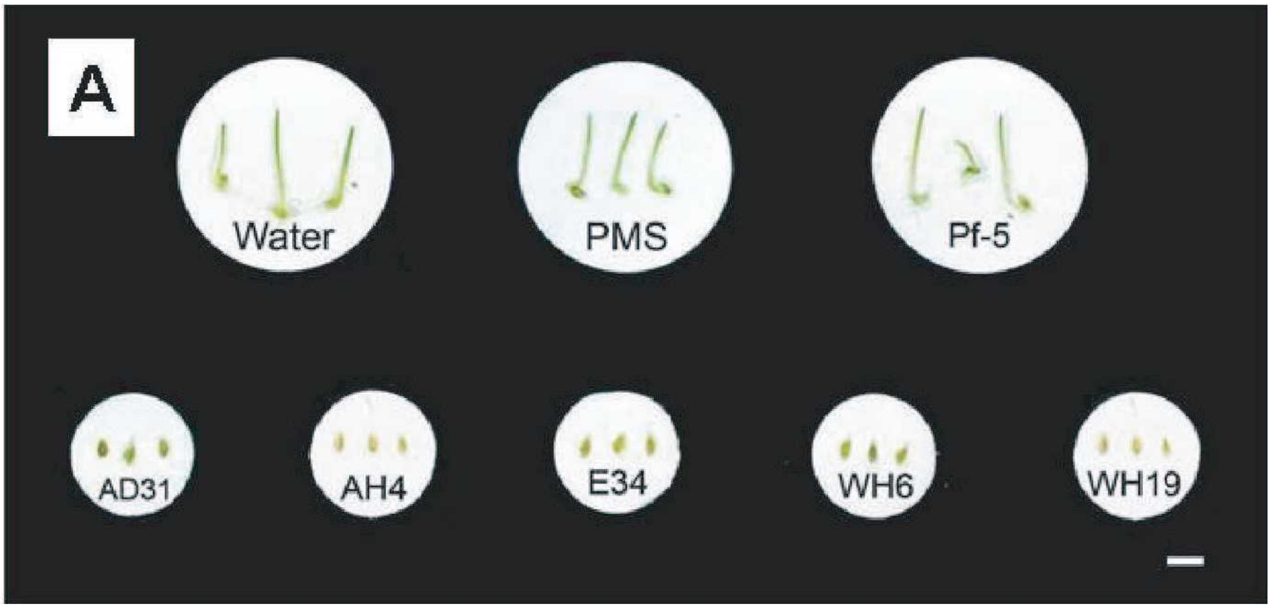

Figure 1. Effect of filtrates from five isolates of *Pseudomonas* on annual bluegrass seed germination. Water, sterile bacteriological medium (PMS), and culture fluid from a *Pseudomonas* isolate that does not produce GAF were included as negative controls (top row).

Table 1. Effect of sterile non-GAF-containing bacteriological medium (PMS) and GAF- containing culture filtrates from bacterial cultures produced in PMS medium on germination of seeds of selected species. Numbers indicate germination scores based on a scale of 0 – 4 where 4 represents complete, normal germination and 0 represents no visible signs of germination.

Species/common name	PMS	GAF-containing culture filtrates
***Poa* species**		
Poa annua (annual bluegrass)	4.0 ± 0.0	1.0 ± 0.0
P. compressa (Canadian bluegrass)	0.9 ± 0.3	1.0 ± 0.0
P. nemoralis (wood bluegrass)	2.7 ± 0.3	1.0 ± 0.0
P. pratensis (Kentucky bluegrass)	2.5 ± 0.4	1.0 ± 0.0
P. scabrella (pine bluegrass)	1.4 ± 0.6	0.9 ± 0.2
P. secunda (big bluegrass)	1.4 ± 0.4	0.5 ± 0.5
P. trivialis (roughstalk bluegrass)	4.0 ± 0.0	1.0 ± 0.0

Table 1. (continued). Effect of sterile non-GAF-containing bacteriological medium (PMS) and GAF- containing culture filtrates from bacterial cultures produced in PMS medium on germination of seeds of selected species. Numbers indicate germination scores based on a scale of 0 – 4 where 4 represents complete, normal germination and 0 represents no visible signs of germination.

Species/common name	PMS	GAF-containing culture filtrates
Grasses grown for seed		
Lolium perenne (perennial ryegrass)		
c.v. Derby	3.7 ± 0.2	1.4 ± 0.1
c.v. Mach 1	3.6 ± 0.2	1.1 ± 0.1
L. multiflorum (Italian ryegrass)		
c.v. Gulf	2.3 ± 0.5	1.5 ± 0.0
c.v. Surrey	2.5 ± 0.5	1.0 ± 0.1
Festuca arundinacea (tall fescue)		
c.v. Kentucky 31 (endophyte free)	3.0 ± 0.4	1.0 ± 0.0
c.v. Kentucky 31 (endophyte)	3.7 ± 0.2	1.1 ± 0.0
Dactylis glomerata (orchardgrass)		
c.v. Hallmark	1.3 ± 0.3	1.0 ± 0.2
Cereals		
Triticum aestivum (wheat)		
c.v. Stephens	2.9 ± 0.4	1.1 ± 0.1
c.v. Madsen	2.4 ± 0.4	1.5 ± 0.1
Hordeum vulgare (barley)		
c.v. Baronesse	3.5 ± 0.2	1.5 ± 0.2
c.v. Morex	2.9 ± 0.4	1.6 ± 0.1
Zea mays (corn, Syngenta GH2684F1)	2.4 ± 0.2	2.2 ± 0.1
Dicots		
Amaranthus hypochondriacus		
(Amaranth) c.v. Burgundy	2.3 ± 0.1	2.3 ± 0.0
Brassica oleraceae (cabbage)		
c.v. Early Jersey Wakefield	2.9 ± 0.3	2.9 ± 0.2
Daucus carota (carrot) c.v. Imperator	1.4 ± 0.2	1.4 ± 0.1
Dianthus caryophyllus (carnation)		
c.v. Chabaud Blend	3.0 ± 0.1	2.7 ± 0.2
Latuca sativa (lettuce)		
c.v. Butter crunch	2.8 ± 0.2	3.1 ± 0.0
Medicago sativa (alfalfa)		
c.v. unknown	2.0 ± 0.3	2.2 ± 0.2
Nicotiana tabacum (tobacco)		
c.v. Wisconsin	1.5 ± 0.0	1.5 ± 0.0
Papaver nudicaule (Iceland poppy)		
c.v. Nudicaule Blend	2.0 ± 0.2	1.6 ± 0.2

CONSERVING AVIAN DIVERSITY IN THE WILLAMETTE VALLEY'S AGRICULTURAL LANDSCAPE WITH OREGON WHITE OAK TREES

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Large, isolated Oregon white oak trees are iconic landmarks in many agricultural fields of the Willamette Valley. Often retained by landowners for aesthetic or sentimental reasons, many of these large trees are hundreds of years old, predating European settlement of the Valley and thus representing "biological legacies" from historic white oak savanna habitats. The abundance of these trees in the Valley, along with the extent of white oak habitats in general, are declining due to land use practices or the gradual dying of existing of trees (Thysell & Carey 2001). To date, no research has been done to determine wildlife use of these biological legacies, the potential role these trees play in the conservation of the Valley's native wildlife, and how landowner practices can improve their contribution to conservation of biological diversity in agricultural areas.

In this study, we investigated bird use of isolated white oak legacy trees in three different site contexts - croplands, pastures, and oak savanna reserves. We assessed how bird use of these isolated trees differed between agriculturally-situated trees and those situated in reserves. We further assessed the relative importance of four factors thought to affect bird use of these trees: (i) the architecture of the tree itself, (ii) the distance of the tree to the nearest tree or forest patch, (iii) the density of forest vegetation in the landscape surrounding each tree, and (iv) the type of field in which the tree is embedded. We evaluated species-specific responses as well as four community-level responses: (i) the total number of bird species; (ii) the number of native bird species associated with oak savanna; (iii) the number of tree foraging bird species; and (iv) the combined number of aerial- and ground-foraging bird species.

We conducted the study in the southern half of the Willamette Valley, an area extending from Salem in the north to just south of Eugene. In total, we sampled 35 individual white oak trees with 13 trees situated in croplands, 13 in pastures, and 9 in oak savanna reserves. Cropland sites were predominantly grass seed production fields with the main crop species being annual or perennial ryegrass and tall fescue. Four of the cropland sites were nursery operations where small saplings of maple, Douglas fir, and noble fir were grown. Pasture sites were either sheep or cattle grazed with the predominant forage species being perennial ryegrass, tall fescue, orchardgrass, and clover. Savanna reserves consisted of sites that were actively managed to replicate historic oak savanna conditions and were characterized by a diverse understory of grasses and forbs interspersed with shrubs of Himalayan blackberry, poison oak and wild rose.

We surveyed each tree for bird use on five separate occasions during the spring and early summer of 2007. Each survey consisted of a 20 minute observation period in which we recorded all bird species that physically landed on the tree. In an attempt to describe how birds are using individual legacy trees, we documented the primary behavior for each bird detected, recording singing, foraging, perching and nesting behaviors.

For each tree, we measured several structural attributes such as tree height; canopy volume and lichen cover to develop tree size and tree complexity indices to capture variation in tree architecture. To determine the relative isolation of each tree, we used a laser range finder to measure the distance to the nearest tree or forest patch and a geographic information system to calculate the density of forest vegetation in the surrounding landscape at multiple scales ranging from 50 to 5000 meters. We analyzed these data to determine the relative influence of these four explanatory factors – tree architecture, the distance to the nearest tree or patch, forest density in the surrounding landscape, and site type – on bird use of individual legacy oak trees.

We recorded 47 bird species using these individual trees, including a high number of oak savanna-associated species that are priority species for conservation in Oregon such as White-breasted Nuthatch and Chipping Sparrow (Table 1). European Starling (n = 20 sites) was the most frequent species encountered followed by American Robin (n = 18) and American Goldfinch (n = 17). Among oak savanna-associated species, American Goldfinch and Lazuli Bunting (n = 11) were observed at the largest number of sites. Bullock's Oriole (n = 10) was the most frequent tree foraging species. Of the 23 species detected using at least 5 sites, only 8 species occupied a higher proportion of reserve sites than agricultural sites with Lazuli Bunting, Spotted Towhee and House Wren most strongly associated with reserves. The most prominent behavior recorded for birds using these individual trees was perching or roosting (n = 266 observations) followed by foraging (n = 105) and singing (n = 73). Eight species were using these individual trees for nesting including American Goldfinch, American Robin, Cedar Waxwing, European Starling, House Wren, Tree Swallow, Violet-green Swallow, and Western Tanager.

The most important factors for predicting bird use were tree size and forest density in the surrounding landscape. In general, bird use increased with increasing tree size and decreasing forest density. Increasing bird use with increasing tree size suggests that, with all else being equal, larger legacy-type trees provide more and higher quality resources for birds than smaller, younger trees. Increasing bird use of isolated trees with decreasing tree cover suggests that the role of isolated trees as focal habitat structures increases as trees become rarer on the landscape. For many bird species, particularly tree foraging and tree nesting species, the presence of a single tree in agricultural fields likely provides critical resources necessary for persistence in an otherwise treeless landscape.

Our findings indicate that a high number of bird species use isolated white oak legacy trees in the Willamette Valley. For the majority of the bird species we recorded, the frequency of use of individual oak trees was similar among crop, pasture and reserve sites indicating the potential for agriculturally-situated trees to positively contribute to landscape-level conservation of a wide range of bird species within the Willamette Valley. Landowners wishing to provide habitat for oak savanna-associated birds should focus on conserving existing white oak legacy trees and fostering the recruitment of replacement trees. Due to the long life expectancy of white oak trees (300-500 years), a recruitment interval of every 45 years may be sufficient (Gibbons et al. 2008). However, to reverse the decline in abundance of white oak legacy trees in the Willamette Valley, multiple trees should be planted for every existing legacy tree. Given the rarity of young Oregon White Oak trees in agricultural fields, it would be of great conservation value for landowners to begin planting or protecting seedlings to ensure the legacy of large oak trees.

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References:

Gibbons, P. et al. 2008. The future of scattered trees in agricultural landscapes. *Conservation Biology* 22(5): 1309-1319

Thysell, D. R. and A. B. Carey. 2001. *Quercus garryana* communities in the Puget Trough, Washington. *Northwest Science* 75(3): 219–235.

Table 1. Bird species recorded using isolated Oregon white oak legacy trees in the southern half of the Willamette Valley during surveys conducted between 4 June and 29 June, 2007.

Species	No. of sites[a] *Ag*	*Res*	Total	Species	No. of sites[a] *Ag*	*Res*	Total
European Starling	16	4	20	American Kestrel	4	0	4
American Robin	15	3	18	Yellow Warbler	1	3	4
American Goldfinch	15	2	17	California Quail	2	1	3
Lazuli Bunting	4	7	11	Mourning Dove	3	0	3
Bullock's Oriole	8	2	10	Dark-eyed Junco	2	0	2
Chipping Sparrow	8	2	10	Hairy Woodpecker	1	1	2
Western Wood-pewee	6	3	9	Red-winged Blackbird	2	0	2
White-breasted Nuthatch	8	0	8	Tree Swallow	2	0	2
White-crowned Sparrow	7	1	8	Turkey Vulture	2	0	2
Black-capped Chickadee	4	3	7	Wilson's Warbler	2	0	2
Black-headed Grosbeak	7	0	7	Acorn Woodpecker	1	0	1
Brewer's Blackbird	7	0	7	Brown-headed Cowbird	1	0	1
Common Yellowthroat	3	4	7	Bushtit	1	0	1
House Finch	7	0	7	Common Raven	1	0	1
Lesser Goldfinch	5	2	7	House Sparrow	1	0	1
Savannah Sparrow	7	0	7	Northern Flicker	1	0	1
Western Scrub Jay	3	3	6	Orange-crowned Warbler	1	0	1
Spotted Towhee	2	4	6	Purple Finch	1	0	1
Cedar Waxwing	5	0	5	Red-breasted Nuthatch	0	1	1
House Wren	1	4	5	Swainson's Thrush	1	0	1
Red-tailed Hawk	5	0	5	Violet-green Swallow	1	0	1
Song Sparrow	4	1	5	Western Bluebird	1	0	1
Western Tanager	4	1	5	Western Kingbird	1	0	1
American Crow	0	4	4				

[a] Number of sites recorded by species. *Ag* = agricultural sites; *Res* = oak savanna reserve sites.

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