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Page

Mapping the Choke Pathogen in Cultivated Orchardgrass Fields in the Willamette Valley 1

Potential Control of Choke in Orchardgrass with the Fungus *Dicyma pulvinata* 6

Annual Ryegrass Seed Production in Acidic Soil 9

Long-Term Evaluation of Annual Ryegrass Cropping Systems for Seed Production 13

Riparian Forest and Adjacent Grass Seed Production Field in Western Oregon: Nitrogen Dynamics and Water Quality 16

Does Gray-Tailed Vole Activity Affect Soil Quality? 18

Cost and Benefit in Control of the Gray Field Slug in Western Oregon 21

On-Farm Conversion of Straw to Bioenergy – A Value Added Solution to Grass Seed Straw 25

Soil Carbon Budget for Annual and Perennial Ryegrass Grown for Seed 31

Crop Rotation and Straw Residue Effects on Soil Carbon in Three Grass Seed Cropping Systems of Western Oregon 32

Sustainability in Seed Production Enterprises – What We've Learned 35

Aphid Control and Barley Yellow Dwarf Virus Suppression in Spring-Seeded Perennial Ryegrass, Western Oregon 38

Postemergence Grass Control Options in Vetch Grown for Seed 42

Tolerance of Teff to Herbicides 43

Comparison of Bee Pollinator Abundance in Red Clover Seed Production Fields With and Without Honey Bee Hives in the Willamette Valley 45

Toxicity of Red Clover Pesticides to a Native Bumble Bee Pollinator 50

Effect of Grotain Treated Urea on Ammonia Volatilization in Kentucky Bluegrass the Columbia Basin 53

Evaluation of Palisade on Fifteen Kentucky Bluegrass Varieties Grown for Seed in Central Oregon, 2009 57

Sod Webworm Management System for Kentucky Bluegrass Seed Production in Central Oregon, 2009 60

Development of a Phenological Model for the Denver Billbug in Central Oregon Kentucky Bluegrass Seed Production, 2009 62

Evaluation of Simulated Hail Damage to Kentucky Bluegrass Seed Production in Central Oregon, 2009 65

Control of Clover Mite and Winter Grain Mite in Orchardgrass Hay Fields and Pasture, 2009 66

Department of Crop and Soil Science Ext/CrS 129, 3/10

The following authors have contributed to this report.

Central Oregon Agricultural Research Center

M.D. Butler, Superintendent
K.J. Marling, Bio Technician
L.L. Samsel, Seed Certification Assistant

Cooperative Extension Service – OSU

R.P. Affeldt, Extension Agent, Jefferson County
N.P. Anderson, Extension Agent, Washington County
M.G. Bohle, Extension Agent, Crook County
M.E. Mellbye, District Extension Agent, Linn, Benton and Lane Counties

Department of Botany and Plant Pathology – OSU

R.E. Berry, Professor Emeritus

Department of Crop and Soil Science – OSU

J.R. Cassidy, Instructor
D.W. Curtis, Faculty Research assistant
R.P. Dick, former Professor, Soil Science
M.I. Dragila, Associate Professor, Soil Physics
A.J. Dreves, Research Associate, Entomology
G.C. Fisher, Professor, Extension Entomology
C.J. Garbacik, Senior Faculty Research Assistant
J.M. Hart, Professor and Extension Soil Scientist
B.J. Hinds-Cook, Faculty Research Assistant
G.D. Hoffman, Research Associate, IPM
A.G. Hulting, Assistant Professor, Extension Weeds Specialist
J.M. Kaser, Faculty Research Assistant, Entomology
C.A. Mallory-Smith, Professor of Weed Science
S. Rao, Associate Professor, Entomology
K.M. Skyrm, Graduate Research Assistant, Entomology
W.C. Young III, Professor and Extension Agronomist

Department of Fisheries and Wildlife

J.A. Gervais, Wildlife Ecologist

Hermiston Experiment Station

J.C. Holcomb III, Graduate Research Assistant
D.A. Horneck, Associate Professor

National Forage Seed Production Research Center - USDA-ARS

S.C. Alderman, Professor and Research Plant Pathologist
G.M. Banowetz, Research Microbiologist and Research Leader
J.H. Davis, Research Affiliate – Soil Scientist
H.M. El-Nashaar, Research Molecular Biologist
W.E. Gavin, Faculty Research Assistant
S.M. Griffith, Assistant Professor and Research Plant Physiologist
R.C. Martin, Research Molecular Biologist
G.W. Mueller-Warrant, Associate Professor and Research Agronomist
J.J. Steiner, former Professor and Research Agronomist
G.W. Whittaker, Research Hydrologist

Other

P.J. Wigington, Jr., Research Hydrologist, EPA, Corvallis
M.E. Zarnstorff, Director of Agricultural Research/Technology, National Crop Insurance Services, Overland Park, KS

MAPPING THE CHOKE PATHOGEN IN CULTIVATED ORCHARDGRASS FIELDS IN THE WILLAMETTE VALLEY

J.M. Kaser and S. Rao

Introduction

The choke disease pathogen (*Epichloë typhina*) is an endophytic fungus that was inadvertently introduced into cultivated orchardgrass fields in western Oregon. The fungus was first reported in 1996 in Oregon, but has quickly spread to ~90% of cultivated orchardgrass seed fields in the region, causing yield losses up to 65% in individual fields (Pfender and Alderman, 2006). The fungus develops intercellularly and maintains systemic endophytic growth in aerial vegetative host tissues. When the host plant enters its reproductive phase, branched hyphal masses (stromata) form externally on grass culms, and occasionally on vegetative tillers (Schardl, 1996). This affects the emergence of the inflorescence and, as a result, no seeds are produced on the affected tillers. Hence, the expression of *E. typhina* in host grasses is called "choke disease."

The choke pathogen must sexually outcross in order to produce ascospores (i.e. infective propagules of the fungus). A fly, hereafter referred to as the choke fly (*Botanophila lobata*), serves as a "pollinator" for the fungus (Bultman et al., 1998). Female choke flies visit the fungus to feed, and to lay solitary eggs on the stroma. During an oviposition behavior, the fly defecates previously consumed fungal spermatia, enabling cross fertilization of the fungus as it drags its abdomen along the stroma surface.

The present study was conducted to gain insights on the spatial distribution of both the choke pathogen and the choke fly which could lead to inferences about factors influencing choke disease expression and spread in Oregon orchardgrass.

Materials and Methods

Sampling Design: The study was conducted over two years in the Willamette Valley in western Oregon in cultivated orchardgrass fields within a 10 kilometer radius of the city of Corvallis. In 2008, ten commercial "Potomac" variety seed-production fields of orchardgrass were selected to represent a range of field ages, from 1 to 28 years since original planting. At each field site, five transects were arranged roughly perpendicular to the longest field edge. Along each transect, a grid (1 m^2 quadrat) was placed at 10 locations and were spaced a minimum of 10 meters and a maximum of 25 meters apart, depending on field width. Fifty quadrats were sampled at all field sites. GPS locations were recorded for each quadrat. Within each quadrat, the total number of orchardgrass plants was recorded. Each plant was categorized as being either infected or uninfected based upon the presence of stromata. If infected, the numbers of fertilized and unfertilized stromata were recorded. Each stroma was inspected for choke fly eggs or brood chambers which were counted to estimate fly presence. Transect sampling was repeated in 2009 at four of the sites (site 1, site 2, site 3 and site 4) to examine variability in the following year. Sampling occurred between June 19 and June 29 in 2008, and between June 18 and June 26 in 2009.

Data Analysis: Spatial patterns of fly density per quadrat, stromata per quadrat and symptomatic orchardgrass hosts per quadrat were characterized using Spatial Analysis by Distance Indices (SADIE) (Perry, 1995). The SADIE index, ν, categorizes, for each parameter, individual quadrat locations as above average "clusters" or below average "gaps". Gaps and clusters were mapped using ArcMap (v. 9.3) with the Spatial Analyst extension using the inverse distance weighted method.

To explore the relationship between fly or fungal spatial pattern with change in probability of fungal reproductive success, a logistic regression was performed separately for each site using the following variables: 1) proportion of plants infected per quadrat; 2) the number of stromata per quadrat; 3) the number of flies per stromata; and 4) presence or absence of unfertilized stromata (dependent variable). The presence of stromata was treated as a binary response, with 1 for quadrats with > 0 unfertilized stromata, 0 for quadrats with no stromata.

To assess change between 2008 and 2009 the proportion of plants infected per quadrat, stromata per quadrat, and flies per quadrat were compared separately for each site using the non-parametric Wilcoxon rank sum procedure. Additionally, the age of field was treated as an explanatory variable for the following responses across sites: 1) proportion of infected plants; 2) total stromata; and 3) mean flies per stromata.

Results

Incidence of Choke Disease: In 2008, a total of 3,979 plants were surveyed in 10 orchardgrass seed production fields, of which 1,207 (30.3%) plants were observed to be infected with choke disease. Across all sites, 24,613 stromata were recorded on the hosts, of which only 17 (0.07%) were unfertilized. Unfertilized stromata were found in only 50% of the fields sampled; at sites 3, 5, 6, 7, and 9. In 2009, a total of 1,462 plants were surveyed, of which 328 (22.4%) plants infected with choke. Across the 4 sites included in 2009, 5,338 stromata developed on the hosts, of which only three (0.06 %) stromata were unfertilized. Only one of the three unfertilized stromata was on a plant that did not have fertilized stromata elsewhere. In 2009, all unfertilized stromata were found in site 1.

Abundance of the Choke Fly: In 2008, on the 24,613 stromata recorded, 70,047 choke fly eggs, larvae or brood chambers were recorded, providing evidence of fly visitations (mean =

2.8 flies per stroma). We noted 37 (3.1%) infected plants which had no fly visitation. Across all sites, the number of flies per stroma on each plant varied from 0 to 9.9, with a mean of 2.48 (±S.E. 0.05). There were 215 (17.83% of infected plants) hosts with means of < 1 flies. In 2009, there were 63 (19.2%) infected plants which had no fly presence. Across all sites, the number of flies per stroma on each plant varied from 0 to 5.64, with a mean of 1.39 (±S.E. 0.06). There were 173 (52.7% of infected plants) hosts which had mean fly per stroma density <1.0. The density of flies or stromata did not correspond with the probability of stromata being cross fertilized in 2008, nor in 2009.

Between Year Comparison: Between 2008 to 2009, there was no difference in mean proportion of infected to uninfected plants for site 2, site 3 or site 4. There was an increase in mean proportion of infected to uninfected plants for site 1 from 2008 to 2009. Mean stromata per quadrat also increased at site 1, but not at site 2, site 3 or site 4. There was no mean change in the number of unfertilized stromata per quadrat between 2008 and 2009 for site 1 and site 3. There were no unfertilized stromata found at site 2 or site 4 in either year, so significance tests were unnecessary.

Spatial Characterization: In 2008, the number of plants infected per quadrat was not spatially random, showing distinct clustering in site 2, site 4, site 7 and site 10 (Figures 1 and 2). The number of stromata observed per quadrat showed significant spatial clustering in site 2, site 4, site 5, site 9 and site 10, in 2008. In 2009, two of the four sites sampled showed clustering of infections (site 1 and site 2) (Figure 1). Stromata per quadrat were clustered at site 1, site 2 and site 3, in 2009. In both 2008 and 2009, plots depicted clusters and gaps with variable within-site distributions (Figures 1 and 2). However, between 2008 and 2009, within site locations expressing gaps and clusters tended to remain similar for individual sites 2 and 3, and to a lesser extent sites 1 and 4 (Figure 1).

The age of the orchardgrass stand in fields included in the study ranged from 1 to 29 years. In 2008, the proportion of the field symptomatic with choke disease had no positive trend with field (Figure 3a). Similar results were obtained in 2009. In 2008, the mean number of stromata per infection also did not show a linear relation with age (Figure 3b). Neither was a trend found in 2009.

Discussion

The high level of disease aggregation in orchardgrass fields presents an opportunity to discover factors which might decrease the susceptibility of plants to infection and disease expression. Choke disease symptoms were spatially aggregated at many sites. Moreover, the location of choke disease "gaps" and "clusters" documented that within-field spatial patterns of choke disease expression was fairly consistent across the two years of the study. Abiotic factors (e.g. soil properties), are likely to be aggregated in space within a field (Stafford 2000). Future studies should seek correlations between within-field variation in abiotic variables and expression of choke infection (e.g., by overlaying a soil map on a map of disease expression). If trends are uncovered, these abiotic factors might be manipulated to reduce disease expression in orchardgrass fields.

This study provides evidence that disease spread in cultivated orchardgrass fields occurs principally during the first few years after planting. Site 1, which was planted in 2007, was the only field that showed an increase in choke disease between 2008 and 2009. The other sites surveyed during both 2008 and 2009 were older than site 1, having been planted between 1982 and 1999. We found no correlation between increasing field age and disease incidence or severity of disease expression when including fields of varying age classes (Figure 3a, b). We speculate that certain hosts tend to remain resistant to infection expression across seasons due to abiotic micro-site conditions or plant genetics.

Interestingly, our analysis suggests that fly "pollination" of the choke disease pathogen does not enhance the overall reproductive success of the fungus in western Oregon. We found that while fly density, proportion of plants expressing disease, and stromata density were quite variable between and within each site, fertilization rates of the choke pathogen varied only slightly between and within sites during both years of the study. At all sites, we found almost complete perithecial development on certain stromata without evidence of fly visitation. Neither fly nor stromata density, nor the proportion of plants expressing infection per quadrat correlated with the probability of unfertilized stromata presence. These results correspond with previous observations of Rao and Baumann (2004) and Alderman and Rao (2008).

References

Alderman, S.C. and S. Rao (2008). Ascosporic fertilization of *Epichloe typhina* in *Dactylis glomerata* seed production fields in Oregon and implications for choke management. Plant Health Progress. doi:10.1094/PHP-2008-0421-01-BR.

Bultman, T.L., J. F. White, T.I. Bowdish and A.M. Welch (1998). A new kind of mutualism between fungi and insects. Mycological Research 102: 235-238.

Perry, J.N. (1996). Simulating spatial patterns of counts in agriculture and ecology. Computers and Electronics in Agriculture 15(2): 93-109.

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.

Rao, S. and D. Baumann (2004). The interaction of a *Botanophila* fly species with an exotic *Epichloë* fungus in a cultivated grass: fungivore or mutualist? Entomologia Experimentalis Et Applicata 112(2): 99-105.

Schardl, C.L. (1996). *Epichloë* species: Fungal symbionts of grasses. Annual Review of Phytopathology 34: 109-130.

Stafford, J.V. (2000). Implementing precision agriculture in the 21st century. Journal of Agricultural Engineering Research 76(3): 267-275.

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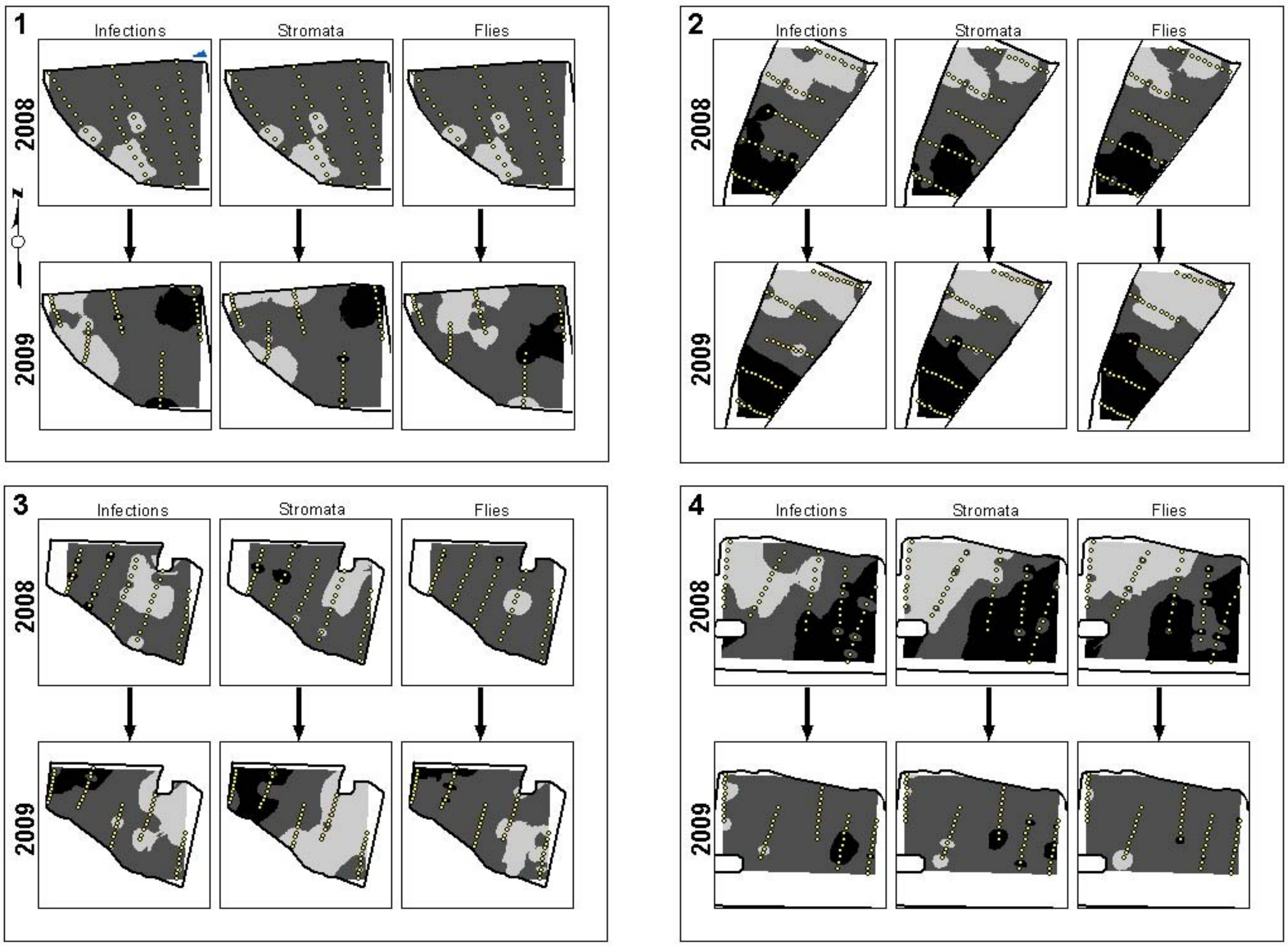

Figure 1. Plots depicting spatial aggregation in sites 1-4 in 2008 and 2009. Within each box, from left to right: spatial pattern of count data for infections per quadrat, stromata per quadrat and flies per quadrat are depicted. Dots represent quadrat sampling locations. Shading represents gaps (light grey), random spatial arrangements (dark grey), and clusters (black). The black lines visible within each box represent field borders.

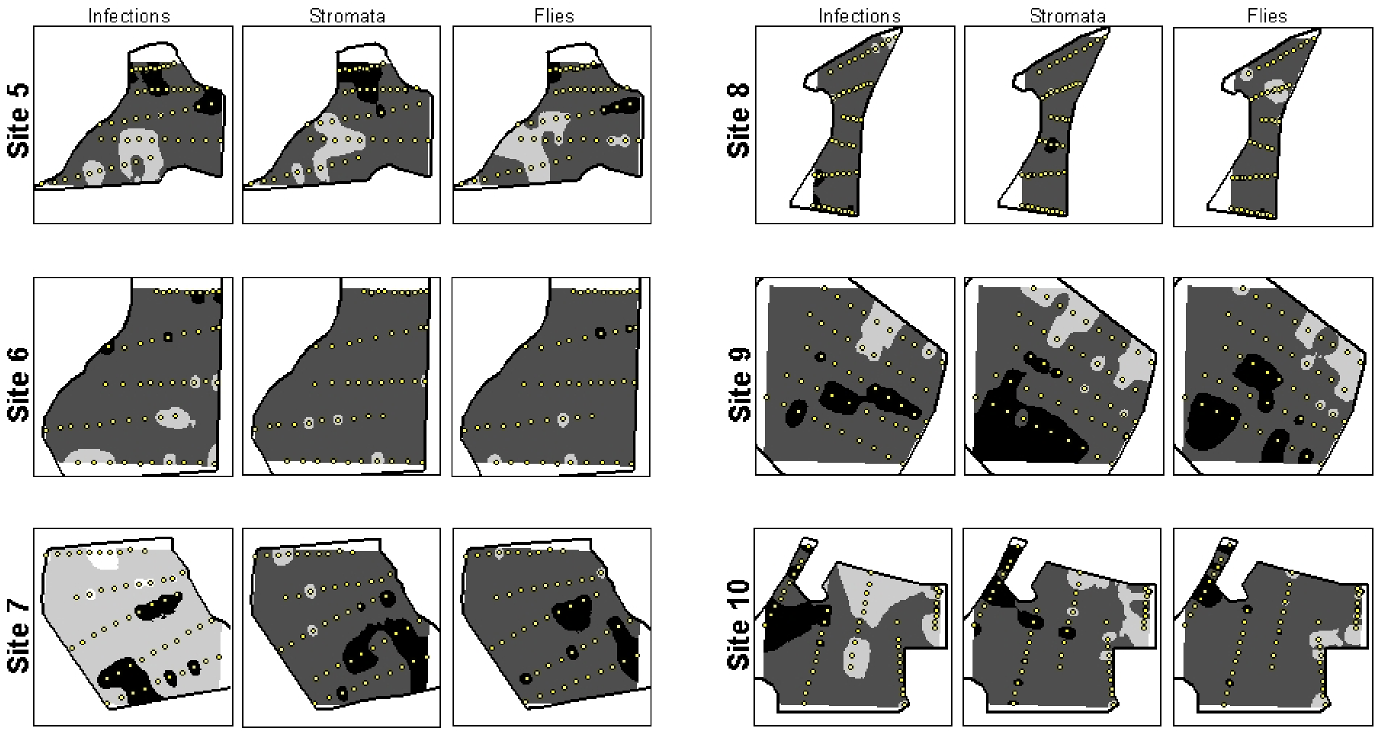

Figure 2. Sites 5 through 10, surveyed in 2008, depicting plots of infections per quadrat, stromata per quadrat, and flies per quadrat. See Figure 1 for further explanation. Six transects were included at site 8, due to an unusually narrow portion of the field which did not allow ten well spaced quadrats.

a)

b)

c)

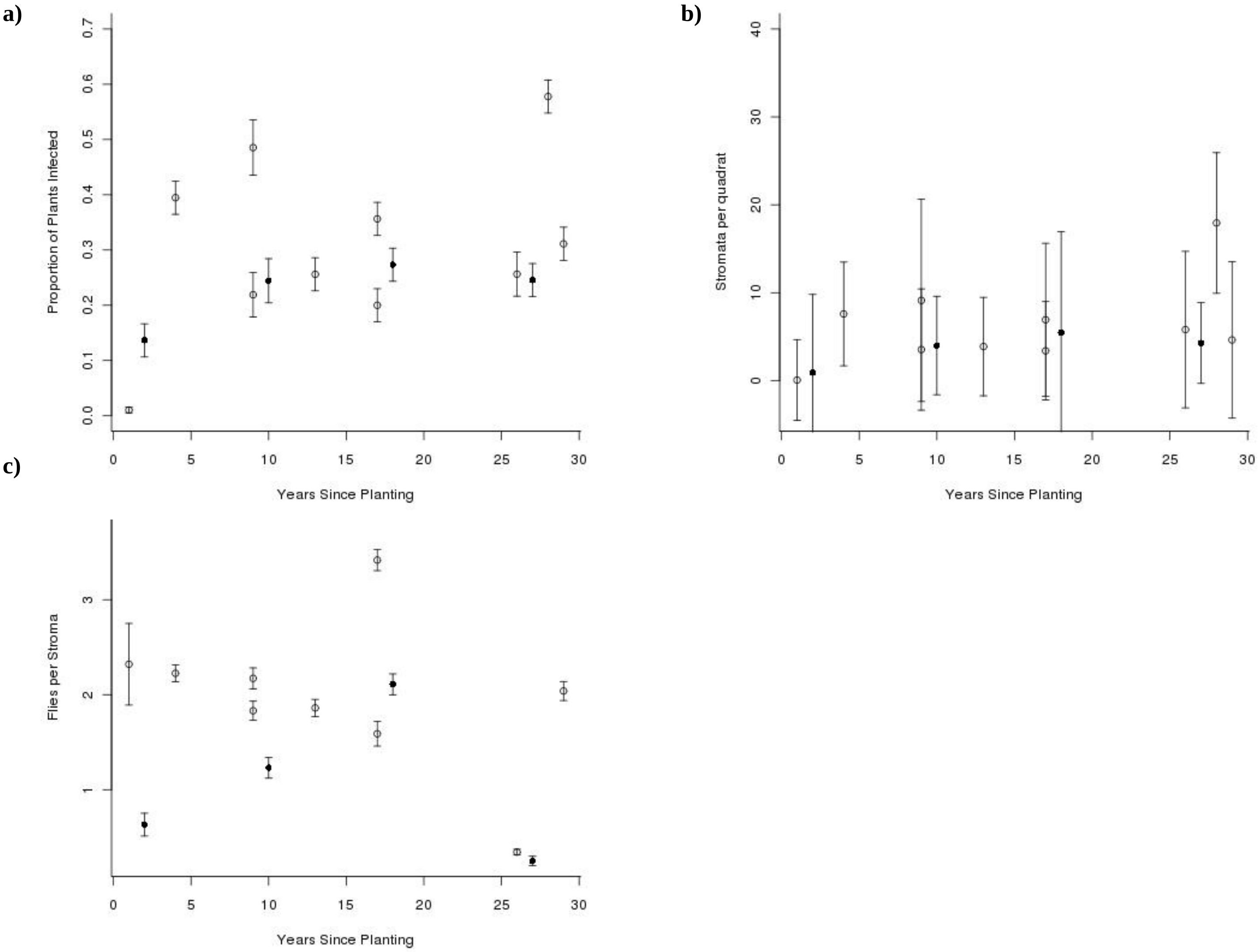

Figure 3. The combined data from 2008 and 2009 for each site plotted against age of field, for: a) Proportion of plants infected in each quadrat; b) Mean stromata per host for each quadrat; and c) Mean flies per stroma for each quadrat. Simple linear regression analysis did not show a linear trend for any of the compared variables (*P*>0.05). Open circles indicate sites from 2008, and filled circles indicate sites from 2009. Standard error bars are depicted.

POTENTIAL CONTROL OF CHOKE IN ORCHARDGRASS WITH THE FUNGUS *DICYMA PULVINATA*

S.C. Alderman, S. Rao and R.C. Martin

Choke, caused by the endophytic fungus *Epichloe typhina*, is well established in the Willamette Valley. Plants are infected systemically and tend to remain infected throughout the life of the plant. Symptoms are expressed only during the reproductive phase of the plant, when the fungus proliferates on the immature panicle, restricting further panicle development. The fungal stromata that develop on infected panicles resemble small cattails (Figure 1), and these can be found in most orchardgrass fields in the Willamette Valley several weeks prior to harvest.

Figure 1. Stroma of *Epichloë typhina*.

During the summer of 2008, a fungus was found growing on stromata of *E. typhina* in a greenhouse at the USDA-ARS facility in Corvallis, OR. We identified the fungus as *Dicyma pulvinata*, a known pathogen of other fungi. It was subsequently found naturally occurring on stromata in an orchardgrass seed production field in the Willamette Valley. Infected stromata had fewer perithecia and appeared shrunken, desiccated, and pale gray to grayish-white, in contrast to the orange colored uninfected stromata with mature perithecia.

Greenhouse and field studies were set up to evaluate the potential of *D. pulvinata* as a biological control for choke in orchardgrass.

Greenhouse trials

To establish pathogenicity of *D. pulvinata* to *E. typhina*, ten healthy, unfertilized *E. typhina* stromata were sprayed with a conidial suspension (1×10^5 conidia/ml) of *D. pulvinata* (treated) and ten control stromata were sprayed with water (control) in a greenhouse. Conidia were collected in water from 3 week old cultures grown on PDA (potato dextrose agar). Just prior to inoculation, conidia were collected from stromata and redistributed among the stromata to fertilize them. Infected plants were grown from tillers removed from infected plants collected from an orchardgrass field near Corvallis, OR, two years earlier. Plants were maintained in the greenhouse and vernalized 12 weeks at 8°C with 8 h photoperiod in a growth chamber to induce reproductive tiller development, as required for initiation and development of stromata. On each plant, one to two stromata were sprayed with conidia or water. Inoculated and control plants were kept separate to avoid potential infection of controls from inoculated plants. All plants were misted by hand with a hand held sprayer twice a day with deionized water to encourage germination and growth of *D. pulvinata* on the stromata. Stromata were evaluated 4 weeks after inoculation. Assessments were made visually. The orange colored perithecia were clearly in contrast to the white unfertilized portions of the stromata. An assessment key with a series of drawings of stromata with various percentages of surface area covered (shaded) was made and used to determine the percentage stroma surface with mature perithecia. Following assessment, *D. pulvinata* was reisolated and the experiment repeated a second time. In each experimental run, a significant reduction in *E. typhina* perithecial development on surfaces of inoculated stromata was observed ($P < 0.5$, t-test) (Table 1) (Figure 2).

Table 1. Mean percentages (+/- standard deviation) of stromatal surfaces covered with perithecia 4 weeks after spraying unfertilized stomata of *Epichloë typhina* with *Dicyma pulvinata* (treated) or water (control).

Trial	Treated	Control
1	3.1 ± 8.8	82.5 ± 9.6
2	12.3 ± 16	58.8 ± 34.5

Figure 2. Stroma of *Epichloë typhina* colonized by *Dicyma pulvinata*.

Field plot trials

To evaluate the potential of *D. pulvinata* to prevent perithecial development in *E. typhina* under field conditions, a conidial suspension derived from 10 single spore isolates of *D. pulvinata* was prepared and sprayed on 12 unfertilized stromata in an established field plot of orchardgrass at the Oregon State University Hyslop Crop Science Farm near Corvallis, OR, on May 19, 2009. A small handheld sprayer was used to uniformly apply to runoff the conidial suspension or water control. The trial was repeated on June 4 using a second set of unfertilized stromata. In each repetition, an equal number of stromata were sprayed with water as a control treatment. All stromata were collected on June 24, stored under refrigeration and evaluated within 24 hours. Stromata were assessed as in the greenhouse trial described above.

A t-test was used to compare percentage stroma surface with perithecial development among treated and control treatments. A significant ($P < 0.05$) reduction in stroma surface fertilized was observed in stromata sprayed with *Dicyma* in trial 1 but not in trial 2. At collection, *Dicyma* was observed sporulating on 67% of inoculated stromata from trial 1 but none from trial 2. However, following incubation of stromata in moist chambers (petri dishes lined with wet tissue paper) for 72 h, *D. pulvinata* sporulated on 92 % of stromata from each of the two trials (Table 2).

Table 2. Percentage stroma surface fertilized and percentage stromata with *Dicyma pulvinata* in two experimental trials in 2009.

	Percentage stroma surface with perithecia		Percentage of stromata with *Dicyma pulvinata* sporulation	
Trial	Treated	Control	At collection	After 72 hr incubation
1	79 ± 9	90 ± 4	67	92
2	84 ± 9	83 ± 9	0	92

Discussion

Results from greenhouse and field trials indicate that *D. pulvinata* can cause a significant reduction in development of perithecia, although it is not yet clear to what extent perithecia would need to be reduced under field conditions to significantly impact the spread of choke within or between fields.

Dicyma pulvinata is widely distributed geographically, including North and South America, Europe, Asia, and Australia (Farr et al., 1989). In the U.S., *D. pulvinata* was recognized as a potential biocontrol agent of a leafspot disease of peanut, caused by *Cercosporidium personatum* (Mitchell et al., 1986, 1987). Studies of *D. pulvinata* in peanut demonstrated its sensitivity to a broad range of fungicides, but it is not known to what extent *D. pulvinata* would be impacted by fungicide sprays in orchardgrass.

There are currently no fungicide or cultural controls for choke in orchardgrass. The primary limitations to fungicide applications are in obtaining complete coverage of stromata, which are typically low in the canopy and covered with foliage, and in spraying stromata that emerge over an extended period of time. However, the ability of *D. pulvinata* to develop and spread among stromata could compensate for incomplete coverage if conidia are applied conventionally in a water suspension.

We suspect that development of *D. pulvinata* may be limited under dry conditions. This accounts for the difference in *D. pulvinata* development in mid May vs early June, in that much of June was unseasonably warm and dry. In additional studies this spring, we plan to determine whether *D. pulvinata* could reduce perithecial development if it is established in late April to early May, when stromata start emerging, and whether it could then spread to parasitize subsequent emerging stromata.

An intriguing aspect of *D. pulvinata* is how it would impact development of the *Botanophila* spp. fly larvae on the stromata. *Botanophila* flies are responsible for fertilization of stromata and their larvae depend on the fertilized stromata to complete their life cycle. Additional studies will need to be conducted to better understand the interaction between *E. typhina*, *Botanophila* and *D. pulvinata* and the implications for choke management in orchardgrass.

References:

Farr, D.A., Bills, G.F., Chamuris, G.P., and Rossman, A.Y. 1989. Fungi on Plants and Plant Products in the United States. American Phytopathological Society, St. Paul. http://nt.ars-grin.gov/fungaldatabases/.

Mitchell, J.K., and Taber, R.A. 1986. Factors affecting the biological control of *Cercosporidium* leaf spot of peanuts by *Dicyma pulvinata*. Phytopathology 76: 990-994.

Mitchell, J.K., Jeger, M.J., and Taber, R.A. 1987. The effect of temperature on colonization of *Cercosporidium personatum* leafspot of peanuts by the hyperparasite *Dicyma pulvinata*. Agric. Ecosystems Environ. 18: 325-331.

ANNUAL RYEGRASS SEED PRODUCTION IN ACIDIC SOIL

J.M. Hart and M.E. Mellbye

Introduction

Annual or Italian ryegrass (*Lolium multiflorum* Lam.) is grown on approximately 125,000 acres in the southern Willamette Valley, primarily on moderately and poorly drained acidic soils. The soil pH in fields typically is below 5.5 (2:1 soil water), the value at which lime is recommended. Annual ryegrass forage production studies in Texas, Louisiana, and Florida have shown an increase in production when lime was applied to fields with a soil pH below 5.0, especially on sandy loam soils (Haby 1995**.** Despite acidic soil in western Oregon, seed yields comparable to or greater than the industry average (2000 lb/a) are commonly obtained at strongly acidic pH levels (below 4.5) that would limit seed production of perennial ryegrass and other perennial seed crops in the area.

Among western Oregon grass seed crops, annual ryegrass has the lowest economic return. Seed producers are cautious about purchasing lime since it is expensive, usually more than $60/t. One strategy employed by growers of annual ryegrass seed is to band granular lime at planting on acidic soil, especially on leased ground where they are uncertain about sufficient time for a return on an investment in conventional agricultural lime. While granular lime is 3-4 times as expensive as agricultural lime, approximately $225/t, the product is used at a rate of 110-150 lb/a and therefore costs 10 to 15% of a conventional 2-3 t/a agricultural lime application. Granular lime is placed with the seed at planting, in theory to neutralize acidity in the zone of germination, improve seedling growth and establishment, and ultimately help maintain seed yields on low pH soils; however this benefit has never been documented in western Oregon seed fields.

While annual ryegrass is considered a widely adapted cool season grass, tolerant of both poor drainage and low soil pH, the excellent seed yields achieved under very low pH levels on some soils in the Willamette Valley are surprising. The reason for this is not well understood.

The purpose of this trial was to: (1) evaluate the changes in soil chemical properties and annual ryegrass seed yield from lime application on acidic soil and (2) compare seed yield when granular lime is banded at a low rate to traditional broadcast lime application.

Material and Methods

A field was selected for this study with an initial pH of 4.2 (2:1 soil water), yet had a history of 2,500 lb/a or greater annual ryegrass seed yield. This yield is above the industry average for Oregon. The soil type was typical for the region where annual ryegrass is grown as a seed crop in the southern Willamette Valley of western Oregon, silt loam surface texture with a subsurface clay accumulation that restricts water movement. The field had been in production of annual ryegrass for over 30 years, managed mostly under a conventional tillage system where the full straw load was flail chopped and worked back into the soil each year. The field had never been limed. Gulf annual ryegrass was the variety grown historically in this field, and is the most commonly grown diploid annual ryegrass cultivar in Oregon. We continued with this variety during the trial period.

In August of 2005, 2.5 and 5 t/a of by-product agricultural lime was applied to the field using commercial lime application equipment and preplant incorporated with a harrow to a depth of approximately 5 inches. Additional treatments were an untreated or "check" and 150 lb/a granular lime (trade name Cal-Pril) annually applied in a band using a standard grain drill equipped with a fertilizer box attachment. All lime treatments are expressed as 100 score material. Soil pH, ammonium acetate extractable Ca, and KCl extractable aluminum were measured during the experimental period.

The trial was arranged in a randomized complete block design with three replications. Individual plots were 60 ft wide by 410 ft long. The variety Gulf annual ryegrass was planted each year in September. Seed yield was measured for three years. The plot area was harvested with grower equipment by first making a 16 ft swath the length of center of each plot, allowing the grass to dry, and threshing with a combine. A weigh wagon was used to measure plot yields. Sub-samples of the harvested seed were collected to determine 1000 seed weight, percent cleanout, and calculate total clean seed weight.

Results and Discussion

Lime application produced a small but significant increase, 200-320 lb/a, in annual ryegrass seed yield (Table 1). In spite of a 4.2 soil pH in the treatment receiving no lime, seed production was 2515 lb/a, which is 25% above the regional average. The application of granular lime and 2.5 t/a by-product lime produced the same yield statistically. The greatest seed yield, 2837 lb/a, was obtained from the incorporation of 5 t/a of lime.

Soil pH and extractable Ca were increased by the conventionally incorporated lime treatments. The 5 t/a lime rate raised the soil pH from 4.2 to 6.0 in the first season following application.

Table 1. The changes in three year average seed yield, soil pH and extractable Ca from lime applications on annual ryegrass seed yields on a strongly acid soil in western Oregon, USA.

Lime rate	pH 10/05	pH 06/08	Ca 10/05	Ca 06/08	Seed yield
(t/a)			---- (meq/100 g soil) ---		(lb/a)
0	4.2	4.4	2.1	2.2	2515
0.075	4.2	4.3	1.8	2.1	2740
2.5[1]	5.4	4.7	6.1	4.4	2723
5[1]	6.0	5.1	11.3	6.5	2837
P Value	0.0007	0.0122	0.0067	0.0035	0.0066
LSD (0.05)	0.24	0.16	1.86	0.77	138

[1] By-product, lime score of 72, applied 20 August, 2005 to provide an equivalent amount of 100 score lime.

The 5 t/a preplant lime treatment increased soil pH and Ca to levels considered adequate in the Oregon State University nutrient management guide for annual ryegrass seed production (Hart *et al.*, 2003). The conventional lime treatments maintained soil pH and Ca values above those from the untreated plots for the three-year period of this study. Soil pH and Ca levels from the conventional lime treatments decreased with time due to annual plowing and mixing of lime plus acidification associated with ammonium-N application. The band application of granular lime did not change soil pH or Ca. This outcome was expected as the application rate of granular lime was low.

Aluminum (Al) toxicity is considered a primary plant growth limiting factor for strongly acidic soils. As soil pH decreased, extractable Al increased exponentially (Figure 1), and grass seed yield decreased linearly (Figure 2).

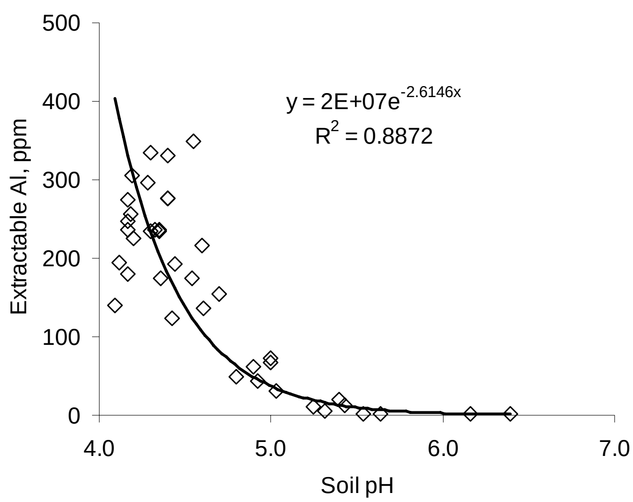

Figure 1. KCl extractable Al change with 2:1 soil:water pH

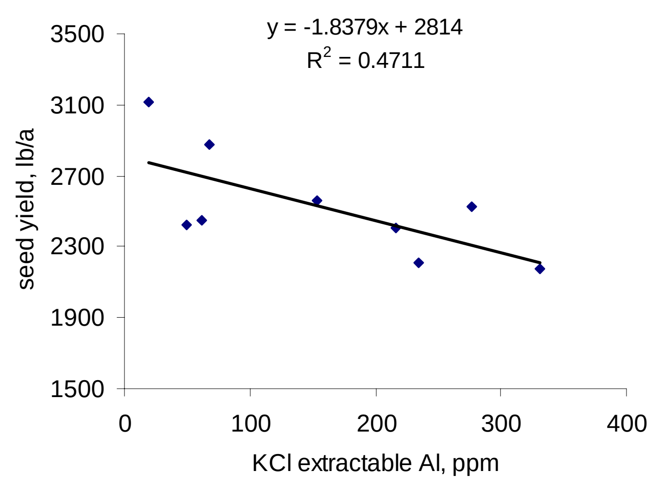

Figure 2. Annual ryegrass seed yield change with KCl extractable Al. Data from treatments receiving no lime and both rates of broadcast lime in 2008.

The soil pH at which Al becomes toxic to plants is dependent on the soil, plant species, and variety grown. In Willamette Valley soils, a pH of 4.7 has been considered a threshold level where Al concentration begins to increase exponentially and affect the growth of grass roots in forage and seed production systems. The increase in extractable Al measured in this trial also showed a sharp increase at approximately pH 4.7 (Figure 1). At soil pH 4.7, the extractable Al was approximately 100 ppm. Maximum annual ryegrass seed yield was measured when the extractable Al was below 100 ppm, supporting the choice of a soil pH 4.7 as threshold value for sufficient Al to limit root growth in this area.

Even when KCl extractable Al was three times the amount where toxicity was thought to affect root growth, 300 ppm, seed yields were above the industry average of 2000 lb/a. One possible reason that seed yield was maintained under these conditions was an Al-complex by organic acids, thus ameliorating the effect of Al toxicity on root growth. This explanation is possible since total soil C at the site was 2.5%. Another possibility is that the Gulf annual ryegrass cultivar grown in Oregon has developed tolerance to lower pH conditions. The seed stock of Gulf annual ryegrass used in this trial came from the same farm and from fields with similar low soil pH. These are plausible reasons for the annual ryegrass to grow well in acidic conditions.

Even though a reasonable relationship exists between KCl extractable Al and annual ryegrass seed yield, use of extractable Al to predict lime need is not recommended. The test is not universally available and critical Al levels are expected to vary with soil and crop. The strong relationship between KCl extractable Al and soil pH shown in Figure 1 shows that soil pH is an adequate indicator of the amount of Al in the soil and therefore, need for lime.

Data from the last two years of this project can be used to strengthen the idea that soil pH is an adequate indicator of lime need. A trend exists between soil pH and relative seed yield (Figure 3). The slope of the regression line differs from 0, but factors other than soil pH change yield. The relative seed yield and soil pH data was sorted into to groups, above 5.3 and below 5.3. The two groups of data plotted in Figure 4 support the OSU recommendation that lime is needed when the soil pH is below 5.5. Yield decreases as soil pH decreases when the pH is below 5.5 and yield does not change as the soil pH increases when the pH is above 5.5.

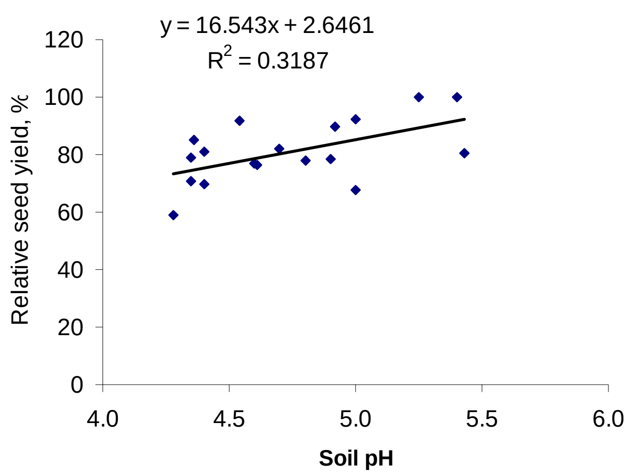

Figure 3. Annual ryegrass relative seed yield change with soil pH. Data from treatments receiving no lime and broadcast lime for 2007 and 2008.

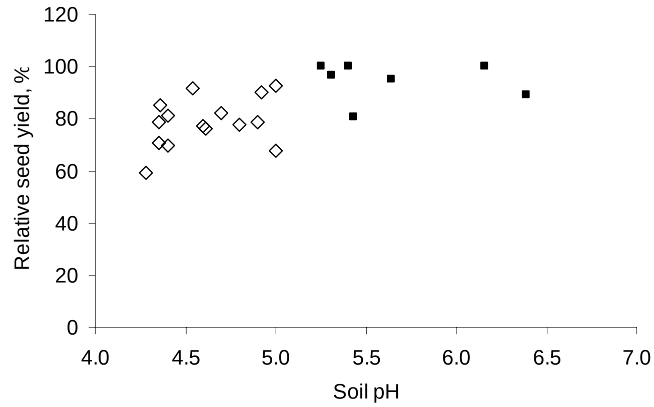

Figure 4. Annual ryegrass relative seed yield as changed by soil pH below 5.3, open diamonds, and above 5.3, solid squares.

The magnitude of yield reduction when soil pH decreases from soil pH 5.5 to 4.5 is 16% as shown by the equation of the regression line in Figure 3. The value of the seed yield decrease is approximately equal in value to one ton of lime. A 2.5 t/a application requires 3 years to recoup the cost of lime application, hence the reluctance of many producers to apply lime. A band application of 150 lb/a granular lime cost is approximately one-quarter to one-third the cost of a ton of agricultural or ground limestone. In addition, the seed yield increase from these two treatments is the same, which then produces a return on investment in one year from the granular lime application.

Annual ryegrass is considered to be a broadly adapted cool season grass, growing on poorly drained and acidic soils. These results confirm that annual ryegrass is tolerant of low soil pH on silt loam soils with relatively high organic matter concentration. However, even under these conditions, annual ryegrass seed yield will increase with lime applications on strongly acid soils. Use of granular lime is a very economical option for maintaining seed yield when the soil pH is below 5.5. The rate of lime used for a band application is insufficient increase soil pH, soil Ca or decrease extractable Al levels throughout the root zone. Conventionally incorporated lime applications, while more expensive, provide greater assurance of increasing soil pH, reducing extractable Al, and increasing seed yields on strongly acidic soils of the Willamette Valley, not only for annual ryegrass, but for other crops that may be grown in rotation.

References

Haby, V.A. 1995. Soil management and fertility practices for annual ryegrass. In: Symposium on Annual Ryegrass, Texas A&M University, Tyler, TX (August 31-September 1, 1995)

Hart, J.M., M.E. Mellbye, W.C. Young III, and T. Silberstein. 2003. Nutrient Management for Annual Ryegrass Grown for Seed (Western Oregon). Oregon State University Extension Service EM 8854-E. Corvallis, OR.

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

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

Introduction

Annual or Italian ryegrass (*Lolium multiflorum* Lam.) is grown on approximately 124,000 acres in the southern Willamette Valley. Production has occurred mostly on soils too poorly drained for cereal and vegetable crops, and on soils less productive than needed for higher value perennial grass and clover seed crops. This has lead to systems of continuous seed production of annual ryegrass, where some fields have been in production for over 40 years without any crop rotation.

Annual ryegrass seed production systems have changed significantly from the time when open field burning and no-till planting was a common and important practice. Prior to the 1990, over 50% of the acreage was open field burned. In recent years, only about 20% of the acreage was open field burned. Legislation in 2009 further restricted burning and essentially eliminated open field burning for annual ryegrass seed production.

Currently, a majority of the annual ryegrass seed crop acreage is successfully managed with conventional tillage and planting systems. However, the cost of tillage is expensive; thus, alternative no-till and volunteer systems are being tested and used. In the volunteer system, a seed crop is produced from seed shattered from the previous crop and is essentially a no-till and no-plant system of production for un-certified seed production (less than 5% of Oregon annual ryegrass is certified). In the volunteer system, grazing and strip or row spraying with herbicides are used to control stand density. When no-till planting is used, a sprout of volunteers and weed seeds are first sprayed with glyphosate herbicide. These systems offer a way to reduce tillage and fuel expenses, and reduce concerns about dust and air quality. Previous field work demonstrated that seed yields under the volunteer and no-till systems decline significantly over time if used more than one year in a row (Young et al., 1997). In the first year of production though, no-till and volunteer methods have been comparable to conventional methods of planting, suggesting a system of alternate year tillage may be a feasible way to maintain seed yields over time. This study was designed to evaluate the long-term economics of these various cropping systems in a continuous annual ryegrass monoculture over multiple years. A secondary objective was to measure the impact on soil properties, especially carbon sequestration, of reduced tillage systems of seed production.

Material and Methods

This study was established at the Hyslop Crop Science Farm in the fall of 2005. The field had been planted to 'Gulf' annual ryegrass the previous two years, and we continued with the same variety. Soil was a moderately well-drained silt loam soil with a pH of 5.4 and soil test levels of P, K, Ca, and Mg above levels considered adequate for seed production. Six treatments were included in a Randomized Complete Block design, and replicated three times with plots 25 feet x 125 feet.. The resulting treatments included:

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

In all except the burn treatment, residue from the previous year's crop was flail chopped and left on the field. Tillage included plowing to a depth of 8 to 10 inches, disking, and pulvi-mulching. A final seedbed was prepared by harrowing and rolling. All treatments except the volunteer included at least one preplant application of glyphosate to control volunteer seedlings. A preplant fertilizer of 200 lb/acre of 16-16-16 was applied to all treatments. A Great Plains no-till drill was used to seed all treatments except the volunteer at a planting rate of 17 lb/acre. The volunteer plots were established by allowing the seeds left on the surface the previous year to germinate and grow. Rows in the volunteer plots were established by spraying out 7 inches of every 10 inches of crop with glyphosate at 40 oz/acre. All herbicide use, pest control and spring fertilization were performed according to OSU recommendations and industry standards.

Plots were harvested by swathing in late June, using a modified John Deere 2280 swather (6 foot cutting width) and combined in mid-July with a Hege 180 plot combine. Seed was cleaned using a Clipper M2B cleaner and clean seed yields, cleanout percentage and seed weight determined. Seed yield results were analyzed as a Randomized Complete Block using treatment means over four years as replications or blocks.

Results and Discussion

The seed yields obtained during the first four years of this long-term study ranged from a high of 2061 lb/acre in 2009 to a low of 1126 lb/acre in 2008. Seed yields in 2008 were significantly affected by slug and vole damage. For this reason, composite yields for the treatments over the four years were below normal for annual ryegrass seed fields in the Willamette

Valley. However, there were significant differences between treatments (P = 0.08) averaged over years (Table 1). The continuous no-till treatment had the lowest yield of the six different systems of production. The burn and no-till planting method alternated with conventional tillage had the greatest mean seed yield. All systems of establishment that included alternate year tillage provided 4-year mean seed yields comparable to or greater than the conventional tillage method of establishment.

Among the six systems of establishment, the continuous conventional tillage and planting approach had the highest cost of production, based on the Oregon State University Enterprise Budget for annual ryegrass (Eleveld et al., 2007). The conventional system was $51to $90/acre more than methods of establishment that used reduced tillage. Continuous no-till provided the lowest cost of production, but also had the lowest seed yield and the highest risk of establishment under Western Oregon conditions. Stand reduction due to slugs was a major reason for poorer yields in the continuous no-till treatment. Slug damage to seedling crops in the region is a common problem and a significant economic risk. Slug numbers in no-till annual ryegrass fields can be 14 to 29 times greater than in plowed and conventionally worked plots (Fisher et al., 1996). Systems that alternate no-till or volunteer methods with tillage have less risk of damage from this widespread and common pest, and over the course of this study to date, the alternate year tillage systems were more profitable than continuous conventional tillage.

One of the reasons for using reduced tillage systems is to maintain soil organic matter levels and potentially increase carbon storage in the soil. After three years, soil samples taken in this study showed that soil organic matter and soil carbon levels were similar under conventional or alternate year tillage systems in the 0-8 inch depth (Table 2). Soil organic matter and carbon were stratified under continuous no-till due to accumulation of soil organic matter in the surface layer (0-2 inch depth). Below 2 inches, soil carbon in the continuous no-till was significantly less. Soil organic matter and nutrient stratification have been observed in previous no-till trials (Mellbye et al., 1999). Despite differences in tillage and organic matter distribution, total accumulation of soil carbon among treatments to date was similar (assuming similar soil bulk density). Results may change over time, but these data suggest alternate year tillage or plowing in annual ryegrass cropping systems can maintain soil carbon at levels similar to those achieved with continuous no-till, at least over a short period of time.

Table 1. Seed yields and economic comparisons of annual ryegrass establishment systems after four years, 2006-2009.

Establishment system (2006-2009)	Total cost	Seed yield 4-year average	Seed yield 4-year average
	($/acre)	(lb/acre)	(% conventional)
Continuous conventional tillage	612	1666 bc[1]	100
Continuous no-till	522	1587 c	95
No-till / conventional tillage rotation	567	1659 bc	100
Volunteer / conventional tillage rotation	528	1731 ab	104
Burn and no-till / conventional tillage rotation	561	1809 a	109
Volunteer / no-till / conventional tillage rotation	526	1680 bc	102
LSD (0.10)	--	115	--

[1]Means followed by the same letter do not differ significantly

Table 2. Soil organic matter, soil carbon, and soil nitrogen levels from selected annual ryegrass establishment systems May 2009.

Selected treatments	Soil depth	Soil organic matter	Soil carbon	Soil nitrogen
	(in)	(%)	(%)	(%)
Continuous tillage	0-8	3.83	1.59	0.090
Continuous no-till	0-8	3.35	1.62	0.107
	0-2	4.32	1.92	0.103
	5-8	3.61	1.48	0.077
Volunteer /conventional (Tillage alternate years)	0-8	3.95	1.63	0.083
Volunteer / no-till / conventional (Tillage every third year)	0-8	3.58	1.64	0.080
LSD (0.05)		0.27	0.10	0.017

Preliminary results after four years demonstrate that alternating a conventional tillage system with a no-till or volunteer method of establishment can provide seed yields comparable to continuous conventional tillage, but at a lower cost of production. In addition, alternate year tillage appears to maintain soil carbon levels comparable to continuous no-till. This trial is designed to last a minimum of 9 years, and a more thorough economic analysis of results will be presented in the future. The take-home message at this time is alternatives to annual conventional tillage exist in annual ryegrass production that reduces costs while maintaining yields.

References

W.C. Young III, T.G. Chastain, M.E. Mellbye, T.B. Silberstein, and C.J. Garbacik. (1997). Crop residue management and establishment systems for annual ryegrass seed production. Seed Production Research at Oregon State University, Ext/CrS 111, 4/98. p. 1-6.

M.E. Mellbye, W.C. Young III. (1999). The Effect of Straw Removal and Different Establishment Systems on Soil Fertility Levels in Annual Ryegrass Seed Fields. In: Proceedings. Fourth International Herbage Seed Conference, Perugia, Italy. p. 147-151.

B. Eleveld, M.E. Mellbye, W.C. Young. E. Lahmann, and C. Younger. (2007). Enterprise budget: Annual ryegrass seed, conventional tillage, South Willamette Valley region. EM 8635. OSU Extension Service.

G.C. Fisher, J.T. DeFrancesco, and R.N. Horton. (1996). Slug populations in grasses grown for seed. Crop residue management and establishment systems for annual ryegrass seed production. Seed Production Research at Oregon State University, Ext/CrS 110, 4/97. p. 23-25.

RIPARIAN FOREST AND ADJACENT GRASS SEED PRODUCTION FIELD IN WESTERN OREGON: NITROGEN DYNAMICS AND WATER QUALITY

S.M. Griffith, J. H. Davis and P.J. Wigington, Jr.

Summary

The effectiveness of riparian zones in mitigating nutrients in ground and surface water depends on the climate, management and hydrogeomorphology of a site. The purpose of this study was to determine the efficacy of a well-drained, mixed-deciduous riparian forest to buffer a river from N originating from a poorly drained grass seed cropping system. The study was conducted on a study site located along the lower Calapooia River in Linn County, Oregon, U.S.A. from fall 1995 through the early summer 1999. The Calapooia River is a free flowing tributary of the Willamette River with a drainage area of 765 km^2 at our study site. The upper portion of the river basin drains forested land in the Cascade Mountains and the lower portion of the river drains low topography, poorly drained agricultural lands. The study site consisted of an intensively-managed perennial ryegrass seed cropping system and a mixed-deciduous riparian forest located on the inside meander bend of the river. An intermittent stream was located within a swale that cut from the cropping system through the riparian forest to the river. Plant communities at the site were described by McAllister et al. (2000). We found that water moved from the cropping system to the river through the slow movement of groundwater and also through the rapid drainage of surface water through the intermittent stream. Low groundwater NO_3^- concentrations (0.2-0.4 mg NO_3^- -N L^{-1}) in the surface wells of the cropping system (Table 1) were associated with low rates of mineralization and nitrification (Table 2) and high amounts of grass seed crop uptake of N (three year mean of 155 kg N ha^{-1} y^{-1}). The grass seed cropping system surface soil and sandy, well-drained riparian forest soil profile were predominantly aerobic, reducing the potential for removal of NO_3^- through denitrification. The riparian forest had higher rates of mineralization (0.32 kg N ha^{-1} d^{-1}) (Table 2) that produced quantities of soil N that were within range of plant uptake estimates leading to relatively low concentrations of groundwater nitrate (0.6-1.8 mg NO_3^- -N L^{-1}). During winter hydrological events, the riparian forest receives river water, giving this system the potential to not only influence nutrient concentrations in groundwater from conterminous agricultural landscapes but also from river water that contains nutrients from agricultural lands higher in the basin. Given the dynamic nature of the hydrology of our Calapooia River site, we believe the riparian forest plays a role not only in reducing export of nitrate from the cropping system to the river but also in processing nutrients from water exported from other in-river water.

Conclusions

- The hydrology of the site controls, to a large extent, the processing of N in ground and surface water.
- The dynamic nature of the water table in the riparian forest allows for both the reduction of nutrients originating from adjacent fields, as well as those transported down the Calapooia River network from lands higher in the basin.
- The very slow movement of water in the cropping system resulted in less water table fluctuations and overland flow through the swale during hydrologic events.
- Although the rapid movement of water from the cropping system through the swale allowed for little or no interaction of stream water NO_3^- with the riparian forest soil, the biogeochemical processing of N within the swale could be important in controlling export of N in this surface water.
- Although denitrification does not appear to contribute significantly to N removal from the site, the potential for biological uptake is high. Crop and forest vegetation had the potential to take up as much N as was contributed through mineralization (riparian forest) and fertilizer applications (cropping system).
- These results are relevant to riparian forests on the inside meander bends of rivers where alluvial deposits form in point bars and floodplain deposits and hyporheic flow of water from rivers and back are common.
- Given the dynamic nature of the hydrology of the site, we believe the riparian forest plays a role in reducing export of nitrate from the cropping system to the river.

Literature

Davis, J.H., S.M. Griffith, W.R. Horwath, J.J. Steiner, and D.D. Myrold. 2006. Fate of nitrogen-15 in a perennial ryegrass seed field and herbaceous riparian area. Soil Sci. Soc. Am. J. 70:909-919.

Davis, J.H., S.M. Griffith, W.R. Horwath, J.J. Steiner, and D.D. Myrold. 2007. Mitigation of shallow groundwater nitrate in a poorly drained riparian area and adjacent cropland. J. Environ. Qual. 36:628-637.

Davis, J.H., S.M. Griffith, W.R. Horwath, J.J. Steiner, and D.D. Myrold. 2008. Denitrification and nitrate consumption in an herbaceous riparian area and perennial ryegrass seed cropping system. Soil Sci. Soc. Am. J. 72:1299-1310.

Dykaar, B.B., and P.J. Wigington, Jr. 2000. Floodplain formation and cottonwood colonization patterns on the Willamette River, Oregon, USA. Environmental Management 25:87-10.

Evans, D.M. 2007. Dissolved Nitrogen in Surface Waters and Nitrogen Mineralization in Riparian Soils within a Multi-Land Use Basin, Oregon State University, Corvallis, OR.

Fernald, A.F., P.J. Wigington, Jr. , and D. Landers. 2001. Transient storage and hyporheic flow along the Willamette River, Oregon: field measurements and model estimates. Water Resources Research 37:1681-1694.

Floyd, W.C., S.H. Schoenholtz, S.M. Griffith, P.J. Wigington, Jr., and J.J. Steiner. 2009. Nitrate-nitrogen, land use/land cover, and soil drainage associations at multiple spatial scales. J. Environ. Qual. 38:1473-1482.

Griffith, S.M., S.C. Alderman, and D.J. Streeter. 1997a. Italian ryegrass and nitrogen source fertilization in western Oregon in two contrasting climatic years. I. Growth and seed yield. J. Plant Nutr. 20:419-428.

Griffith, S.M., J.S. Owen, W.R. Horwath, J. P.J. Wigington, J.E. Baham, and L.F. Elliott. 1997b. Nitrogen movement and water quality at a poorly-drained agricultural and riparian site in the Pacific Northwest. Soil Sci. Plant Nutr. 43:1025-1030.

McAllister, L.S., K.A. Dwire, and S.M. Griffith. 2000. Vegetation characterization of three contrasting riparian sites, Willamette Valley, Oregon., p. 29-33, *In* P.J. Wigington, Jr. and R.L. Beschta, eds. International Conference on Riparian Ecology and Management in Multi-Land Use Watersheds., Vol. TPS-00-2. American Water Resources Association, Middleburg, Virginia.

Wigington, P.J., T.J. Moser, and D.R. Linderman. 2005. Stream Network Expansion: A Riparian Water Quality Factor. Hydrological Processes 19:1715-1721.

Wigington, P.J., S.M. Griffith, J.A. Field, J.E. Baham, W.R. Horwath, J. Owen, J.H. Davis, S.C. Rain, and J.J. Steiner. 2003. Nitrate removal effectiveness of a riparian buffer along a small agricultural stream in western Oregon. J. Environ. Qual. 32:162-170.

Table 1. Mean and standard error of groundwater nitrate concentrations in the riparian forest (Rows 1-4) and cropping system (Rows 5 & 6) at the various depths. Note that the shallowest wells are at different depths in the cropping system and riparian forest. Letters denote differences among rows for each depth with all dates combined ($p \leq 0.05$).

	Nitrate Concentrations ($mg\ NO_3^-$-N L^{-1})				
Row	Depth 1 (0.15 - 0.47 m)	Depth 1 (0.9 - 1.4 m)	Depth 2 (1.5 - 2.0 m)	Depth 3 (2.1 – 2.6 m)	Depth 4 (2.7 – 3.2 m)
1	-	14 (5.0) a	13 (3.0) a	1.9 (0.53) a	1.1 (0.49) a
2	-	0.64 (0.15) b	0.65 (0.15) b	1.3 (0.20) a	1.6 (0.28) a
3	-	1.6 (0.56) b	1.6 (0.39) b	1.8 (0.26) a	3.1 (0.21) b
4	-	1.8 (0.41) b	1.2 (0.21) b	1.4 (0.21) a	1.2 (0.14) a
5	0.24 (0.07) a	-	6.7 (1.1) c	4.8 (0.42) b	-
6	0.44 (0.28) a	-	6.7 (0.62) c	6.5 (0.63) c	-

Table 2. Mean and standard error of mineralization and nitrification rates for the cropping system and riparian areas. Lake Creek (a contrasting poorly-drained riparian area adjacent to a poorly-drained grass seed crop) data were calculated from Davis et al. (2008) for comparison.

	Riparian		Cropping System	
	Mineralization ($kg\ ha^{-1}\ d^{-1}$)	Nitrification ($kg\ ha^{-1}\ d^{-1}$)	Mineralization ($kg\ ha^{-1}\ d^{-1}$)	Nitrification ($kg\ ha^{-1}\ d^{-1}$)
Calapooia				
1996-97	0.32 (0.08)	0.31 (0.08)	0.06 (0.03)	0.06 (0.02)
1997-98	0.30 (0.06)	0.30 (0.06)	0.16 (0.03)	0.17 (0.02)
1998-99	0.35 (0.06)	0.35 (0.06)	0.03 (0.01)	0.03 (0.01)
Lake Creek				
1996-97	0.21 (0.09)	0.04 (0.02)	0.18 (0.07)	0.11 (0.04)
1997-98	0.17 (0.05)	0.03 (0.01)	0.19 (0.05)	0.22 (0.04)
1998-99	0.28 (0.14)	0.00 (0.00)	0.23 (0.17)	0.08 (0.07)

DOES GRAY-TAILED VOLE ACTIVITY AFFECT SOIL QUALITY?

J.A. Gervais, S.M. Griffith, J.H. Davis, J.R. Cassidy and M.I. Dragila

Summary

Voles are well-known crop pests in grass seed cropping systems especially when post-harvest grass straw is chopped and remaining on the field, and particularly in years when peak populations are present. Their role in soil fertility and impacts on agricultural sustainability, however, are not well understood. We conducted a study in a perennial grass seed production system in the Willamette Valley, Oregon to better understand vole burrow structure and the impact that vole activity has on soil chemical properties. The study was performed in the spring of 2006, five months after the abrupt disappearance of a gray-tailed vole population in the valley following a significant vole irruption. This irruption was particularly noteworthy due to the millions of dollars of losses to the grass seed, plant nursery, and wine industries. Based on other fossorial mammals' impacts on nutrient cycling and carbon (C) and nitrogen (N) cycling, we hypothesized that concentrations of soil C, N-nutrients, trace elements, and moisture would be greater directly below vole burrows than above or away from the burrows. We also hypothesized that soil that had supported vole populations would have greater amounts of soil organic matter, greater concentrations of carbon and nitrogen, and greater soil moisture than soil with no vole activity. In this study we examined burrow structure, determined concentrations of trace elements, carbon and nitrogen in the soil immediately surrounding vole burrows, and compared soil chemical properties to a depth of 90 cm between areas with prior vole activity and areas of no activity. Vole tunneling activity was confined to the top 10 cm of the soil profile and was coincident with the majority of root biomass. Soil NH_4^+, NO_3^-, extractable organic carbon, and soil organic matter were greater below vole tunnels than above; however, due to small sample sizes, differences were not significant (Table 1). There were no differences in trace elements (Al, Ba, B, Ca, Cu, Fe, Mg, Mn, P, K, S, Si, Z) with respect to position around vole tunnels. Vole activity was associated with increased soil NO_3^- concentrations (Figure 1) and decreased soil pH (Figure 2) to a depth of 90 cm, indicating that nitrification might be enhanced by vole activity, and that this effect continues after vole populations crash.

Conclusions

- This study is the first to elucidate the signature of vole activity on soil in a perennial grassland ecosystem in the Willamette Valley of Oregon.
- Vole activity had the greatest impact on the production of NO_3^- in these soils.
- Greater concentrations of NO_3^- and decreased pH extended to soil depths of 60-90 cm in areas with previous burrowing activity, even though the burrows appeared to be largely confined to the top 10 cm of soil.
- Greater inorganic N could have long-term effects on ecosystem productivity.
- Changes in soil chemistry due to vole activity seem to outlast the population spikes that create the characteristic extensive burrow network.
- The effects voles have on soil processes that influence C and nutrient cycle requires further investigation.

References

Cassidy, J. 2002. The role of microtine rodents in contaminant/solute transport at the landscape level. M.S. Thesis, Oregon State University, Corvallis.

Clark, J.E., E.C. Hellgren, J.L. Parsons, E.E. Jorgensen, D.M. Engle, and D.M. Leslie, Jr. 2005. Nitrogen outputs from fecal and urine deposition of small mammals: Implications for nitrogen cycling. Oecologia 144:447-455.

Sirotnak, J.M., and N.J. Huntly. 2000. Direct and indirect effects of herbivores on nitrogen dynamics: Voles in riparian areas. Ecology 81:78-97.

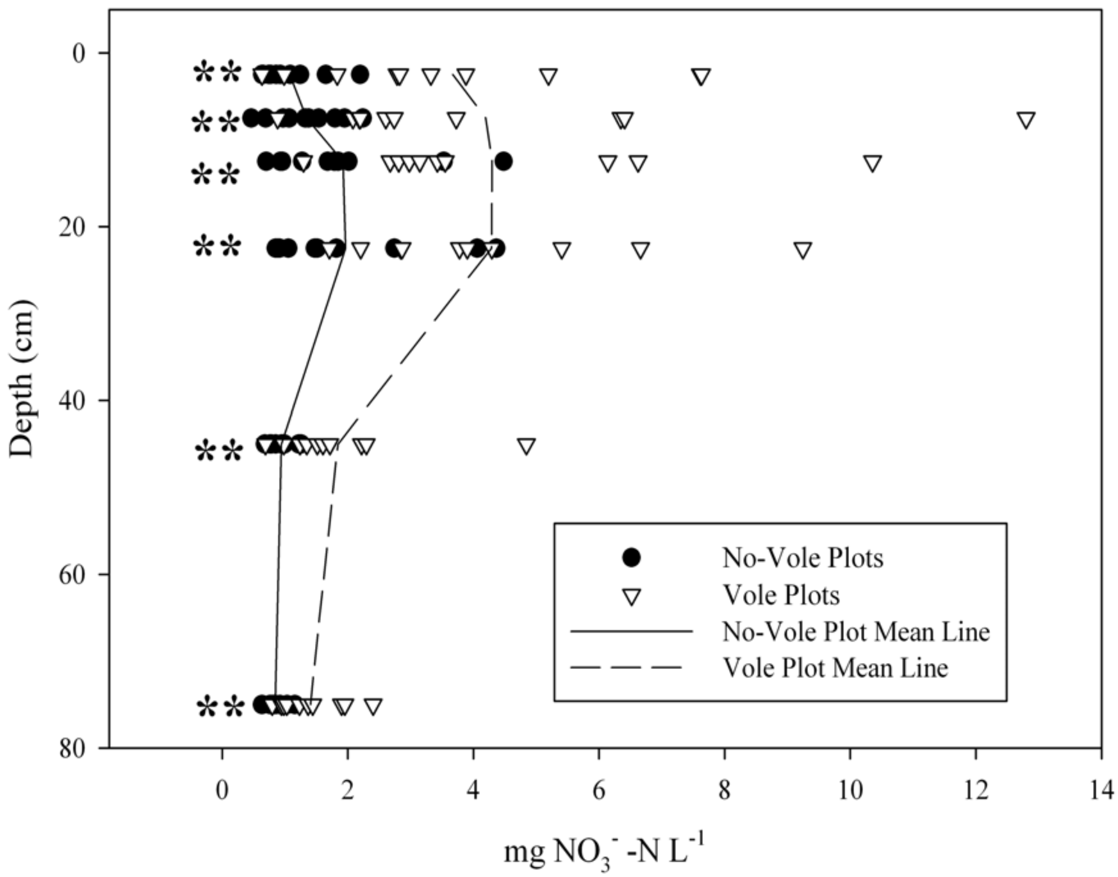


Figure 1. Relationship between soil depth and soil NO_3^- in plots with and without vole activity in the Willamette Valley, Oregon in May 2005 Lines connect means for each soil depth class (0-5, 5-10, 10-15, 15-30, 30-60, and 60-90 cm). Differences between no-vole and vole plots were significant at all depths ($P \leq 0.10$). The untransformed raw data are presented. Significance is denoted at $P \leq 0.10$ by * and at $P \leq 0.05$ with **.

Table 1. Geometric means and 90% confidence limits (in parentheses) of soil parameters from the vole burrow vicinity study. "Above" refers to soil samples taken within 5 cm above burrows, "below" refers to soil samples taken from within 5 cm below burrows, samples from "above away" were taken 25cm above a burrow and "below away" were taken 25 cm below a burrow. Units are mg N kg^{-1} dry soil for nitrate (NO_3^-), ammonium (NH_4^+), and extractable total nitrogen (ETN), mg C kg^{-1} dry soil for extractable organic carbon (EOC) and percentages for soil organic matter (SOM) and gravimetric soil moisture (GSM).

Soil Parameter	Above (n=4)	Below (n=5)	Above Away (n=1)	Below Away (n=2)
pH	5.34 (5.17-5.52)	5.55 (5.27-5.83)	5.60	5.67 (4.33-7.01)
NH_4^+ (mg/kg)	1.32 (0.84-1.81)	13.1 (-10.8-37.0)	1.36	1.10 (1.00-1.20)
NO_3^- (mg/kg)	0.84 (0.70-0.99)	1.17 (0.69-1.65)	0.96	0.90 (0.24-1.55)
ETN (mg/kg)	8.49 (6.84-10.2)	18.0 (-1.58-37.6)	8.42	7.71 (5.94-9.48)
EOC (mg/kg)	54.3 (49.0-59.7)	67.5 (48.1-86.9)	60.6	54.2 (42.6-65.8)
SOM (%)	3.64 (2.1-4.47)	3.91 (3.38-4.44)	3.28	3.19 (2.21-4.18)
GSM (%)	16.1 (15.1-17.2)	21.5 (19.7-23.3)	14.7	16.3 (13.0-19.6)

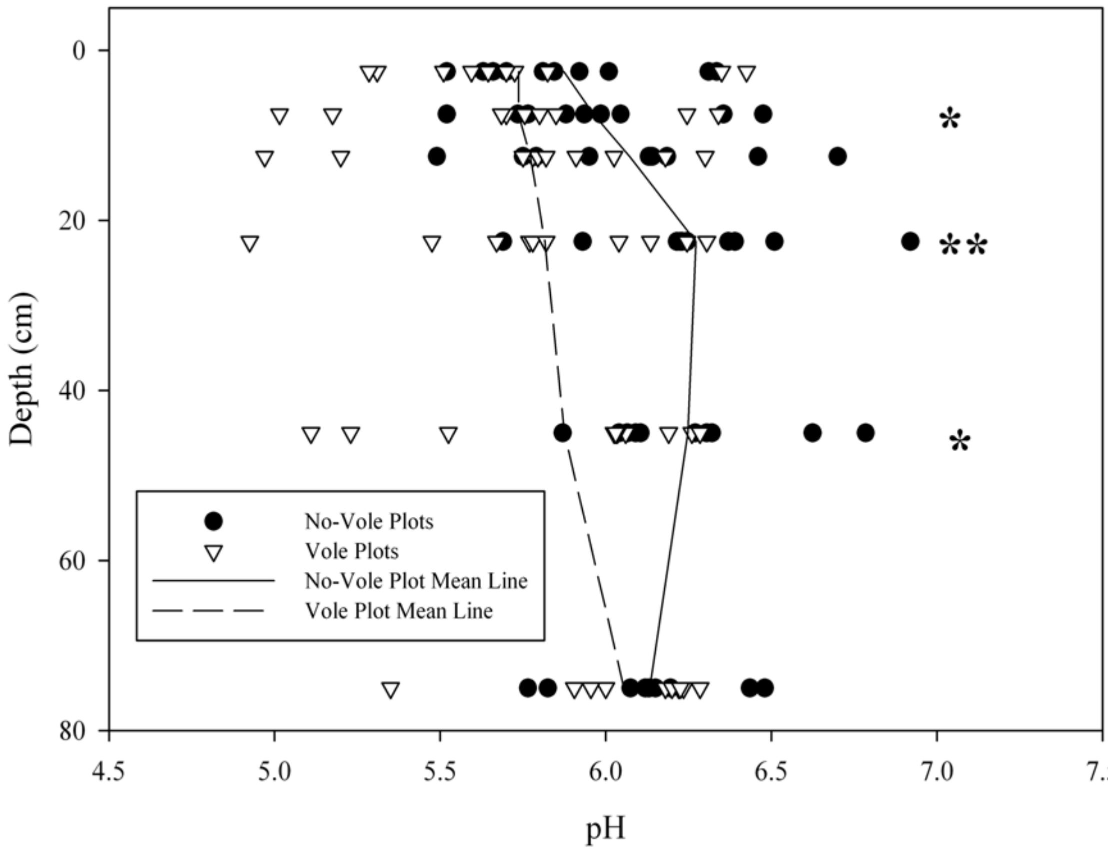


Figure 2. Relationship between soil depth and soil pH in plots with and without vole activity in the Willamette Valley, Oregon in May 2005. Lines connect means for each soil depth class (0-5, 5-10, 10-15, 15-30, 30-60, and 60-90 cm). Differences between no-vole and vole plots were significant at depths 15-30 cm and 5-10 cm and 30-60 cm ($P \leq 0.10$). The un-transformed raw data are presented. Significance is denoted at $P \leq 0.10$ by * and at $P \leq 0.05$ with **.

COST AND BENEFIT IN CONTROL OF THE GRAY FIELD SLUG IN WESTERN OREGON

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

Introduction

Controlling slugs in western Oregon agricultural fields can be problematic during wet winter and spring conditions when slug damage to newly emerging seedlings can be severe. The rising cost of products and operating inputs, and an increased awareness of environmental concerns, have been coupled with increasing slug populations partly caused by disappointing attempts to reduce slug populations. In this study, a large greenhouse study was conducted to quantify the effect of slug baits and poison, and combinations of these products, on slug mortality and percent seedling survival. We also quantified egg fecundity to determine whether specific control strategies might reduce the number of slugs during future cycle outbreaks.

Laboratory Methods

Experiments were conducted in a cool (10 °C) greenhouse under winter light conditions utilizing the products and product combinations listed in Table 1. Ten gray garden slugs were placed in round arenas (30 cm diameter) that were covered with screened lids, and partially filled with native soil (Dayton/Woodburn, 25% soil moisture). Slugs were field collected and held in growth chambers (10°C, 8 hrs. daylength) for three weeks before use in experiments and fed lettuce twice per week. Sixty perennial ryegrass seeds were planted in a center row arrangement and emerged seedlings were used in the experiment when they reached five days of age.

A complete randomized-block design experiment was laid out to provide equal cooling and lighting. To achieve the 6 repicates of each product and rate combination, tests were run in three groups (time blocks), 2 reps of each combination of product and rate, in each time block (for a total of 6 replicates). Pre-moistened cotton felt pads (3mm thick) were used in each arena as slug rests and egg-laying sites. Experiments were conducted for two weeks after which seedling damage, slug mortality, and egg laying were quantified. Surviving slugs were maintained for an additional 14 days to validate recovery.

The baits used in this study were: Deadline MP (DMP, 4% metaldehyde, pellet); OR-CAL Blue, 3.25% metaldehyde, pellet; MetaRex (MR, 4% metaldehyde, pellet); Sluggo shorts (1% iron phosphate. We investigated Durham 3.5 and Durham 7.5 a granular, sand-based product, enhanced with an attractant and weathering protection (3.5 and 7.5%, metaldehyde, respectively), two non-bait products that are not attractive to earthworms, and SlugFest AWF (all-weather-formula, 25%, metaldehyde), a liquid spray product. These non bait products do not need to be discovered by slugs, a potentially limiting factor in slug control. SlugFest is sprayed onto foliage and is consumed by the slugs, while slugs acquire metaldehyde from Durham by trans-dermal absorption across its foot when crawling over the fine granules. Liquid treatments were applied using a calibrated sprayer (15 psi; 20 gal/a rate; 80-02 nozzle, Tee-Jet®) and allowed to dry for thirty minutes. All other dry formulations were calibrated per surface area (60% of $1ft^2$).

Results

The greenhouse experiment showed that there is a diminishing improvement in slug control and seedling survivorship as the rates and cost of the applications increased. For all the single product regressions of Slug Death versus Cost, the polynomial factor was significant at $P < 0.05$ (Figure 1a). This means that with increasing cost the improvement in slug mortality declined for a given increase in dollars spent. There were differences among products. The most cost effective was Sluggo ($P < 0.0001$), while the MetaRex, Durham 3.5 and OR-CAL were least effective. SlugFest AWF effectiveness was poor at the lower three rates, but high at the three higher rates. Some of the product differences could be attributed to the moisture conditions of the experiment (25% soil moisture). For example Sluggo has been shown to be more effective in low moisture conditions, while MetaRex requires higher amounts of rain/soil moisture to become palatable, and it retains effectiveness under high moisture conditions. The three combination treatments (Combinations 12, 13, and 15)with highest cost effectiveness relative to single products all contained Sluggo as a component.

There was a significant increase in seedling survival with increased application rates and cost (Figure 1b). However the relationship between Seedling Survival and Slug Death (0.0162) was not significant ($P = 0.7975$). This can be most clearly seen in the Sluggo treatment group. Although Sluggo was most cost effective in causing slug death (Fig 1a), it was least effective in protecting seedlings (Fig 1b). Overall SlugFest AWF was the most effective in protecting seedlings ($P < 0.05$), although it was relatively poor in causing slug death. These relationships may in part be due to the fact that SlugFest is sprayed on the seedlings and slugs consume it along with the foliage. It is possible that a learned repellency is also involved, which limits slug death but protects the plant. Conversely, slugs can feed on seedlings before they encounter Sluggo pellets. In addition, Sluggo is a stomach poison that requires several days to cause slug death. There may be additional slug feeding damage until the active ingredient (iron phosphate) takes effect.

Combinations (Treatments 9 and 11) were as cost effective in increasing seedling survival as the most effective single product application, SlugFest (Fig 2b). Both of these combination treatments contained Sluggo; in Treatment 9 it is combined with Durham 3.5, and in Treatment 11 with OR-CAL. Combination Treatments 14 and 15 were the least effective of the combinations. These contained Sluggo and SlugFest as ingredients. This poor performance was not expected given that Sluggo is the most effective slug mortality product, and SlugFest is the most effective at protecting seedlings.

Egg Fecundity (numbers of eggs laid) also had a polynomial relationship with Cost, with decreasing reductions in egg laying as costs increased above $20-$25 (data not shown). SlugFest, Deadline MP, and MetaRex were the most cost effective at reducing slug egg laying. Of the product combinations tested, Treatment 13 which contained MetaRex and Sluggo was the most cost effective at reducing egg laying, but was no more effective than straight SlugFest at the same cost.

These results make it difficult to come to a conclusion on the best product, rate or combination to use. In experimental conditions with higher moisture, the effectiveness of Sluggo can be expected to decline while the relative effectiveness of MetaRex could increase. It is clear that in this test environment spending more than $20-$25 per acre on an application gave diminishing returns for both slug mortally and seedling survivorship. Is also appears that the most effective combinations of products are no more cost effective at killing slugs, reducing damage, or reducing egg fecundity than the most effective single products.

Conclusions

We learned that there is a point at which higher application rates result in diminished increases in slug mortality and seedling survival. This occurs when only 30-45% of the slugs have been killed, and 50% of the seedling have survived. While slugs can be killed by ingesting or absorbing poison baits, the direct impact of slug mortality on reducing seedling loss is unclear. It is likely that there is need to think beyond the concept of slug mortality equals slug “control” when evaluate slug control / seedling protection tactics are evaluated.

These results suggest that growers should limit the amount of slug control product used at each application. Unfortunately however, it is also possible to apply too little bait to be truly effective, i.e., the minimum rates used in this study. This study does indicate the range of application rates that should be cost effective, and in general, those rates that constituted cost effective slug control differed among the products tested as far as how they affect slug mortality, seedling survival, and slug egg laying.

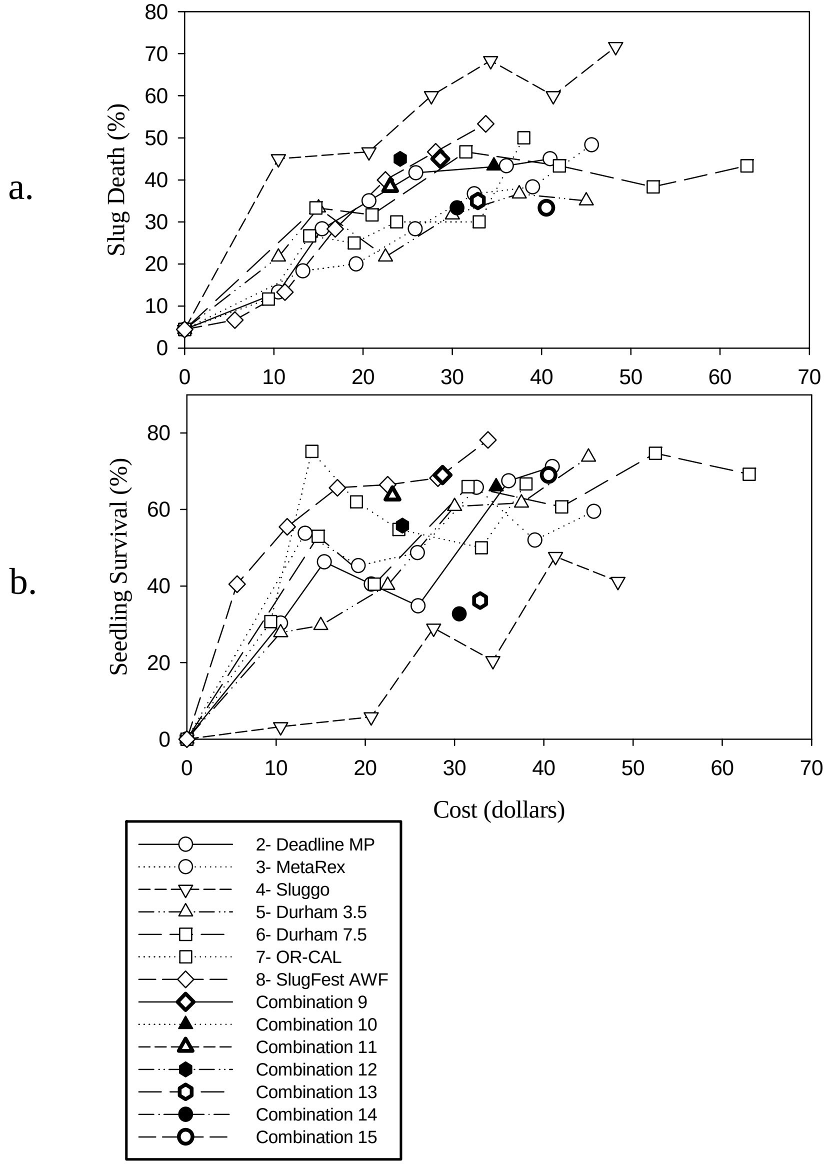


Figure 1a**:** Regression of percent Slug Death (7 products at 6 rates) versus Cost of the product. The regression equation [Slug Death = block + Cost + CostSquared + Product] was significant at $P < 0.0001$. The treatments (9-15) that were comprised of a combination of products are incorporated into the figure to assess whether on a cost basis product combinations are more effective than single product applications.

Figure 1b. Regression of percent Seedling Survival (7 products at 6 rates) versus Cost of the product. The regression equation [Seedling Survival = block + Cost + CostSquared + Product] was significant at $P < 0.0001$.

Table 1. Product, rate, and cost data. All bait rates were adjusted to normalize the cost/acre, when possible.

Treatment Number	Treatment	% Slug Death	SEM	% Seedling Survival	SEM	No. of Eggs	SEM	Cost
1	Control 1	4	2.413	0	0.000	67	3.654	$0.00
	Deadline MP 7.25 lbs/a	13	2.109	6	4.888	47	3.128	$10.50
	Deadline MP 11.25 lbs/a	28	8.852	7	9.663	35	2.692	$15.40
2	Deadline MP 14.75 lbs/a	35	8.335	16	7.302	21	4.752	$20.65
	Deadline MP 18.5 lbs/a	42	10.140	21	5.096	16	2.114	$25.90
	Deadline MP 25.75 lbs/a	43	8.467	35	1.546	7	1.721	$36.05
	Deadline MP 29.75 lbs/a	45	10.855	47	3.590	6	2.156	$40.95
	MetaRex 5 lbs/a	17	4.945	2	5.657	47	5.597	$13.25
	MetaRex 7.35 lbs/a	20	4.473	6	7.758	22	1.642	$19.21
3	MetaRex 10 lbs/a	27	10.222	16	11.119	16	3.023	$25.84
	MetaRex 12.5 lbs/a	35	7.639	16	5.970	16	1.564	$32.46
	MetaRex 15 lbs/a	37	6.668	22	12.895	6	2.445	$39.00
	MetaRex 17.25 lbs/a	45	9.576	47	3.515	2	1.424	$45.61
	Sluggo shorts 7 lbs/a	42	11.669	6	7.562	44	8.440	$10.50
	Sluggo shorts 14 lbs/a	47	7.603	9	2.454	30	3.440	$20.65
4	Sluggo shorts 18.75 lbs/a	60	5.775	22	9.433	30	7.610	$27.65
	Sluggo shorts 23.5 lbs/a	60	5.775	30	7.336	22	1.587	$34.30
	Sluggo shorts 28 lbs/a	68	6.010	30	6.690	9	3.294	$41.30
	Sluggo shorts 32 lbs/a	72	7.033	44	2.167	6	1.500	$48.30
	OR-CAL 7.5 lbs/a	12	9.191	8	3.480	46	4.249	$9.38
	OR-CAL11.5 lbs/a	25	9.918	27	2.977	41	5.499	$14.00
5	OR-CAL 15.25 lbs/a	27	3.652	29	6.870	35	3.192	$19.00
	OR-CAL 19 lbs/a	30	9.663	35	8.179	29	3.199	$23.75
	OR-CAL 26.5 lbs/a	30	14.609	41	4.643	27	4.673	$33.00
	OR-CAL 30.5 lbs/a	50	4.774	46	6.605	8	2.405	$38.00
	Durham 3.5 7 lbs/a	13	7.033	10	9.627	46	3.767	$10.50
	Durham 3.5 10 lbs/a	18	11.549	15	8.022	44	3.566	$15.00
6	Durham 3.5 15 lbs/a	22	4.945	26	5.125	28	2.405	$22.50
	Durham 3.5 20 lbs/a	28	9.100	28	5.547	26	3.795	$30.00
	Durham 3.5 25 lbs/a	30	7.925	44	10.452	15	9.592	$37.50
	Durham 3.5 30 lbs/a	33	7.603	46	4.986	10	6.965	$45.00
	Durham 7.5 7 lbs/a	32	8.029	7	8.682	42	2.527	$14.70
	Durham 7.5 10 lbs/a	33	8.726	17	8.503	41	4.234	$21.00
7	Durham 7.5 15 lbs/a	38	12.826	22	5.810	36	5.674	$31.50
	Durham 7.5 20 lbs/a	43	9.890	36	9.077	22	6.477	$42.00
	Durham 7.5 25 lbs/a	43	10.778	41	7.693	17	2.861	$52.50
	Durham 7.5 30 lbs/a	47	10.543	42	7.310	7	5.305	$63.00
	SlugFest AWF 1 pt/a	7	2.109	4	3.878	55	4.303	$5.63
	SlugFest AWF 2 pts/a	13	4.945	6	6.445	43	1.764	$11.25
8	SlugFest AWF 3 pts/a	32	10.140	22	7.108	30	1.834	$16.88
	SlugFest AWF 4 pts/a	37	12.826	30	5.556	22	7.957	$22.50
	SlugFest AWF 5 pts/a	47	16.059	43	6.110	6	2.667	$28.13
	SlugFest AWF 6 pts/a	53	13.084	55	6.727	4	1.283	$33.75
9	Durham 3.5 10 lbs/a + Sluggo shorts 9.25 lbs/a	45	9.918	23	9.308	23	2.376	$28.65
10	Durham 7.5 10 lbs/a + Sluggo shorts 9.25 lbs/a	43	6.668	23	10.923	23	8.161	$34.65
11	OR-CAL 7.5 lbs/a + Sluggo shorts 9.25 lbs/a	38	4.774	36	6.344	36	5.565	$23.03
12	Deadline MP 7.25 lbs/a + Sluggo shorts 9.25 lbs/a	45	5.628	54	8.110	54	6.652	$24.15
13	MetaRex 7.35 lbs/a + Sluggo shorts 9.25 lbs/a	35	5.628	6	8.257	6	4.121	$32.86
14	SlugFest AWF 3 pts/a + Sluggo shorts 9.25 lbs/a	33	13.827	20	14.900	20	3.049	$30.53
15	SlugFest AWF 3 pts/a + Phor-Ti-Phy 4 G/a + Sluggo shorts 9.25 lbs/a	33	10.543	36	12.147	36	6.191	$40.53

ON-FARM CONVERSION OF STRAW TO BIOENERGY – A VALUE ADDED SOLUTION TO GRASS SEED STRAW

G.W. Mueller-Warrant, G.M. Banowetz, G.R. Whittaker and H.M. El-Nashaar

Perhaps the most contentious aspect of intensive grass seed production systems has been the management of post-harvest residues. Conflicts over possible adverse effects of smoke from field burning on human health and economic impacts of regulating burning on the grass seed industry have raged in courtrooms, legislatures, elections, and the mass media for decades. Because use of burning to dispose of grass seed and cereal straw throughout the Pacific Northwest (PNW) is now either banned or restricted in most areas, agricultural producers have actively sought cost-effective alternatives to burning. In higher rainfall regimes such as Oregon's Willamette Valley, thorough chopping of the full straw load in the dry, late summer facilitates its decompostion in the wet fall and winter while remaining compatible with high yields of quality seed. Growers using this method view retention of nutrients and building of soil organic matter as adequate trade-offs for the nuisance of chopping straw and somewhat greater problems controlling pests, particularly slugs and weeds. Other growers bale their residues for domestic use and overseas export as livestock feed and fodder, often receiving little more than the cost of baling. In collaboration with partners including the electrical power industry, researchers at the National Forage Seed Production Research Center have built a pilot plant in Spokane, WA, for conversion of grass seed straw to syn-gas, which can then be converted into electricity to be fed back into the regional power grid. The nominal size of the plant is 1,100 tons of straw per year, comparable to straw produced on a medium-sized PNW grass seed or cereal farm. Testing of the syn-gas generator is focusing on the impact of operating conditions on the carbon monoxide and hydrogen content of the syn-gas, and on gaseous and solid impurities that could damage the diesel engine powering the electrical generator.

Analysis of the geospatial distribution of straw from grass seed and cereal crops across the Pacific Northwest (PNW) indicates that optimally sited bioenergy conversion plants of 1,100 tons per year capacity should be able to obtain needed straw from within a radius of a very few miles, opening up the possibility of using farm-scale equipment such as forage choppers, wagons, silage blowers, and bunkers to handle the straw from the field to the syn-gas generator. The economic advantages of not needing to bale and truck the straw long distances will at least partially offset efficiencies of scale likely present in large plants operating at 100 or more times the capacity of the farm-scale unit.

Knowledge of the geospatial distribution of straw from grass seed and cereal production in the PNW is vital to the accuracy and reliability of feasibility studies comparing scales of operation of proposed bioenergy conversion plants. Because existing data on straw availability were limited to county-wide summaries, our first step in identifying optimum locations for straw-based bioenergy conversion plants was to map the location of all grass seed and cereal production in the PNW using remote sensing methods. For satellite imagery necessary for remote sensing classification, we used MODIS 16-day composite NDVI, 820 ft by 820 ft pixels, covering the periods from April 23 through August 29 in 2005, 2006, and 2007. Crop areas and yields per acre within counties were obtained from yearly USDA-NASS summary statistics for winter, spring, and durum wheat, barley, and oats. Areas and yields per acre for grass seed crops were primarily obtained from OSU Extension Service estimates within Oregon and USDA-NASS summaries in Idaho and Washington. Ground-truth data for the remote sensing classifications of the various cereals were derived from USDA-NASS National Crop Land Data layers (NLCD) covering southern Idaho in 2005, Washington in 2006, and the entire PNW in 2007. Ground-truth data for grass seed crops were a mixture of our in-house, western Oregon GIS and the NLCD. Once maps of field locations had been created, we converted them into straw yield maps by use of county-wide average per acre yields and harvest indices (ratios of seed or grain to total above-ground biomass), and then subtracting crop-specific estimates of residue requirements to protect soils from erosion. Larger quantities of straw were "left behind in the field" for annual crops such as winter wheat or Italian ryegrass than for perennial grasses whose crowns and roots help protect the undisturbed soil from erosion.

Our estimates of total available cereal and grass seed straw in the PNW (after subtracting amounts needed for soil erosion protection) were 7.7, 6.9, and 6.2 million tons in 2005, 2006, and 2007. We then used the individual year estimates and multi-year averages of available straw in procedures that identified the optimal locations for each new bioenergy plant, based on local density of straw and location of all previously sited plants. Each new plant was sited at the position of the maximum straw density over a neighborhood adequate to supply all the straw needed for plants with capacities of 1,100, 11,000, and 110,000 tons per year. The straw assigned to each new plant was then removed from the raster and the location of the maximum density of remaining straw recalculated.

Approximately 6,200 farm-scale plants (1,100 tons per year capacity) distributed across landscape would be required to convert all the available straw in the PNW into bioenergy. Approximately 620 of the medium-sized plants (10 X larger capacity than the farm-scale ones) would be needed to process all the available straw (Figure 1). The bioenergy conversion plants in both figures are coded to denote the range from which straw would need to be gathered to meet plant capacity. The (dark blue) astericks show the locations of the first 20% of plants that would be built if minimizing distance from field to plant was the sole criteria in deciding where plants should be built. The first 11,000 ton per year plant built could obtain all its straw from within a distance of only 1.2 miles, and the 124th plant (20% of 620) would only need a range of 2.5 miles to meet its straw needs. Relative to the distance required to supply straw to the first 10% of plants, a range of twice that distance was sufficient for 70% of the smallest sized plants, and 60% of the medium- and largest-sized ones. The final 20% of straw shown as (red) circles requires substantially greater collection distances for all plant sizes, and the last 10% is extremely hard to justify ever going after. Locations of the (dark blue) astericks, (light blue) stars, and (green) crosses clearly show the regions across the PNW within which a straw-based bioenergy industry is most likely to initially develop. Maps of the 6,200 smallest-sized plants are not included in this document because they are extremely hard to read when printed at regular page size, but they tend to show a more egalitarian distribution of optimal locations across all production areas in the PNW. In contrast, the strongest regional differences in how far straw would have to be transported occurred for the largest-sized plants. Distribution of the 62 largest (110,000 tons per year) capacity plants (Figure 2) differs somewhat from that of the medium capacity plants (Figure 1), with the best 20% of sites (dark blue astericks) for the largest plants all occurring in the Willamette Valley, except for one in the eastern Snake River Valley of southern Idaho. The next best locations (light blue stars) occur over a broader set of regions, including the Palouse and the Columbia Basin in eastern Washington.

One obvious concern with the methods we used to identify optimal plant locations is that they are based on a single estimate of production of cereals and grass seed crops. Because the specific crops grown within individual fields often change from year to year, a logical question is what impact this yearly variation has on the efficiency of plant siting. In other words, if plant locations are optimized for crop (and straw) distribution patterns of one year (e.g., 2005), how well do those locations function as centralized collection points for another year (e.g., 2006)? Since the bioenergy conversion plants are unlikely to be mobile, a relatively simple way to evaluate the impact of yearly variation in cropping patterns was to measure how much straw was available around plants whose locations and collection distances were optimized for one year when a second year's straw distribution was assumed. Practical limitations in programming methods used to optimize plant locations caused some variability to exist in amount of straw present within the defined ranges around each plant even when the same year was used to define locations (and ranges) and measure straw availability. Using the coefficient of variability (CV) of the straw availability at each plant for the "same year" analysis as the standard, a ratio of the CVs can be calculated showing how much less stable the straw supply would be in some other year compared to the one used to locate the plants. The worst combination we found was when medium-sized plants were located based on 2007 straw distribution and tested using 2005 straw distribution, with a CV ratio of 11.6 X (Table 2). The smallest CV ratios occurred when the 3-year average straw distribution was used to define plant locations, with ratios for 2005, 2006, and 2007 ranging from 1.7 to 2.2 X for the smallest plants, 2.6 to 3.9 X for the medium sized plants, and 1.5 to 2.2 X for the largest plants. The individuals CVs generally followed a pattern of slowly decreasing with increasing plant size, with mean CVs for all combinations of years-defining and year-testing straw availability averaging 50.0, 32.3, and 27.1% for the smallest-, medium-, and largest-sized plants.

In a "young" straw as bioenergy industry, yearly variation in cropping practices and straw yields around individual plants will merely generate small changes in the distance that will have to be included to supply sufficient straw to support the plant. In a "mature" bioenergy industry, the yearly variations will likely also impact how close to full capacity the plants can operate and the prices paid for straw. The largest scale straw to bioenergy plants currently under development in the Willamette Valley are designed to utilize 160,000 tons per year. A plant that large would only need 2.3% of the total available straw in the PNW. As a consequence, there is ample opportunity for market forces to determine how much straw will continue to be exported as livestock feed, how much will be converted into electricity and other energy products, and what mix of small-scale, on-farm and large-scale, industrial park bioenergy projects will operate to convert the straw into bioenergy.

Table 1. Average distances required to provide sufficient straw to supply 1100, 11000, and 110000 tons per year nominal capacity straw conversion plants by state for each 10 percentile increment in total straw assigned using 3-year average density of available straw to define optimal plant sites.

	Incremental Percentiles of Total Available Straw Assigned to Optimal Plant Site Locations									
State	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
	Average Range Required for Adequate Straw to Meet Plant Capacity (miles)									
1,100 tons per year capacity										
Idaho	0.7	0.9	1.1	1.1	1.2	1.3	1.4	1.8	3.0	19.4
Oregon	0.6	0.7	0.9	0.9	1.1	1.2	1.3	1.5	2.1	11.9
Washington	0.9	1.1	1.1	1.2	1.3	1.5	1.7	2.5	3.7	10.3
entire PNW	0.7	0.9	1.0	1.1	1.2	1.3	1.5	1.9	2.9	14.3
11,000 tons per year capacity										
Idaho	2.3	2.7	3.0	3.4	3.8	4.3	5.1	7.1	10.9	55.2
Oregon	1.4	1.7	1.9	2.2	2.5	3.0	3.6	4.6	6.9	24.6
Washington	2.9	3.2	3.4	3.7	4.3	5.1	6.2	7.6	11.2	41.3
entire PNW	2.2	2.5	2.7	3.0	3.4	4.1	4.8	6.3	9.6	40.3
110,000 tons per year capacity										
Idaho	8.7	10.2	10.9	11.2	15.7	17.1	18.0	28.8	61.0	171.8
Oregon	4.9	5.7	6.6	7.3	8.2	9.2	13.5	17.6	29.2	115.8
Washington	9.2	10.1	12.2	13.0	15.3	16.4	20.0	24.5	27.8	184.1
entire PNW	7.3	8.9	9.4	10.1	13.1	14.7	16.2	24.4	42.4	151.3

Table 2. Straw availability at plant site locations optimized for straw source year and nominal plant capacity and evaluated against 2005, 2006, 2007, and 3-year average straw density rasters.

Data source used to define plant site location series: Year	Data source used to define plant site location series: Nominal plant capacity	Data source used in measuring straw availability	Straw availability at defined plant site locations: Mean	Standard deviation	CV	Ratio of standard deviation to that for site location data source
	(ton y^{-1})	(Raster year)	(1000 ton y^{-1})		(%)	
2005†	1,100	2005†	1.25	0.32	26.13	1.00
2005	1,100	2006	1.11	0.85	76.94	2.63
2006	1,100	2005	1.39	0.96	69.33	3.04
2006†	1,100	2006†	1.25	0.32	25.51	1.00
2007	1,100	2005	1.52	1.76	115.87	5.65
2007	1,100	2006	1.36	1.29	94.55	4.12
2007†	1,100	2007†	1.22	0.31	25.53	1.00
2007	1,100	3-y avg.†	1.37	0.97	71.12	3.12
3-y avg.	1,100	2005	1.33	0.60	44.66	2.09
3-y avg.	1,100	2006	1.19	0.49	40.61	1.70
3-y avg.	1,100	2007	1.07	0.64	59.67	2.24
3-y avg.†	1,100	3-y avg.†	1.20	0.29	23.77	1.00
Mean	1,100		1.28	0.65	50.00	2.11
2005†	11,000	2005†	11.92	2.91	24.41	1.00
2005	11,000	2006	10.58	4.91	46.34	1.69
2006	11,000	2005	12.09	5.05	41.80	2.71
2006†	11,000	2006†	10.82	1.86	17.22	1.00
2007	11,000	2005	12.95	9.95	76.85	11.61
2007	11,000	2006	11.59	7.02	60.56	8.19
2007†	11,000	2007†	10.42	0.86	8.23	1.00
2007	11,000	3-y avg.	11.65	5.47	46.97	6.39
3-y avg.	11,000	2005	11.68	3.51	29.97	3.64
3-y avg.	11,000	2006	10.46	2.54	24.20	2.63
3-y avg.	11,000	2007	9.39	3.79	40.33	3.94
3-y avg.†	11,000	3-y avg.†	10.52	0.96	9.14	1.00
Mean	11,000		11.12	3.67	32.31	3.04
2005†	110,000	2005†	129.79	33.65	25.93	1.00
2005	110,000	2006	115.33	37.50	32.51	1.11
2006	110,000	2005	139.63	53.24	38.13	1.53
2006†	110,000	2006†	124.88	34.89	27.94	1.00
2007	110,000	2005	135.47	61.57	45.45	5.78
2007	110,000	2006	121.21	40.50	33.41	3.80
2007†	110,000	2007†	108.92	10.65	9.78	1.00
2007	110,000	3-y avg.	121.86	34.20	28.07	3.21
3-y avg.	110,000	2005	120.05	25.56	21.30	2.23
3-y avg.	110,000	2006	107.57	17.65	16.41	1.54
3-y avg.	110,000	2007	96.62	24.80	25.67	2.17
3-y avg.†	110,000	3-y avg.†	108.07	11.44	10.59	1.00
Mean	110,000		121.62	33.60	27.08	1.81

†Same data source used in defining plant site location series and measuring straw availability.

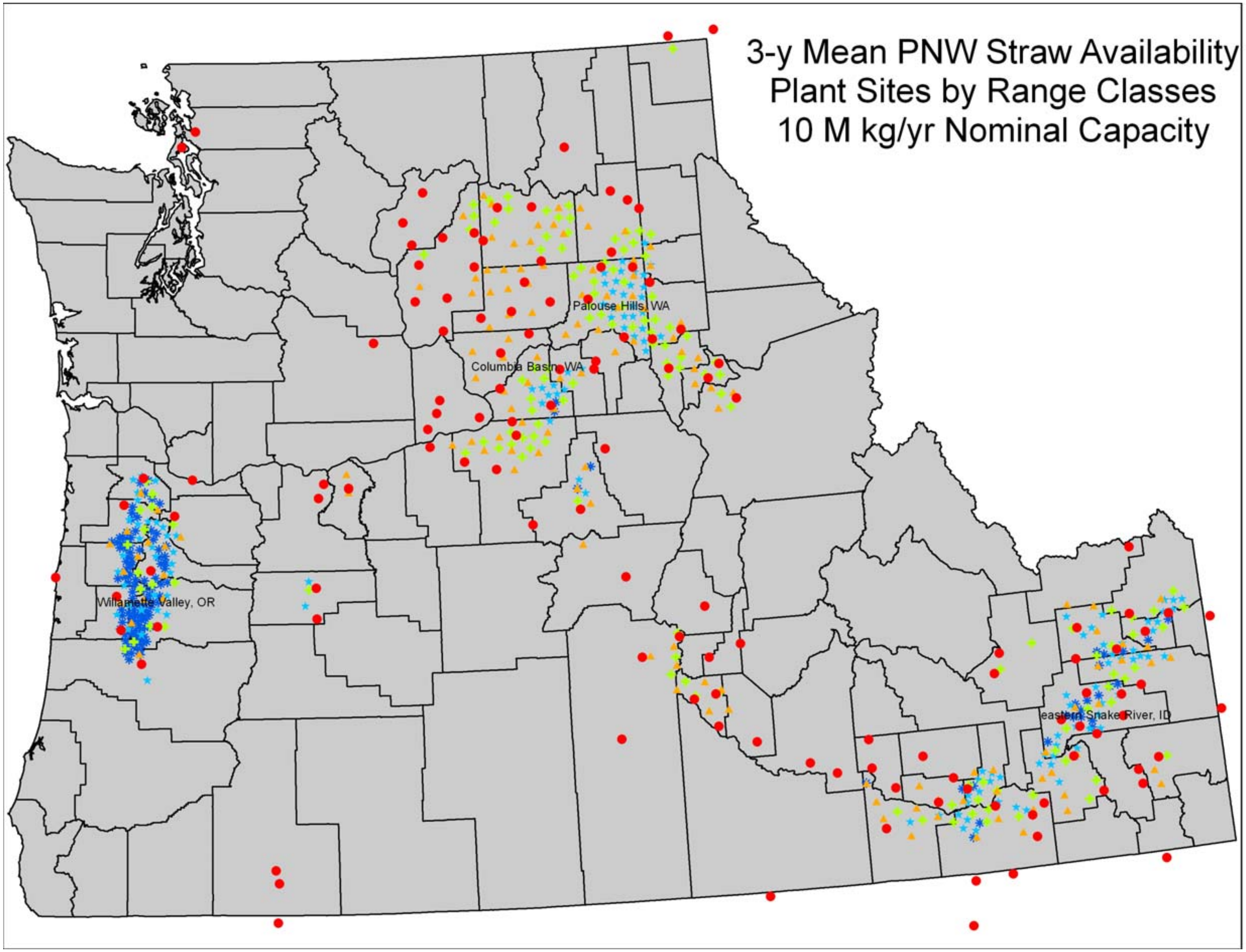


Figure 1. Optimized locations for 11,000 ton y^{-1} capacity bioenergy plants based on 3-yr average straw availability. Symbols indicate quantiles of range required to supply straw, with dark blue astericks, light blue stars, green crosses, orange triangles, and red circles donating 1.2 to 2.5, 2.5 to 3.7, 3.7 to 4.3, 4.3 to 7.5, and 7.5 to 373 miles. County boundaries are outlined.

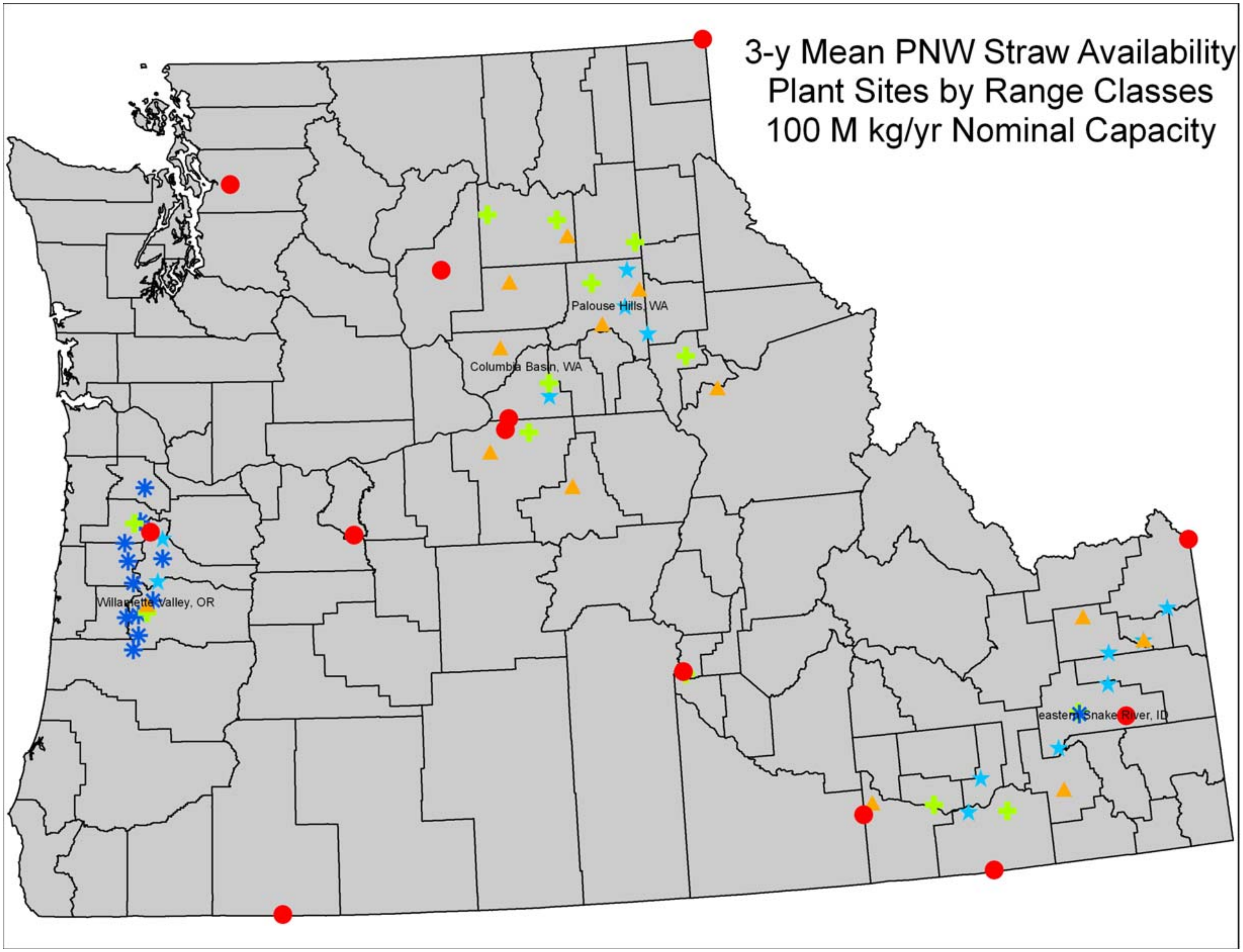


Figure 2. Optimized locations for 110,000 ton y^{-1} capacity bioenergy plants based on 3-yr average straw availability. Symbols indicate quantiles of range required to supply straw, with dark blue astericks, light blue stars, green crosses, orange triangles, and red circles donating 5 to 9, 9 to 12, 12 to 17, 17 to 29, and 29 to 303 miles. County boundaries are outlined.

SOIL CARBON BUDGET FOR ANNUAL AND PERENNIAL RYEGRASS GROWN FOR SEED

S.M. Griffith, J.H. Davis and G.M. Banowetz

Summary

There is much interest in carbon (C) sequestration (C accounting) in cropping systems due to the potential for agriculture to participate in 'Cap and Trade' opportunities, or purely as a matter of understanding soil quality. Here we have constructed C budgets for two temperate grass species, perennial ryegrass (*Lolium perenne* L.) (Table 1) and annual ryegrass (*L. multiflorum* Lam.) (Table 2). Data were collected from western Oregon grown seed crops. Both data sets are comparable to what was previously reported for a 12-yr-old pasture (mixture of annual and perennial grasses) in western Oregon near Corvallis, OR (Sharrow and Ismail, 2004) of 40,980 kg C ha^{-1} (0-15cm soil depth). We hypothesize that most temperate grass systems grown in western Oregon that are not limited by water or nutrients will have similar C budgets. It has been shown that sometimes soil C in grass seed cropping systems, over the long term, can be affected by crop rotation and residue management (Griffith et al., 2010). Usually, however, that is not the norm. Regardless, soils of grass seed production systems in western Oregon have high organic C levels (Table 3), greater than those frequently observed in conventional cropping systems that involve annual soil disturbance for crop establishment. Future reports will construct more precise C budgets with more subcomponents (e.g., longer vs. shorter term sequestered C), but these data establish a baseline that will be useful for evaluating C cycling in grass seed production systems.

References

Griffith, S.M., J.H. Davis, R.P. Dick, G.M. Banowetz, and J.J. Steiner. Crop rotation and straw residue effects on soil carbon in three grass seed cropping systems of western Oregon. *In* Young III, W.C. (ed.) 2009 Seed Production Research at Oregon State University, USDA-ARS Cooperating. Dep. Crop and Soil Science Ext/CrS 129, April. Corvallis, OR. 2010. (Technical Bulletin)

Sharrow, S.H. and S. Ismail. 2004. Carbon and nitrogen storage in agroforests, tree plantations, and pastures in western Oregon, USA. Agroforestry Systems 60:123-130.

Table 1. Preliminary carbon data: Perennial ryegrass, 3-year rotations, on-farm study for the 2004-2005 crop year.

Component	Total carbon	
	Conventional tillage (first seed year)	No-tillage (second seed year)
	--------------- (kg C ha^{-1})------------	
Crop shoot/seed	8,954 ± 1,527	7,551 ± 1,264
Crop root	211 ± 21	833 ± 94
*Crop residue	5,820	4,908
Soil (0-15 cm depth)	22,385 ± 464	30,960 ± 603
Total	28,416	36,701

*Assumed to be 65% of total crop biomass.

Table 2. Preliminary carbon data: Long-term annual ryegrass trials at Hyslop for the 2006-2007 crop year.

Component	Total carbon	
	Continuous conventional tillage	Continuous no-tillage
	--------------- (kg C ha^{-1})------------	
Crop shoot/seed	4,010 ± 1340	7,990 ± 717
Crop root	635 ± 320	965 ± 221
Crop residue	2,610 ± 410	2,870 ± 145
Soil (0-15 cm depth)	29,800 ± 951	31,400 ± 1040
Total	33,000	35,300

Table 3. Percent soil organic matter: Perennial ryegrass, 3-year rotations, on-farm study.

Soil depth	Percent soil organic matter			
	Conventional tillage		No-tillage	
	First seed year	Second seed year	Second seed year	Third seed year
0 to 15 cm	4.43 ± 0.05	5.69 ± 0.06	5.06 ± 0.04	5.33 ± 0.07

CROP ROTATION AND STRAW RESIDUE EFFECTS ON SOIL CARBON IN THREE GRASS SEED CROPPING SYSTEMS OF WESTERN OREGON

S.M. Griffith, J.H. Davis, R.P. Dick, G.M. Banowetz and J.J. Steiner

Introduction

As grass seed crop field burning in western Oregon was phased-out, alternative non-thermal practices such as post harvest straw removal or incorporation of the residue into the soil, and crop rotations were being developed. At the time, there was little information available on the practicality and impacts of non-thermal grass seed cropping systems on soil quality. Consequently, in 1992, the multidisciplinary non-thermal cropping systems project was initiated by USDA-ARS (Corvallis, OR) and cooperating scientists from Oregon State University at three diverse locations in the Willamette Valley, Oregon (see Nelson et al., 2006; Steiner et al., 2006; 2007a; 2007b). These experimental plots provided an excellent platform to evaluate soil quality indexes to help identify early indicators of change in soil management.

The overall objectives of this study concerning soil quality were to (1) determine the effects of crop rotation and straw residue management on soil biological, chemical, and physical properties; (2) evaluate biological indexes as temporally sensitive indicators of soil quality; and (3) relate changes in soil properties to yield of temperate grass seed crops. This report will only discuss the portion of the research addressing soil carbon (C). Detailed findings of the entire study will be forth coming in a future publication.

Methods

Research was conducted from 1992 to 1998 at three Willamette Valley, Oregon locations that represented contrasting physical environments differing in soil drainage classifications, suitable for perennial grass seed production in the Pacific Northwest temperate marine ecoregion (i.e., western Oregon). At each site we compared crop rotations for each particular grass species (Table 1). The design was a split plot (four replications) with rotation as the main plot (18 m x 34 m) and residue as the subplot (9 m x 17 m) prepared in autumn 1991. The crop rotations were continuous grass seed production (G), grass/legume (GL), and grass/legume/cereal (GLC). Residue treatments consisted of post-harvest grass straw removed (raking and baling) versus residue remaining (flail chopped and returned to the field). All treatments were investigated without burning the grass straw after seed harvest. All plots were fertilized each spring with 134 kg N ha^{-1}, with urea 46-0-0-0. Site crop management was fully described in detail by Steiner et al. (2006).

Table 1. Three temperate grass species grown for seed using common crop rotation sequences found in western Oregon's Willamette Valley. Rotation sequences lasted six years (1992 to 1998). As indicated, conventional (CT) or no tillage (NT) crop establishment was used.

Perennial ryegrass - Linn County

Grass (G_P): perennial ryegrass; CT

Grass/Legume (GL_P): white clover/meadowfoam/perennial ryegrass; CT

Grass/Legume/Cereal (GLC_P): white clover/perennial ryegrass/wheat/meadowfoam; CT

Tall fescue - Benton County

Grass (G_T): tall fescue; CT

Grass/Legume (GL_T): wheat/red clover/meadowfoam/tall fescue; CT

Grass/Legume/Cereal (GLC_T): tall fescue/wheat/red clover/meadowfoam; CT

Creeping red fescue - Marion County

Grass (G_F): fine fescue; NT

Grass/Legume (GL_F): fine fescue/fine fescue/ red clover; CT

Grass/Legume/Cereal (GLC_F): fine fescue/wheat/red clover/fine fescue; CT

Grass stands of representative species were already being produced at each location before the start of the experiment. One grass species suited to each of the three growing conditions was used: (i) perennial ryegrass (*Lolium perenne* L.) var. Riviera on a poor drained Amity silt loam (fine-silty, mixed, mesic Argiaquic Xeric Argialbolls) in Linn County (44° 28′ 56" N, 123° 11′ 01" W; 76 m elevation), herein referred to as the Linn site; (ii) tall fescue (*Schedonorus phoenix* (Scop.) Holub var. Titan on a poor to moderate drained Woodburn silt loam (fine-silty, mixed, mesic Aquulitic Argixerolls) grown in Benton County (44° 38′ 01" N, 123° 12′ 01" W; 70 m elevation), herein referred to as the Benton site with slow permeability and a seasonally high water table; and (iii) creeping red fescue (*Festuca rubra* L.) var. Jasper on a Nekia silty clay loam 2 to 12 percent slopes of well drained soils (Clayey, mixed, mesic Xeric Haplohumults) in Marion County (44° 56′ 24" N, 123° 45′ 19" W; 236 m elevation), herein referred to as the Marion site.

All continuous perennial grass crops grown for seed were in place for three seed-years and then reestablished into grass. Rotational crops included the following, but their use was dependent upon the soil conditions at each location: white clover (*Trifolium repens* L.) var. S1 Louisiana, red clover (*Trifolium pratense* L.) var. Marathon, wheat (*Triticum aestivum* L.), and meadowfoam (*Limnanthes alba* Hartw. & Benth.) var. Floral). Clover was grown for two seed years, wheat and meadowfoam for one seed-year. These grass seed crop treatment combinations were used as examples and not meant to represent all production options available to farmers in western Oregon. At all locations, conventional tillage (CT) was used for crop establishment, except at the Marion site. At the Marion site, the continuous grass rotation (G) was established using no tillage (NT) the first seed-year and left undisturbed for a total of three seed-years and then NT established again to complete the six-year rotation. No tillage was conducted into the undisturbed soil of a previous grass seed crop of at least three years of age and CT utilized one disc plowing at 20 cm depth.

The Marion soil was representative of soils in the north Willamette Valley foothills compared to the Benton and Linn sites that represented some of the southern valley soils. At the Marion site, soil water permeability was moderately slow. All soils were non-calcareous and low pH. At the Benton site soil water permeability was moderate in the upper part of the subsoil and slow in the lower part. At the Linn site, soil water permeability was slow and some overland flow was not uncommon. These soils were chosen for the study for their extensive presence in the area and contrasting physical and chemical characteristics that are thought to influence soil C cycling.

Results

Total carbon. At the Linn site, there were no significant ($P \leq 0.05$) differences in soil total C among rotation and residue treatments at the 0-10 and 10-20 cm depths by 1998, six years from the start of the cropping sequences. Across all treatments, the mean soil total C concentration at 0-10 cm depth was 19.3 $\pm$ 1.5 g kg^{-1} in 1998, a significant ($P \leq 0.05$) decline of 18% from initial 1992 mean of 23.3 $\pm$ 0.5 g kg^{-1}. At the 10-20 cm soil depth, the 1998 soil total C concentration was 13.1 $\pm$ 0.6 g kg^{-1}, a significant ($P \leq 0.05$) decline of 35% from the initial 1992 mean of 20.2 $\pm$ 0.7 g kg^{-1}. Soil total C concentration was 28% greater at the 0-10 cm depth compared to the lower 10-20 cm depth.

At the Benton site in 1998, the G_T rotation treatment had significantly ($P \leq 0.05$) greater total C, 15.9 $\pm$ 0.9 g kg^{-1}, compared to GLC_T, 14.2 $\pm$ 0.4 g kg^{-1} and GL_T at 13.2 $\pm$ 0.1 g kg^{-1}. High straw residue significantly increased G_T total C by 10.7% from the G_T low straw treatment. There was no significant difference in total C between GLC_T and GL_T rotation and residue treatments at the 0-10 or 10-20 cm depths or G_T at the 10-20 cm depth. The soil total C mean at the 10-20 cm depth was 11.5 $\pm$ 0.4 g kg^{-1}. The total C concentration at 0-10 cm depth in 1992 was 14.9 $\pm$ 0.3 g kg^{-1} and at 10-20 cm was 14.5 $\pm$ 0.3 g kg^{-1}; these concentrations were not significantly ($P \leq 0.05$) different. From 1992 to 1998, total C concentration stayed at the same level for G_T and GLC_T rotations but significantly declined by 1998 in the GL_T residue treatment by 12.1% (13.1 + 0.14 g kg^{-1}) at the 0-10 cm depth.

At the Marion site, total C at a depth of 20 cm was not significantly ($P \leq 0.05$) affected by rotation or residue treatments, nor did total C significantly ($P \leq 0.05$) change from 1992 to 1998. However in 1998, the mean total C at 0-10 cm, 32.4 $\pm$ 0.5 g kg^{-1}, was significantly higher than the mean total C at the 10-20 cm depth, 24.3 $\pm$ 0.5 g kg^{-1}.

Location effect on total soil C was also examined. Total soil C at the 0-10 cm depth was significantly ($P \leq 0.05$) different at each location across all rotation and residue treatments. Total C means for Linn, Benton, and Marion sites were 19.3 $\pm$ 0.27, 14.0 $\pm$ 0.11, and 32.4 $\pm$ 0.73 g kg^{-1}, respectively. At the 10-20 cm depth, total C at the Marion site (24.3 $\pm$ 0.68 g kg^{-1}) was significantly ($P \leq 0.05$) different from Benton (11.6 $\pm$ 0.19 g kg^{-1}) and Linn sites (13.1 $\pm$ 0.28 g kg^{-1}). Total C at the Linn and Benton sites were not significantly different from one another at the 10-20 cm depth.

Soil organic matter (SOM). For the Benton site in 1998, the G_T rotation with high straw residue treatments had significantly higher SOM at 0-10 cm depth, but not at 10-20 cm depth, compared to the other Benton treatments. At Linn, G_T high straw treatment increased SOM over straw removed but there was no rotation effect on SOM. At the Linn site after a six-years (1992-1998), SOM at the 0-10 cm depth significantly ($P \leq 0.05$) declined from the by 10% in plots of G_P-low straw, GLC_p-low straw, GL_P high and low straw treatments. All other treatments remained unchanged from the 1992 mean of 4.65%. At the 10-20 cm depth SOM remained unchanged from the mean 1992 value of 3.81%. At Benton, SOM at the 0-10 cm depth declined 9% from the 1992 mean of 3.37% in the low straw treatments of GLC_T and GL_T receiving low straw since 1992. All other treatments remained the same. In 1998, the Benton SOM at the 10-20 cm depth in did not change since 1992.

At the Marion site, the percent SOM at a depth of 20 cm was not significantly ($P \leq 0.05$) affected by rotation or residue treatments, nor did SOM significantly ($P \leq 0.05$) change from 1992 to 1998. The Marion 1992 mean SOM at 0-10 cm and 10-20 cm was 8.10% and 5.38%, respectively.

Across all rotation and residue treatments, a location effect for SOM was evident at the Marion site. Marion site SOM at the 0-10 cm depth was 7.22 $\pm$ 0.13%, significantly different from the both the Benton and Linn sites, 3.24 $\pm$ 0.07 and 3.87$\pm$ 0.06%, respectively. At the deeper 10-20 cm depth, the Marion site SOM (5.32 + 0.14%) was also significantly higher than Benton (2.92 + 0.06%) and Linn (2.7 + 0.07%) sites. Benton and Linn sites were not significantly different from each other at the 0-10 or 10-20 cm depths.

Microbial biomass carbon (MBC). At the Linn site, MBC at the 0-10 and 10-20 cm depths was significantly ($P \leq 0.05$) affected by rotation but not residue treatment. At the 0-10 cm depth, the rotation treatment GLC_P, with high straw load, had 51% greater soil MBC, than G_P and GL_P. Microbial biomass C for rotation and residue treatments G_P and GL_P were not significantly different from each other. At the 10-20 cm depth, G_P low and high straw treatments had 45% higher MBC than GL_P and GLC_P; neither GL_P nor GLC_P were significantly different from each other. In 1998, MBC for the G_P and GL_P low and high residue treatments at the 0-10 cm depth were significantly ($P \leq 0.05$) lower from the initial MBC measurement in 1994 of 433 μg C g^{-1}, but unchanged from the GLC_P low and high straw treatments. Linn soil MBC in 1994 was 177 μg C g^{-1} at the 10-20 cm depth and not significantly different from the 1998 G_P low and high straw treatments but 998 GL_P and GLC_P rotation and residue treatments were 39% lower.

At the Benton site, the G_T rotation had 74% greater soil MBC at the 0-10 cm depth than the GL_T and GLC_T, and for all rotation treatments, high straw treatment maintained higher MBC than low straw. The GL_T and GLC_T rotations were not significantly different from one another at the 0-10 cm depth and G_T, GL_T, and GLC_T rotation and residue treatments were not significantly different at 10-20 cm depth. At the 10-20 cm depth, MBC averaged 74.6 μg C g^{-1}. The initial MBC mean in 1994 at Benton was 275 μg C g^{-1} at the 0-10 cm and not significantly different from 1998 means of similar depth. At the 10-20 cm depth, the 1994 MBC mean was 98 μg C g^{-1} and 35% higher than GL_T high straw treatment but not different from all other 1998 rotation and residue treatments.

At the Marion site in 1998, G_F rotation treatment soil MBC was 27% greater than GL_F and GLC_F treatments at the 0-10 cm soil depth but no residue effect. At the 10-20 cm depth, there was no rotation or residue effect. The 0-10 cm depth MBC mean in 1992 was 305 μg C g^{-1} but by 1998, G_F high residue treatment had 1.58-fold higher MBC, while all other 1998 treatments remained unchanged. At 10-20 cm depth, there was no significant change in MBC concentration as a function of rotation or residue treatment in 1998 and no change in MBC from 1994, 124 $\pm$ 14 μg C g^{-1}, to 1998, 133 μg C g^{-1}.

Dissolved organic carbon (DOC). There was no rotation or residue treatment effect on soil DOC from 1992 to 1998 at the Linn site. The combined mean of all treatments for DOC was 123 $\pm$ 6.0 mg C kg^{-1}. Rotation had a significant effect on soil DOC at the Benton site. The G_T rotation with high straw load significantly increased soil DOC over all other treatments. The G_T rotation and high residue treatment DOC mean was 90.3 $\pm$ 0.84 mg C kg^{-1}, while the other combined treatment mean was 62.6 $\pm$ 1.84 mg C kg^{-1}. At the Marion site, G_F plus high residue also had significantly higher soil DOC, 72.3 $\pm$ 0.30 mg C kg^{-1} then other treatments, 58.6 $\pm$ 2.7 mg C kg^{-1}.

Conclusions

- Crop rotation with different crop species or straw residue removal had little effect on total soil C in the grass seed production systems used in this study.
- Often, soil organic matter (SOM) was greater in continuous grass systems, especially where residue was chopped and unincorporated.
- SOM often increased in the upper soil layer after straw was chopped and returned to the field.
- In all cases, the greatest concentration of soil C was in the top 10 cm of soil.
- Higher soil C appeared to be linked to higher microbial biomass (MBC), and in most cases appeared to be linked to straw returned to the field.
- Soil at the Marion site had higher MBC than the other sites.
- Greater amounts of soil dissolved organic carbon (DOC) was associated with residue remaining treatments and may be related to residue decomposition processes.
- Relative to many other conventional crop systems, perennial grass seed crops in western Oregon maintain high soil C levels sequestered in organic matter and other soil fractions.
- There is some indication that tillage in well-drained soils may have little long-term effects on SOM and total soil C in perennial grass seed cropping systems.

References

Nelson, M.A., S.M. Griffith, and J.J. Steiner. 2006. Tillage effects on N dynamics and grass seed crop production in western Oregon (U.S.A.). Soil Sci. Soc. Am. J. 70:825-831.

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

Steiner, J.J., G.W. Mueller-Warrant, S.M. Griffith, G.M. Banowetz, and G.W. Whittaker. 2007a. Conservation practices in western Oregon perennial grass seed systems. II: Meadowfoam rotation crop management. Agron. J. 98:1501-1509.

Steiner, J.J., W.E. Gavin, G.W. Mueller-Warrant, S.M. Griffith, G.W. Whittaker, and G.M. Banowetz. 2007b. Conservation practices in western Oregon perennial grass seed systems. III: Impacts on gray-tailed vole activity. Agron. J. 99:537-542.

SUSTAINABILITY IN SEED PRODUCTION ENTERPRISES – WHAT WE'VE LEARNED

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

Introduction
Approximately 25% of the land in the Willamette Valley is devoted to grass seed production and associated rotation crops. In many cases, farms that produce this seed represent Century Farms that have been operated by the same family for 100+ years. The long-term presence of these and other families in the seed production business has required management decisions that ensured economic sustainability and long-term soil quality. In addition to the need to produce profitable crops in a sustainable manner, producers are also faced with societal expectations and state and federal legislations regarding air and water quality.

During the past 18 years, we have conducted long-term studies under contrasting production conditions in the Willamette Valley to quantify the impact of different production practices on economic seed yield, soil quality, and the quality of surface and ground waters adjacent to seed production enterprises. Our more recent research has also quantified earthworm populations present under contrasting production systems because there is evidence that their presence is one indicator (and facilitator) of long-term soil health.

The intent of this report is to summarize what these studies, and the cooperating growers, have taught us. In some cases, this work has uncovered gaps in our knowledge that point to additional studies that are needed to understand how these unique perennial grass seed production systems function and respond to various production practices in western Oregon's unique marine climate.

Soil carbon
There is considerable interest in quantifying the amount of carbon sequestered in the perennial grass seed production systems commonly used in the Pacific Northwest. There may be potential for seed producers to participate in "cap and trade" opportunities, and many producers have interest in the long-term impact of their management approaches on soil carbon as an indicator of soil quality. We know that soil carbon levels can be influenced by tillage and residue management, but these perennial production systems under Willamette Valley climate conditions tend to have more stable soil carbon levels that recover from tillage relatively rapidly. We speculate that this recovery may be due in large part to climatic conditions that favor rapid microbial growth, including that of soil fungi, for much of the year. We believe this because our studies of soil invertebrates showed that the majority of the species found in these production systems were fungivores. Presumably, the nature of the species found is representative of the food sources available to support those populations. Our estimates of soil carbon show approximately 12 to 16 tons of carbon are sequestered per acre each year at a 0 to 6 inch soil depth. We need to conduct further studies to determine how stable this carbon is in Willamette Valley soils (i.e., how long the carbon remains sequestered).

Residue management
We completed a 10-year experiment in western Oregon at three contrasting locations that demonstrated perennial grass seed crops can be economically produced without burning by using minimum tillage in combination with chopping back straw onto fields after harvest. Compared to conventional tillage establishment with straw removed by baling, these conservation practices reduced soil erosion 40 to 77%, shallow ground water nitrate 6-fold, establishment costs $27-162 per acre, and in some cases, increases seed yields.

Surface water quality
The 407 square-mile Calapooia River watershed originates in the Cascade Mountains in Willamette National Forest and drains through mixed-use and agricultural lands into the Willamette River at Albany, OR. Aquatic wildlife habitat is a primary concern of the watershed because of cutthroat trout, steelhead, salmon, and other native fishes and amphibians that use the river. In addition, there are listed concerns for water temperature and bacteria under the Clean Water Act. Since seed production is a major activity within the watershed, this area provides an ideal model system for quantifying the impact of management practices on natural resource quality. Our long-term evaluation of surface water quality in the Calapooia watersheds has been conducted with the assistance of Oregon State University Dept. of Fisheries and Wildlife (F&W), a partnership that enabled us to extend our analyses from the field into the aquatic habitats that provide ecosystem services to the watershed. While we quantified concentrations of nutrients and sediment in streams that drained a variety of land uses in the watershed, our F&W partners actually conducted stream surveys of aquatic organisms, an expertise that was lacking among most of our agricultural science collaborators. Our F&W partners showed that native fish use seasonal streams near grass seed fields during the winter. More than 95% of the aquatic wildlife using seasonal agricultural drainages are native and different assemblages were characteristic of different sub-watersheds.

Our own measurements showed that nutrient and sediment concentrations in these drainages were generally less than those reported to adversely affect fish health, and some fish species even used these drainages to reproduce. Also, trees naturally growing in fields along drainages where shown to provide habitat for winter songbirds. University of Massachusetts and ARS scientists showed seventeen-times more birds were found along forested than non-forested drainages, but only 15% of the total land cover was needed to be in trees to maximize songbird diversity. This research shows that in addition to providing farmers income from their crops, the seasonal drainages and vegetation near their fields are providing valuable habitat supporting native fish and bird populations in a landscape that is significantly impacted by cities and towns. Because aquatic wildlife protected under Endangered Species Act can be sensitive to high concentrations of sediment and nutrients found in field runoff, these findings will support landowner applications for conservation program payments under the USDA Farm Bill and help demonstrate compliance with provisions of the Clean Water Act. These studies led to some very targeted research in the Santiam Canal in 2005 when it was suspected that agricultural practices were impacting Albany drinking water quality. The results of our targeted research in the watershed showed that agriculture was not a contributing factor to the issue at hand.

Ground and surface water quality

We demonstrated that in southern Willamette Valley grass seed production landscapes, stream water nitrate, ammonium, sediment, and the herbicide diuron concentrations throughout the year were below those reported to affect the survival, growth, and malformation of frogs that live in Willamette Valley riparian zones. Atypical elevation of shallow groundwater nitrate can occur after plowing or when the field is left fallow. Following these events, short-term shallow ground water nitrate concentrations can exceed 50 ppm during the wet winter months. This is minimized during the first seed-year if a fall crop is planted and growing through the winter. For the most part, grass seed cropping systems, unlike conventional cropping systems are usually left undisturbed for years. Typical in these landscapes and associated valley climatic conditions, local high precipitation causes rapid dilution of shallow ground and surface water chemistries. We see no major area of concern based on data collected thus far.

Riparian area function

During the course of these long-term studies, we conducted two specific projects that focused on how riparian zones adjacent to grass seed production fields functioned in processing nitrogen. The study sites included one at Lake Creek in Linn County and one on the Calapooia River mainstream in Benton County. At both sites we found that water moved from the cropping system to the riparian zones through the slow movement of groundwater and also through the rapid drainage of surface water (i.e., overland flow). These studies showed that there are complex hydrological factors that impact how water moves through these systems, but that both the seed crop and the riparian vegetation were capable of processing nitrogen that was present in shallow groundwater. Typical groundwater nitrate levels measured during this study were in the range of 0.6-1.8 ppm NO_3^--N, well within the standards generally applied to drinking water.

Future Studies

During the 18 years covered by this study, a number of factors have impacted agricultural production practices used in the Willamette Valley. When we began this study, the seed industry was still in the process of developing new approaches to produce seed crops, largely without the use of open field burning. Recent legislation has reduced the availability of burning even more. Increased labor and fuel prices that growers are faced with today have driven some to adopt production practices that reduce fuel use by field operations including the use of minimum or shallower tillage. Recent market conditions have also prompted interest in alternative crops. As the industry continues to adapt to changing policy and market conditions, there will be a need for new understanding of how production practices impact the productivity of soils in the unique environment of the Willamette Valley. These studies are needed to better understand how these poorly drained soils can be utilized by a diversity of crops that might fit into regional or national niche markets, especially if the demand for grass seed significantly declines with time.

Improvement of minimum tillage/direct seed establishment approaches

Our findings showed that direct seeding could be used successfully in combination with chopped back straw resulting in higher economic seed yields for two-of-three perennial grass seed crops (perennial ryegrass and tall fescue, but not fine fescue). In some cases, however, particularly with small-seeded crops and during years with high numbers of slugs, stand establishment by direct seeding invites more intensive pest management. Future research is needed to extend the advantages of direct seeding to more growers under more challenging field conditions.

Potential for participation in carbon markets based on sequestration in perennial systems

There has been much speculation about the value of grass seed crops competing in the volatile carbon markets of present. Certainly, grass seed crops rank high with regard to sequestering atmospheric carbon. Grass seed crop soils are generally rich in carbon organic matter. Additionally, these perennial systems are conservation rich because they minimize erosion, reduce soil disturbance over conventional crops, have high nutrient absorptive characteristics, and produce large quantities of biomass that can be returned to the soil to enhance sustainability. If however, current carbon market trends continue to base payments on trajectories of improvement in carbon sequestration over a defined short term period, grass seed crops will not show as much gain in trajectory as would a conventional annual crop that is plowed every year. We also need further research to determine how stable carbon sequestration is in grass seed cropping systems. Long-term stability of carbon in the soil is the desired goal of carbon sequestration for carbon credit markets.

Literature

Gohlke, T., Griffith, S.M., and Steiner, J.J. 1999. Effects of crop rotation and no-till crop establishment on grass seed production systems in the Willamette Valley, Oregon. USDA, NRCS Technical Notes, Agronomy Technical Note No. 30, November 1999.

APHID CONTROL AND BARLEY YELLOW DWARF VIRUS SUPPRESSION IN SPRING-SEEDED PERENNIAL RYEGRASS, WESTERN OREGON

A.J. Dreves and G.C. Fisher

Introduction

The purpose of this research is to determine if aphid control with carefully timed insecticide application reduces barley yellow dwarf virus (BYDV) symptoms and increases seed yield of perennial ryegrass (PRG) grown without irrigation in western Oregon. Two replicated field trials were initiated in the fall of 2008. The sites were located in Tangent-Oakville area (Linn County, Oregon), in a newly-planted field of PRG.

Methods

The fields were planted with proprietary seed by the grower on 10 May, 2008. Both fields had good seedling stands, were vigorous and were breaking summer dormancy in October. Fields were bordered by other grass seed fields, forested areas of oaks and conifers, and houses on the south side. A randomized block design with three replications was used in both fields. Plots were flagged on 3 October, 2008. Replications measured 250 x 105 feet and 300 x 105 feet in sites 1 and 2, respectively. Seedling grasses in both fields were monitored for aphids through the summer. Yellow water traps placed beside the fields provided aphid flight information for 2008 and 2009 (Figure 1). Very few to no aphids were detected, and plots were not treated at this time. The first foliar treatments were applied to the plots on the morning of 9 October, 2008 in response to increasing numbers of aphids detected in the yellow water traps. The morning was overcast with intermittent light rain showers (accumulated 0.02 inches) and air temperature was 47°F at time of application. The temperature the previous day was 65°F and sunny.

Liquid products were delivered in the equivalent of 12 gallons per acre with a grower-applied tractor mounted boom. A 20-nozzle boom, 36 inches above the ground and operating at 50 psi with TJ8005 nozzles covered a 70 feet swath. Insecticides applied were: imidacloprid as Admire Pro (4.6 lb a.i. per gallon) at 8 oz/acre (0.575 lb a.i./a), spirotetramat as Movento (2 lb a.i. per gallon) at 6 oz/acre (0.094 lb a.i./a), and cyfluthrin as Baythroid XL (1 lb a.i. per gallon) at 2.8 oz/acre (0.2 lb a.i./a). Three untreated check plots were included in each field within the RCB design. No surfactant was used on first application of treatments. Subsequent applications received MSO at 0.25% by volume of spray solution. Precipitation and mean temperatures during the trials were obtained from Corvallis, Oregon AgriMet station (Lat 44.6342, Long 123.30, Elev 230 ft).

Adjacent to site 1, seed was treated with Imidacloprid (equivalent of Gaucho 480) at 6 oz/cwt and seeded on 10 May, 2008. Three plots, 250 x 105 feet were flagged. These plots were also treated with a foliar spray, Mustang®, 6oz/acre on 29 October, 2008 as well as the following spring.

A second foliar application to the plots was made the following spring (29 May, 2009) as winged aphid counts increased in the water pan traps. A third spray was made in the fall to the plots at site 1 on 28 September, 2009. This was after the first seed harvest

Aphids were monitored in the plots beginning in 2008 by different methods: visually counting aphids per unit row of seedling grass during establishment year, sweep net (10 samples of ten, 180° arc) sampling in the plots as the grass grew taller, and by taking five, 6-inch core samples over the rows and 2 inches down into the soil per plot and extracting aphids with Berlese funnels. Individual grass tillers, randomly-selected (n=100 plants) within plots were rated for presence or absence of BYDV symptoms on 15 June, 2009 (slightly past peak symptom expression).

Five, 6-inch cores of grass were collected and processed from each plot prior to application of insecticides, 28 May, 2009 and again on 6 July, 2009, prior to harvest. Total numbers of aphids extracted by plot were recorded.

Plots were swathed on 10 July, 2009. On 24 July (site 1) and 25 July (site 2) individual plots were combined directly into a weigh-wagon to record seed weights that could be converted to seed lb/acre.

After 1st year harvest, a third application of three foliar products was made to site 1 on 28 September, 2009 as aphids increased in yellow water traps. The same products and rates with surfactant were used (see above). The temperature at time of application was approx. 60°F with a light wind from SW, partly cloudy. Rain fell 7 hours after application (0.01inches) and continued to fall the next day (0.10 inches) The PRG was greening and had approx. 2 inches of regrowth. These plots were evaluated for aphids on 8 October, 2009 at 10-day post application using the soil core and Berlese funnel extraction method.

Results

Aphid control. Few to no aphids were seen on seedling grasses through the summer, 2008. First sprays were applied on 9 October, 2008 in response to increased aphid numbers in yellow water traps (Figure 1). Second sprays were applied on 29 May, 2009 also in response to increased aphid numbers in yellow water traps. Aphid control was evaluated by taking five, 6-inch diameter soil cores through grass crowns randomly selected in the plots beginning in January 2009. Aphids were extracted with Berlese funnels, counted and recorded. Movento-treated plots were not evaluated. Aphid numbers

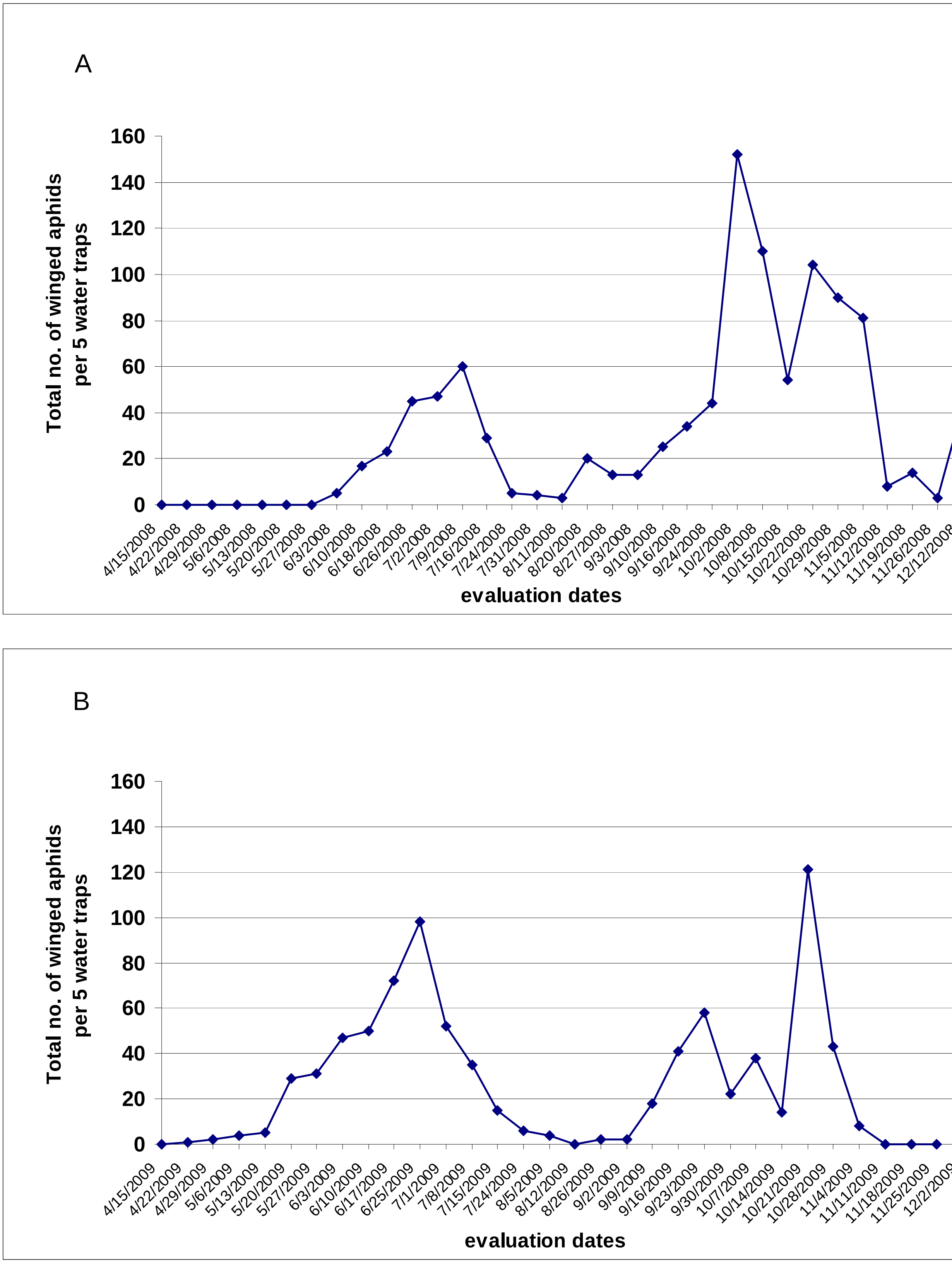


Figure 1. Winged aphid counts in yellow water traps placed on borders of established perennial ryegrass fields in the south Willamette Valley, 2008 (A) and 2009 (B).

Table 1. Aphid numbers found in treated-plots of perennial ryegrass, site 1, using Berlese funnel extraction, 2009.

Treatment[3]	Product rate/acre	Mean no. of aphids per five, 6-inch grass cores in perennial rye field [1,2] 22 Jan	06 Apr	28 May	6 July	8 Oct
Admire Pro	8 oz	1 b	7 a	84 a	11 a	9 b
Baythroid XL	2.8 oz	0 b	11 a	43 a	13 a	92 b
Movento	6 oz	not applicable	not applicable	not applicable	26 a	28 b
Check	--	38 a	288 a	43 a	5 a	475 a
$P < 0.05$		0.0091	0.1345	0.4051	0.2009	0.0117

[1] Means separated using Fisher's LSD, log-transformed (x + 0.01), and significance level of 0.05. Original means are presented in table.
[2] Mean numbers of aphids extracted from on five, 6-inch grass cores, replicated three times, totaling 15 cores.
[3] Field was seeded on 10 May, 2008. First, second and third applications were applied on 20 October 2008 (fall 08), 29 May 2009 (spring 09) and 28 September 2009 (fall 09), respectively. The Movento treatment was not applied until 29 May 2009.

Table 2. Aphid numbers found in treated-plots of perennial ryegrass, site 2, using Berlese funnel extraction, 2009.

Treatment[3]	Product rate/a	Mean no. of aphids per five, 6-inch grass cores in perennial rye field [1,2] 22 Jan	06 Apr	28 May[3]	6 Jul
Admire Pro	8 oz	1 a	1 b	38 a	5 a
Baythroid XL	2.8 oz	0 b	0 b	128 a	5 a
Movento	6 oz	not applicable	not applicable	not applicable	8 a
Check	--	11 a	65 a	76 a	23 a
$P < 0.05$		0.2137	<0.0038	0.5837	0.4081

[1] Means separated using Fisher's LSD, log-transformed (x + 0.01), and significance level of 0.05. Original means are presented in table.
[2] Mean numbers of aphids extracted from on five, 6-inch grass cores, replicated three times, totaling 15 cores.
[3] Field was seeded on 10 May 2008. First, second and third applications were applied on 29 October 2008 (fall 08), 29 May 2009 (spring 09) and 28 September 2009 (fall 09), respectively. The Movento treatment was not applied until 29 May 2009.

Table 3. Aphid numbers found in Gaucho-treated seed plots of perennial ryegrass, site 1, using Berlese funnel extraction, 2009.

Treatment[1]	Rate/cwt	Mean no. of aphids per five, 6-inch grass cores in field [2,3] 22 Jan	06 Apr	28 May[3]	6 Jul	8 Oct
Gaucho 480-treated seed + Mustang	2 oz.	0 b	0 b	0 a	9.3 a	111 b
Untreated check	--	37 a	288a	43 a	5.00 a	475 a
$P < 0.05$		< 0.0002	<0.0081	0.198	0.3094	0.0232

[1]Seed was treated with imidacloprid (Gaucho 480) at 4 lb/gal and applied to 29.38 acres on 10 May, 2008.
[2] Means separated using Fisher's LSD, log-transformed (x + 0.01), and significance level of 0.05. Original means are presented in table.
[3] Mean numbers of aphids extracted from on five, 6-inch grass cores, replicated three times, totaling 15 cores.

remained low during late January and early April 2009 in Baythroid and Admire treated plots of both fields; less than 5% of the numbers recorded in untreated checks (Table 1, 2, and 3). By 28 May 2009 aphids in treated plots had increased to numbers statistically equal to the numbers in the untreated plots of both fields. Winged aphids increased in water traps. Sprays were applied. On 6 July, prior to harvest, aphid counts were taken and although populations were lower in plots than in May, their numbers were not statistically different from those in the untreated plots of both fields. On 28 September, 2009, a third spray was applied to site 1. Ten days later aphids were evaluated using soil cores and Berlese funnels. Significant reductions in aphids compared to the untreated plots was noted in all treated plots (98% reduction-Admire®, 94% reduction-Movento®, 81% reduction-Baythroid). Fewer aphids were recorded through time in the untreated plots found in site 2 than in site 1, from 4 to 20 times fewer aphids during peak numbers.

Barley yellow dwarf virus control. There was a reduction of visual symptoms in treated plots compared to the untreated plots (Table 4). Site 2 had fewer aphids throughout the year. Nearly 60% of plants in untreated of field site 1 expressed BYDV-symptoms compared to 22% of plants for field site 2. These data were taken just before first harvest. At site 1, the seed treatments, plots Admire Pro and Baythroid plots had significantly fewer BYDV-infected leaves than the untreated. In site 2, none of the plots had statistically fewer infected leaves than in the untreated plots.

Grass seed yields. All treatments increased seed yields in site 1, from 2 to 8% relative to the untreated as measured by weigh wagon in the field (Table 4 and 5). However, these increases were small and not statistically significant. At site 2, Movento and Baythroid plots had increased seed yields of 6% and 4%, respectively; Admire plots had slightly depressed yields (-2%) when compared to the untreated plots in this field.

Discussion

It appears that insecticide seed treatments and foliar sprays reduce aphid numbers for a few weeks (months perhaps for the seed treatment) after application. However, it is apparent that not all aphids are controlled. Those remaining increase and move among plants. This is reflected in not only aphids counted at different times through the season, but also reflected by symptom expression of BYDV in plots. In general, yields were increased with insecticide use, but these increases were slight and not statistically significant.

The grass plots at site 1, were re-treated last fall after harvest. Data will be collected from these plots in 2010 as in the first year. Second year seed yields will be taken from these plots to determine effects of insecticide applications for aphid control over two consecutive seasons.

Table 5. Comparison of perennial ryegrass seed yield increases over untreated plots, 2009.

Treatment	Seed yield increase (lb/a) over check plots and percent increase (%) 24 Jul site 1	25 Jul site 2
Admire Pro	147 (7%)	-33 (-2%)
Movento	162 (8%)	131 (6%)
Baythroid XL	115 (6%)	85 (4%)
Gaucho480 Seed + Mustang	46 (2%)	Not applied

Table 4. First-year seed yield (lb/a) at two sites and visual ratings of BYDV-symptoms, 2009.

	Seed yield[1] lb/acre		BYDV-like symptoms rating per 100 tillers[3]	
Treatment	24 Jul site 1	25 Jul site 2	15 Jun site1	15 Jun site 2
Admire Pro	2175 a[2]	2119 a	37 bc	18 ab
Movento	2190 a	2283 a	49 ab	27 a
Baythroid XL	2143 a	2237 a	44 bc	13. b
Gaucho480 Seed + Mustang	2074 a	not applicable	34 c	not applicable
Check	2028 a	2152 a	61 a	22 ab
$P < 0.05$	0.7644	0.7092	0.0310	0.1035

[1] Means separated by Fisher's LSD. Means followed by the same letter are not significantly different.
[2] The 3rd rep in UTC was weak due to a low, wet area. Reduced seed yield in this rep was more of an artifact of the experiment and most likely not due to aphid pressure or effects of BYDV.
[3] One hundred random tillers were rated for presence or absence of BYDV-like symptoms.

POSTEMERGENCE GRASS CONTROL OPTIONS IN VETCH GROWN FOR SEED

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

Introduction
Common vetch (*Vicia sativa*) and hairy vetch (*Vicia villosa*) are grown in the Willamette Valley for seed production. Both species are annuals with stems up to six feet long. Leaves are pinnately compound and both species have tendrils and many purplish-red flowers per cluster. Common vetch has larger leaves and seed than hairy vetch. Currently there are no postemergence grass control herbicides registered for use in vetch grown for seed. Two studies were conducted, one with hairy vetch and one with common vetch, to evaluate the tolerance of the vetches to herbicides already registered and used for grass weed control in legume crops.

Methods
The 2009 studies were conducted in Yamhill County. The hairy vetch study was conducted near Carlton and the common vetch study was conducted near McMinnville. The experimental design for each study was a randomized complete block with four replications and plots that were 8 ft by 25 ft. Herbicides treatments were applied with a unicycle sprayer calibrated to deliver 20 gallons per acre at 20 psi. Herbicides evaluated in the studies were clethodim (Select) applied at two rates, sethoxydim (Poast) applied at two rates, imazamox (Raptor) applied at two rates and imazamox applied in combination with bentazon (Basagran).

The soil type at the hairy vetch study site was a Woodburn silt loam with a pH of 5.9 and an organic matter content of 3.56%. The soil type at the common vetch study site soil was a Woodburn silt loam with a pH of 5.6 and an organic matter content of 4.8%. Visual evaluations of vetch injury were conducted periodically after herbicide application. The vetch crops were swathed and threshed in August. Germination percentage tests were conducted with the seed of both species by placing a known amount of seed in a controlled growth chamber environment for 14 days in the Weed Science Lab at OSU.

Results
The final visual ratings of vetch injury are presented in Tables 1 and 2. None of the herbicide treatments in the hairy vetch study caused significant injury symptoms and there were no statistical differences among the vetch seed yields or percent germination means (Table 1). All of the imazamox treatments caused significant injury to the common vetch (Table 2). The injury ratings on the common vetch following the imazamox treatments were between 33% and 80%; however, the seed yield and percent germination was comparable to that from the untreated check.

None of the herbicides in these two studies are currently registered for use in hairy or common vetch grown for seed. These results will be used to develop future herbicide registrations for use in vetch seed production.

Table 1. Visible injury, seed yield and seed germination of hairy vetch following herbicide applications, 2009.

		Hairy vetch		
Treatment[1]	Rate	Injury[2]	Seed yield[3]	14 day germ
	(lb a.i./a)	(%)	(lb/a)	(%)
Check	0	0	506	70
Clethodim	0.12	3	529	61
Clethodim	0.24	0	526	69
Sethoxydim	0.47	0	522	76
Sethoxydim	0.94	0	523	67
Imazamox	0.031	0	468	75
Imazamox	0.062	10	440	75
Imazamox +	0.031	0	433	64
Bentazon	0.25			
LSD (0.05)			NS	9

[1]Applied March 19, 2009
[2]Evaluated May 12, 2009
[3]Harvest August 19, 2009

Table 2. Visible injury, seed yield and seed germination of common vetch following herbicide applications, 2009.

		Common vetch		
Treatment[1]	Rate	Injury[2]	Seed yield[3]	14 day germ
	(lb a.i./a)	(%)	(lb/a)	(%)
Check	0	0	1867	70
Clethodim	0.12	5	1533	67
Clethodim	0.24	0	1512	68
Sethoxydim	0.47	5	1489	66
Sethoxydim	0.94	0	1641	69
Imazamox	0.031	33	1782	71
Imazamox	0.062	80	1778	79
Imazamox +	0.031	38	1680	76
Bentazon	0.25			
LSD (0.05)			NS	NS

[1]Applied March 19, 2009
[2]Evaluated May 12, 2009
[3]Harvest August 19, 2009

TOLERANCE OF TEFF TO HERBICIDES

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

Introduction

Teff (*Eragrostis tef*), a warm season annual grass native to Ethiopia, is grown in Oregon for forage, hay and grain. There are no herbicides registered for the control of broadleaf or grass weeds in teff. A preliminary field study was conducted to evaluate the tolerance of teff to a variety of herbicides. This study will guide future research related to weed management in teff.

Methods

The 2009 study was conducted at David McCready's farm near Lebanon, OR. The experimental design was a randomized complete block with four replications and the plots were 8 ft by 25 ft. Herbicide treatments were applied with a unicycle sprayer calibrated to deliver 20 gallons per acre at 20 psi. Preemergence herbicides evaluated in the study were mesotrione (Callisto), dimethenamid-p (Outlook), diuron (Karmex), sulfentrazone (Spartan) and pendimethalin (Prowl H_2O). Postemergence herbicides evaluated were flufenacet-metribuzin (Axiom), metribuzin (Sencor), pyrosulfotole-bromoxynil (Huskie), dicamba (Clarity), carfentrazone (Aim), pyroxsulam (Powerflex), pinoxaden (Axial XL), flucarbazone (Everest), mesosulfuron (Osprey), florasulam-MCPA (Orion), clopyralid (Stinger), MCPA amine (Rhomene), clodinafop (Discover), florasulam-fluroxypyr-pyroxsulam (Goldsky), pyraflufen (Vida), fluroxypyr (Starane), aminopyralid (Milestone), 2,4-D amine (Weedar64), nicosulfuron (Accent), metsulfuron (Ally), chlorsulfuron (Glean) and tribenuron (Express).

The soil type at McCready Farm is a Coburg silty clay loam with a pH of 5.5 and an organic matter content of 4.4%. The weed species present at the site were redroot pigweed, common lambsquarter and barnyard grass. Visual evaluations of crop injury were conducted periodically after herbicide applications. The teff crop was harvested on September 14, 2009 with a forage harvester.

Results

The final visual ratings of crop injury are included in Table 1. Mesotrione, dimethenamid-p and pendimethalin treatments resulted in 100% injury to the teff when applied preemergence. Mesotrione, pinoxaden and clodinafop treatments resulted in 60% or more injury to the teff when applied postemergence.

There was no teff yield from the preemergence applications of mesotrione, dimethenamid-p and pendimethalin. The clodinafop treatment caused 80% injury to the teff and did not control the weed species present in the study area; therefore, we did not harvest the plot.

The postemergence treatments that caused little or no teff injury and warrant further evaluation are flufenacet-metribuzin, metribuzin, flucarbazone, clopyralid, florasulam-fluroxypyr-pyroxsulam, pyraflufen, fluroxypyr, metsulfuron, chlorsulfuron, and tribenuron. However, some of these treatments did not control the weed species spectrum present at the McCready site. Therefore, because the yield data in Table 1 represents total biomass (teff and weeds in some cases) the forage yield should be interpreted with caution. The two treatments at this site that resulted in the highest levels of weed control, teff safety and teff yields were postemergence applications of metsulfuron and chlorsulfuron.

2,4-D amine has been submitted to IR-4 program, but there are no herbicides registered for use in teff. The only chemical option available for weed management is to apply glyphosate to emerged weeds prior to planting teff.

Table 1. Visible injury and forage yield of teff McCready Farm, 2009.

Treatment	Rate	Application code[1]	Teff Injury[2]	Teff Forage yield
	(lb a.i./a)		(%)	(tons/a)
check	0		0	6.0
Mesotrione	0.188	A	98	0
dimethenamid-p	0.98	A	88	0
diuron	1.5	A	48	6.1
sulfentrazone	0.25	A	28	5.5
pendimethalin	3	A	93	0
flufenacet-metribuzin	0.42	B	1	6.6
metribuzin	0.141	B	0	6.4
mesotrione	0.188	B	63	5.7
pyrasulfotole-bromoxynil	0.186	B	33	6.0
dicamba	2	B	16	6.3
carfentrazone	0.012	B	4	6.8
pyroxsulam	0.0164	B	10	5.5
pinoxaden	0.054	B	70	7.2
flucarbazone	0.026	B	5	5.3
mesosulfuron	0.0134	B	10	6.7
florasulam-MCPA	0.315	B	6	7.0
clopyralid	0.125	B	0	6.0
MCPA amine	1	B	11	7.9
clodinafop	0.25	B	78	0
florasulam-fluroxypyr-pyroxsulam	0.105	B	8	4.8
pyraflufen	0.0033	B	5	5.1
fluroxypyr	0.125	B	1	7.1
aminopyralid	0.11	B	20	6.2
2,4-D amine	2	B	14	7.2
nicosulfuron	0.046	B	20	6.6
metsulfuron	0.0155	B	0	7.6
chlorsulfuron	0.0078	B	1	7.6
tribenuron	0.0078	B	1	6.4
LSD (0.05)			--	1.7

[1]A – Applied July 15, 2009
B – Applied August 5, 2009
[2] Evaluated August 17, 2009

COMPARISON OF BEE POLLINATOR ABUNDANCE IN RED CLOVER SEED PRODUCTION FIELDS WITH AND WITHOUT HONEY BEE HIVES IN THE WILLAMETTE VALLEY

S. Rao and N.P. Anderson

Introduction

Red clover is an important forage legume that has been greatly valued as a rotation crop for increasing soil fertility due to its ability to fix nitrogen. A key region for red clover seed production in the US is the Willamette Valley due to favorable climatic conditions. The valley gets more than 40 in. of rain annually, mostly during the winter months, and remains relatively dry during bloom and harvest. Red clover can thus be grown in this region with minimal irrigation, and dried in the swath with little risk of rain damage during the summer (http://www.oregonclover.org/seedproduction.html).

Red clover is self incompatible, and hence a critical factor affecting seed production is pollination (Williams 1925). Bees are the primary pollinators of red clover, and growers in the Willamette Valley typically rent 1-2 honey bee hives per acre. However, due to diseases caused by the tracheal mite and the Varroa mite, and the recent colony collapse disorder, the availability of honey bees has decreased while the cost of renting hives has increased. This has led Willamette Valley red clover growers to consider raising red clover seed without incurring the cost of renting honey bee hives. Alternative pollinators of red clover are bumble bees which are considered to be 2.5 times as efficient as honey bees in red clover (Petersen et al., 1960). In the majority of the United States, growers can purchase commercial bumble bees for crop pollination. However, in Oregon introduction of commercial non-native bumble bees is prohibited due to speculated simultaneous inadvertent introduction of diseases in the past. Thus, Oregon farmers who raise red clover seed crops are dependent upon naturally occurring bumble bee populations.

There is considerable diversity in bumble bees in the Willamette Valley. Their abundance is also high in red clover seed production fields especially during mid-late bloom (Rao and Stephen 2009). Given the high abundance of bumble bees, it appears possible that adequate pollination of red clover seed crops can be achieved in the Willamette Valley without renting honey bee hives. However, this needs to be investigated. Hence, the objective of the current study was to compare the abundance of bumble bees and honey bees foraging on red clover bloom in fields with and without the presence of honey bee hives.

Methods

The study was conducted in 2009 in the Mid-Valley (Polk/Linn/Benton Counties) and in the North Valley (Washington County) in two fields with and two fields without honey bee hives.

In each of the 8 fields, bumble bee and honey bee foragers were estimated during 10 sets of 2 minute counts during visual observations made while walking in the field. Mid Valley fields were counted 3 times per day while North Valley fields were counted twice per day. The study was commenced during the 1st week of July and continued for 7 weeks. In the two fields in Polk County that did not have honey bee hives, data were not collected on July 30 as the fields were sprayed with an insecticide.

Results

Bumble Bee Abundance. Bumble bees foragers were present in all 8 red clover fields with and without honey bee hives in the North Valley and the Mid Valley. Across all fields, their abundance was highest towards the end of July-early August (Figure 1A,C; 2, 3). They were also more abundant in fields with no hives. The highest abundance of bumble bees was recorded during week 5 across the 4 fields with no honey bees (Figure 3).

In the North Valley, bumble bee abundance was similar in fields with and without honey bee hives during the first three weeks of the study. Subsequently, the numbers increased dramatically in fields without honey bee hives. Over the 7 weeks, the average weekly abundance of bumble bees ranged from 1.1 to 27.7 individuals per 2 min count in fields without honey bee hives and from 0.2 to 13.4 individuals per count in fields with honey bee hives.

In the Mid Valley, bumble bee abundance was slightly higher in fields without honey bee hives during the first three weeks of the study. However, in fields without honey bee hives, the numbers increased dramatically towards the end of July. It was not possible to assess the abundance of bumble bees in fields without hives during the same period as both fields were sprayed with an insecticide. Over the 7 weeks, the weekly average abundance ranged from 0.9 to 10.9 in fields without honey bee hives and from 0.6 to 25.7 in fields where honey bee hives were present.

Honey Bee Abundance. Honey bees were present in all 8 fields in the North Valley and the Mid Valley including those that did not have honey bee hives. As expected, honey bee foragers were more abundant in fields with honey bee hives (Figure 1,3,4). In contrast to bumble bees, honey bee abundance was highest during early bloom and largely absent during late bloom (Figure 1 B,D; 2,4).

In fields with honey bee hives, honey bee abundance peaked in mid July and then dropped. The average weekly abundance of honey bees ranged from 0 to 8.4 individuals per 2 min count in the North Valley and from 0 to 17.4 in the Mid Valley in fields without honey bee hives. In fields with honey bee hives, average weekly abundance across all weeks ranged from 0 to 18.3 individuals per count in the North Valley and from 0 to 25 in the Mid Valley.

Discussion

This study documented that bumble bee abundance was high in red clover fields in the North Valley and the Mid Valley. However, variation in abundance was observed across the bloom period. Lower abundance was observed during early bloom and in fields when honey bee hives were present. Data from an earlier study (Rao and Stephen 2009) and observations from the current study suggest that adequate pollination may be achieved in red clover seed production fields in the Willamette Valley by naturally occurring bumble bees.

The basis for the lower abundance of bumble bees during early bloom is not known. It is possible that during this period they forage on some other crop or that overall abundance of workers is lower during this period. Availability of pollen and nectar sources through early bloom could have led to an increase in bumble bee colony sizes resulting in the presence of higher abundance of workers towards mid to late bloom. The increase in numbers during mid to late bloom could also be due to the production of males at the end of the season. Further research is needed to determine factors leading to the variation in bumble bee abundance between early and late bloom.

Variation was also observed in honey bee abundance during red clover bloom. However, in contrast to bumble bees, honey bee abundance dropped during late bloom. Based on earlier observations with pollen traps, we speculate that this is due to honey bee preference for alternative pollen sources present in the area. Similar observations have been reported from other areas (Petersen et al 1960).

Comparison of bumble bee abundance between fields with and without honey bee hives suggest that there may be competition between the two bee species. It is possible that red clover producers may be able to attract a greater number of native bumble bees to their crop by removing costly honey bee hives from their fields. The higher abundance of bumble bees during early bloom may result in increased pollination and seed set thereby leading to more economic crop production.

Further studies are needed to evaluate potential use of flowers planted around the borders of crops and/or the use of companion planting of other early blooming seed crops to increase abundance of native bumble bees during early bloom. Currently, red clover is typically cut for hay early in the summer allowing for bloom to begin in early July. Additional studies could investigate whether crops could be cut at different times in an effort to align peak bloom with times when bumble bee abundance is at its greatest.

Acknowledgments

The authors would like to thank red clover seed producers in the Willamette Valley for permitting the study to be conducted in their fields. We also thank Alex Derkatch, Kim Skyrm, Toni Taylor, Julie Kirby and REU participants for assistance with data collection. This research was funded by the Oregon Clover Commission.

References

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. 2009. Bumble bee pollinators in red clover seed production. Crop Science. 49: 2207-2214.

Williams, R. D. 1925. Studies concerning the pollination, fertilization, and breeding of red clover. Welsh Plant Breeding Station Bulletin Series H. 4:1-58

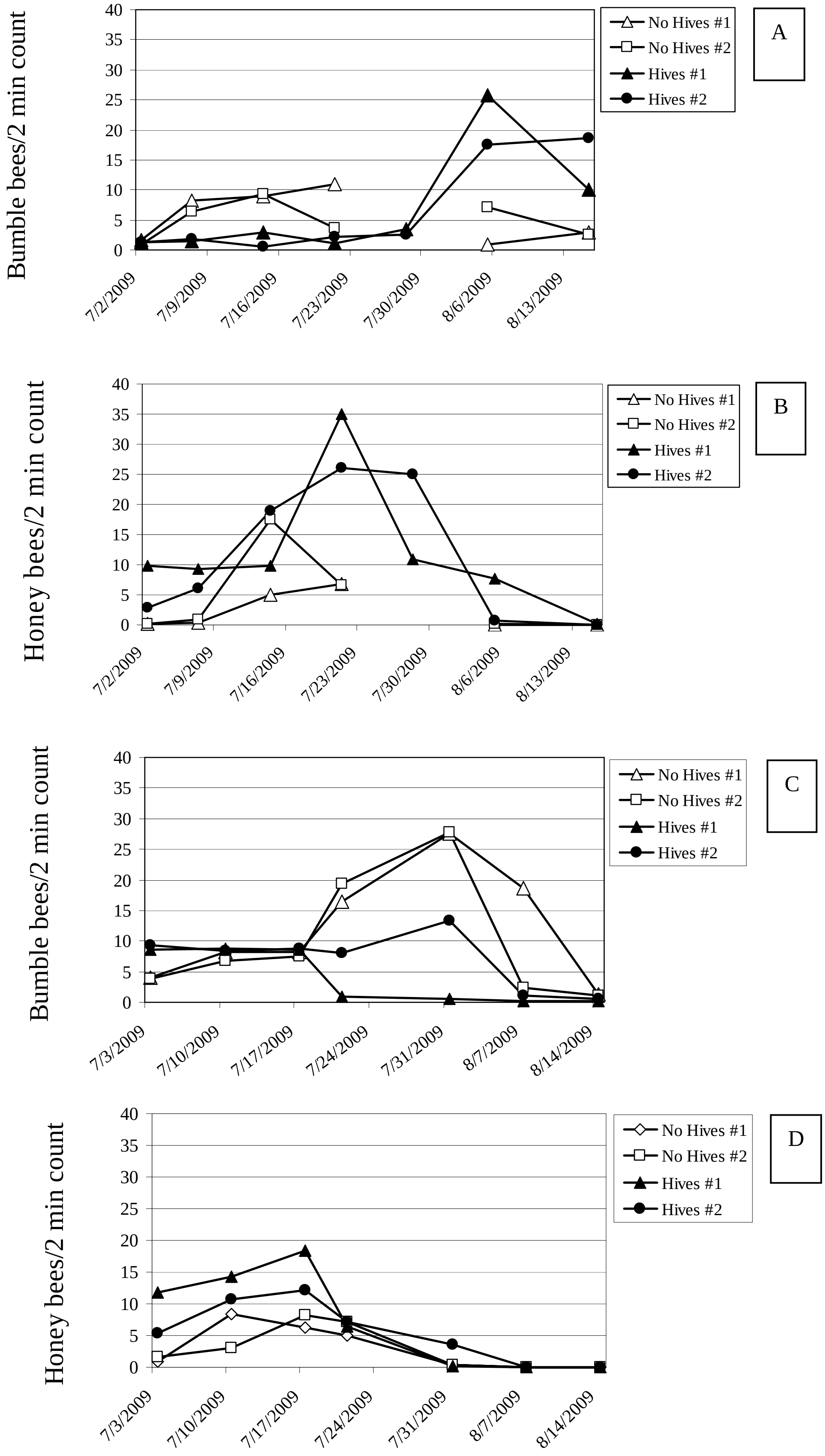


Figure 1. Average number of bumble bees and honey bees observed foraging on red clover bloom in summer 2009 in seed crops in fields with and without honey bee hives. Gaps represent periods when no observations were made as fields were sprayed with an insecticide. A, B = Fields in Polk/Linn/Benton Counties. C, D = Fields in Washington County.

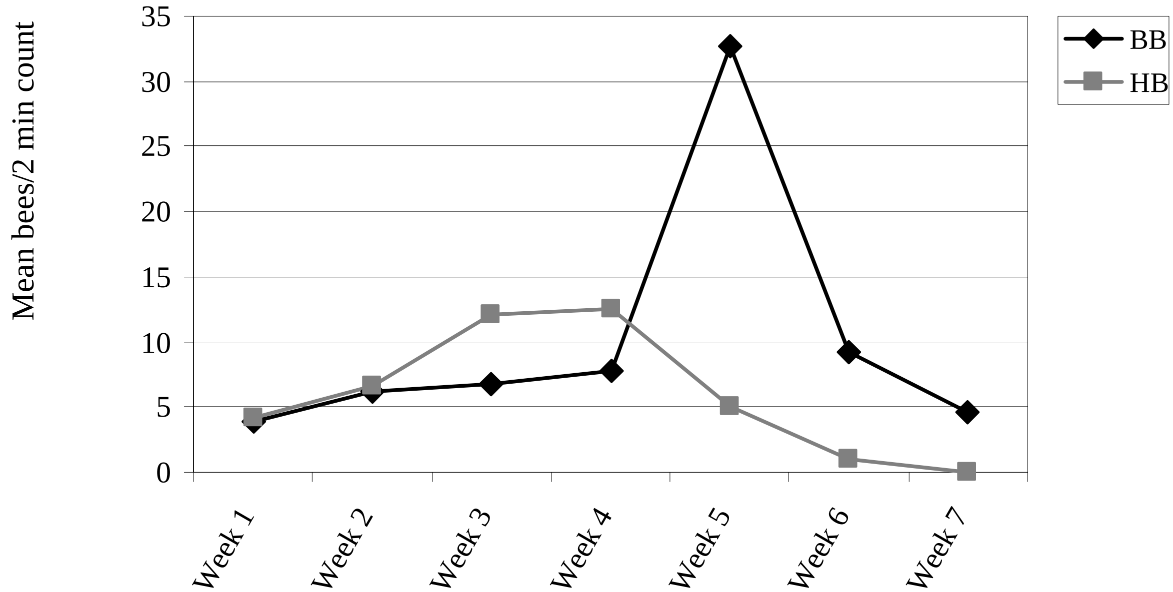


Figure 2. Mean number of bumble bees (BB) and honey bees (HB) observed during 2 minute visual observations made during bloom in 8 red clover fields in the Mid Valley and North Valley except for week 5 when counts were not made in 2 Mid Valley fields due to insecticide sprays.

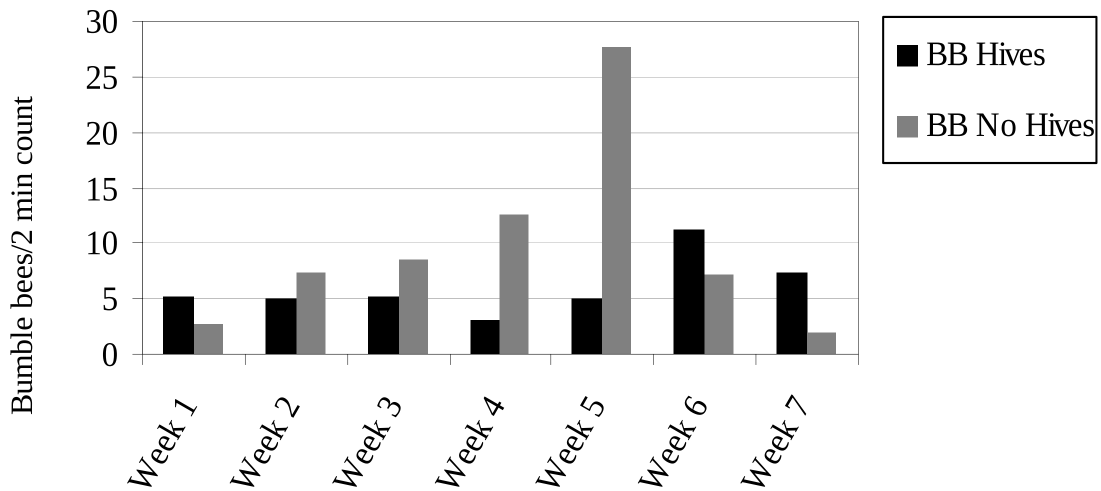


Figure 3. Mean number of bumble bees (BB) observed during 2 minute visual observations made during bloom in 4 fields with hives and 4 fields without hives in the Mid Valley and North Valley except for week 5 when counts were not made in 2 Mid Valley fields due to insecticide sprays.

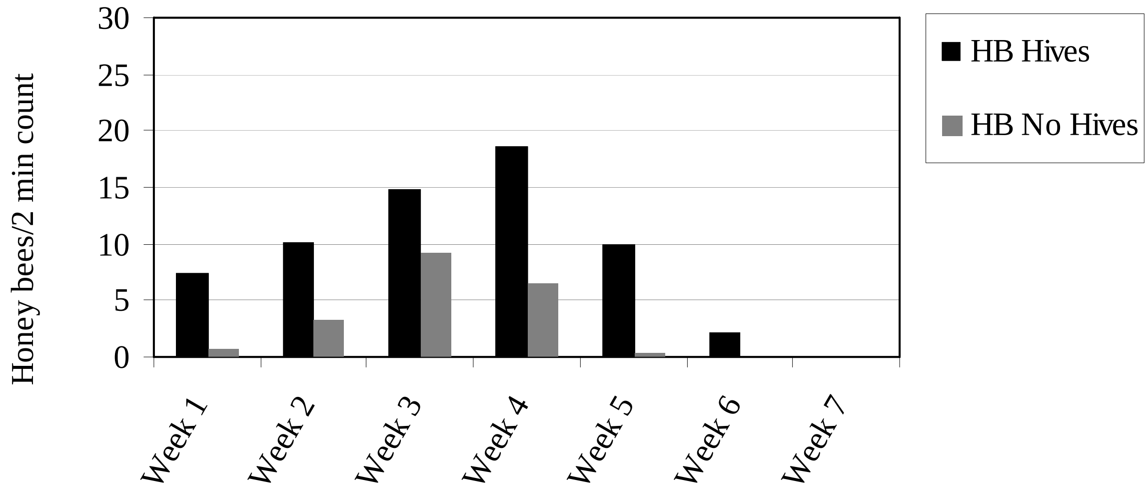


Figure 4. Mean number of honey bees (HB) observed during 2 minute visual observations made during bloom in 4 fields with hives and 4 fields without hives in the Mid Valley and North Valley except for week 5 when counts were not made in 2 Mid Valley fields due to insecticide sprays.

TOXICITY OF RED CLOVER PESTICIDES TO A NATIVE BUMBLE BEE POLLINATOR

K.M. Skyrm, S. Rao and G.C. Fisher

Introduction

Red clover is a biennial forage legume crop grown for seed in the Willamette Valley of western Oregon. A key factor in maximizing red clover seed production is obtaining adequate seed set through cross pollination. Bees serve as the primary pollinating agents for red clover seed production. While honey bee hives are rented for pollination, wild bees such as bumble bees are considered to be efficient pollinators of red clover (Rao and Stephen, 2009). Currently, there are worldwide declines in the availability and abundance of both honey bee and native bee species. One of the principal causes of this decline has been attributed to the extensive use of pesticides in agricultural ecosystems (Goulson et al., 2008). Bees are affected by pesticides via direct contact with sprays, contaminated nectar, pollen sources from flowers, and residues on plants (Johansen, 1966).

Historically, honey bees have attracted the majority of interest with regard to evaluating the toxicological effects of pesticides on bees (Devillers et al., 2003). Few studies have examined the effects of pesticides on feral bee populations. As such, pesticide label precautions regarding rates and timing for applications to crops requiring cross pollination have been established based on the responses of honey bees to pesticide exposure (Riedl et al., 2006). Given the differences in physiology, life history, ecology, and foraging behavior of bees, these data are not appropriate for assessing and comparing the toxicity of pesticides on populations of wild bee pollinators such as bumble bees (Thompson, 2001). Hence, there is a need to evaluate the toxicity of pesticides to feral bumble bees. The objective of this study was to determine the toxicity of insecticides used in the production of red clover seed, to a dominant feral bumble bee, *Bombus vosnesenskii*.

Methods

Plant material and bees. Red clover plant material was collected from an unsprayed field located in Polk County, OR. Three insecticides currently registered in Oregon and used on red clover to control clover aphid and pea aphid were tested: Metasystox-R (MSR® Spray Concentrate), Lorsban® Advanced and Brigade® 2EC (Fisher and Dreves, 2009). Labels for Lorsban® Advanced and Brigade® 2EC specifically indicate that these products are not to be applied to blooming crops or crops with actively foraging pollinators. The MSR® Spray Concentrate label allows for an early morning application prior to pollinator activity. A fourth unregistered product, Admire® 2, was also evaluated because of recent publicity concerning the toxicity of its active ingredient, imidacloprid to honey bees. Its label specifically prohibits the use of imidacloprid as Admire® to crops grown for seed. The minimum, maximum and 2X maximum recommended field rates for aphid control were used as treatments in the experiment (Fisher and Dreves, 2009). Each chemical was prepared and applied as a dilute spray in the equivalent of 100 gallons per acre. Treatments were replicated six times. Worker bumble bees, *Bombus vosnesenskii,* were used given their late season abundance in red clover during bloom. A total of 384 wild caught worker bees were field collected and subsequently exposed to the test materials in these bioassays on the day of collection.

Bioassay. Standard cylinder cages described by Johansen et al. (1983) consisting of a 15 cm plastic petri dish and a 45.7 cm x 5.1 cm strip of metal screen (6.7 meshes per cm) were used for all bioassays. Prior to application, plant samples consisting of flowers, leaves and stems were condensed to 2.5-5 cm lengths and 15.5 g were placed inside cages (Johansen et al., 1983). Pesticides were applied to plant material within cages using a Potter precision laboratory spray tower at a rate of 2ml of solution per cage (Potter and Way, 1958) (Figure 1). After application, residues were allowed to dry for a period of 1-2 hours prior to the introduction of bees. Bees were anesthetized to facilitate handling and randomly assigned to treatments (Figure 2). Each cage received four worker bees. Bees were provided a 50% nectar solution by a cotton wick feeder attached to the bottom of each cage (Johansen et al., 1983). Prior to experimentation, cages were situated on a tray consisting of all four treatments spaced equidistantly from one another. Cages were kept under controlled environmental conditions of humidity (50-60%), temperature ($28^{o}C \pm 2^{o}C$) and photoperiod (D7:L17). Mortality was assessed after 24, 48 and 72 hours by recording the number of dead bees within each cage.

Results and Discussion

After just 24 hours of exposure, Lorsban® Advanced and Brigade® 2EC resulted in 83% to 100% bumble bee mortality at all three rates evaluated (Table 1). For both Lorsban® Advanced and Brigade® 2EC mortality increased significantly over that of the untreated check as the rate increased for the three periods of exposure. The minimum, maximum and 2X maximum field rates did not differ from each other. In contrast, bumble bee mortalities in the Admire® 2 and MSR® treatments were not significantly different from the natural mortalities observed in the untreated controls over the three days the trial was conducted. There were no significant differences across all treatments and periods of exposure for Admire® 2 and MSR®. Based on these results, growers are encouraged to time pesticide applications to reduce or avoid non-target impacts on the mortality of feral pollinators. Aphid control in red clover with insecticides should be made prior to bloom to avoid killing native bumble bees that are essential for increased seed yields.

References

Devillers, J., Decourtye, A., Budzinski, H., Pham-Delegue, M.H., Cluzeau, S. and Maurin, G. 2003. Comparative toxicity and hazards of pesticides to *Apis* and non-*Apis* bees. A chemometrical study. *Environ. Res.*, 14: 389-403.

Fisher, G. and Dreves, A. 2009. Clover seed pests. *In* Hollingsworth, C.S., Ed. Pacific Northwest Insect Management Handbook, 57-62.

Goulson, D, Lye, G.C., and Darvill, B. 2008. Decline and conservation of bumble bees. *Ann. Rev. Entomol.*, 53: 191-208.

Johansen, C.A. 1966. Digest on bee poisoning, its effects and prevention. *Bee World*, 47(b): 9-25.

Johansen, C.A. Mayer, D.F., Eves, J.D. and Kious, C.W. 1983. Pesticides and bees. *Environ. Entomol.*,12(5): 1513-1518.

Potter, C. and Way, M.J. 1958. Precision spraying *In* Shepard, H.H., Ed., Methods of testing chemicals on insects, Vol. 1, Burgess Publishing Company, Minneapolis.

Rao, S. and W. P. Stephen. 2009. Bumble bee pollinators in red clover seed production. *Crop Science*, 49: 2207-2214.

Riedl, H., Johansen, E., Brewer, L. and Barbour, J. 2006. *How to reduce bee poisoning from pesticides*. Pacific Northwest Extension publication, 591 pp.

Thompson, H.M. 2001. Assessing the exposure and toxicity of pesticides to bumblebees (*Bombus* sp.). *Apidologie*, 32: 305-321.

Figure 1. The Potter precision laboratory spray tower used in pesticide applications.

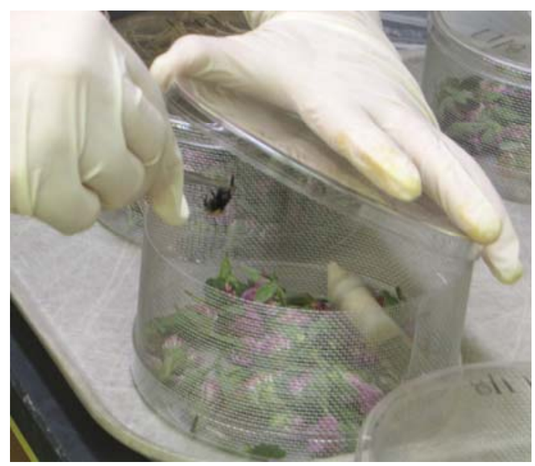


Figure 2. A marked bumble bee (*Bombus vosnesenskii*), worker being assigned to a standard cylinder cage used in bioassays.

Table 1. Mean mortality (% ± SE) values of worker bumble bees after exposure to field rates of pesticides applied to red clover plant material.

Pesticide (chemical - a.i. %)	Mortality (Mean % ± SE)[a b] Rate/acre: Untreated check	Minimum	Maximum	2X maximum	Analysis[c] F	P
Admire 2® (imidacloprid - 21.4 %)	--	0.03 lb	0.04 lb	0.08 lb		
24 hrs	8.33 ± 5.27	0.00 ± 0.00	0.00 ± 0.00	12.50 ± 8.54	1.63	n.s.
48 hrs	20.83 ± 11.93	33.33 ± 5.27	33.33 ± 12.36	33.33 ± 10.54	0.61	n.s.
72 hrs	20.83 ± 11.93	41.67 ± 5.27	54.17 ± 15.02	62.50 ± 10.70	2.69	n.s.
Metasystox-R® (MSR) (oxydemeton-methyl - 25.5 %)	--	0.38 lb	0.50 lb	1.00 lb		
24 hrs	16.67 ± 8.33	0.00 ± 0.00	0.00 ± 0.00	16.67 ± 8.33	3.08	n.s.
48 hrs	25.00 ± 9.13	37.50 ± 10.70	25.00 ± 6.45	33.33 ± 12.36	0.26	n.s.
72 hrs	37.50 ± 14.07	41.67 ± 8.33	45.83 ± 11.93	58.33 ± 10.54	0.89	n.s.
Lorsban Advanced® (chloropyrifos - 40.18 %)	--	0.50 lb	1.00 lb	2.00 lb		
24 hrs	20.83 ± 4.17a	83.33 ± 8.33b	100.00± 0.00b	100.00 ± 0.00b	41.35	<0.001
48 hrs	20.83 ± 4.17a	95.83 ± 4.17b	100.00± 0.00b	100.00 ± 0.00b	80.67	<0.001
72 hrs	29.17 ± 7.68a	100.00 ± 0.00b	100.00 ± 0.00b	100.00 ± 0.00b	80.00	<0.001
Brigade 2EC® (bifenthrin - 25.1 %)	--	0.06 lb	0.10 lb	0.20 lb		
24 hrs	0.00 ± 0.00a	87.50 ± 8.54b	91.67 ± 8.33b	95.83 ± 4.17b	45.48	<0.001
48 hrs	8.33 ± 5.27a	95.83 ± 4.17b	91.67 ± 8.33b	100.00 ± 0.00b	47.75	<0.001
72 hrs	33.33 ± 10.54a	95.83 ± 4.17b	91.67 ± 8.33b	100.00 ± 0.00b	19.55	<0.001

[a] n=6.

[b] Data analyzed using ANOVA with $\alpha = 0.05$. Data were arcsine(sqrt) transformed prior to analysis to meet the assumptions of normality.

[c] Mean values with the same letter are not significantly different at $P = 0.05$ (*n.s*), according to Tukey multiple means comparison.

EFFECT OF AGROTAIN TREATED UREA ON AMMONIA VOLATILIZATION IN KENTUCKY BLUEGRASS IN THE COLUMBIA BASIN OREGON

J.C. Holcomb III and D.A. Horneck

Introduction

With the unavailability of ammonium nitrate, urea has become the most commonly used form for nitrogen fertilization. Urea is inexpensive, safe to handle, and provides a high percent of nitrogen (46%). As any ammonium based fertilizer, it lends itself to nitrogen loss through ammonia (NH_3) volatilization. However, only urea goes through a process called hydrolysis that increases ammonia loss. The hydrolysis of urea has the following basic formula:

$$\text{urea} \rightarrow \text{ammonium} + \text{hydroxide.}$$

The creation of hydroxide increases short term pH, which increases ammonia volatilization risk. Nitrogen loss by volatilization creates both a loss in fertilizer efficiency and a source of atmospheric ammonia.

Historically, in the lower Umatilla Basin there is approximately 20,000 acres in grass seed production (OAIN). Nitrogen fertilizer is applied both late-fall and spring; each application can create an opportunity for ammonia volatilization. Agrotain International, LCC (St. Louis, MO) markets a urease inhibitor N-(n-butyl) thiophosphoric triamide (NBPT) that when added to urea has the potential to limit nitrogen loss through ammonia volatilization. This inhibitor can be applied to both urea and urea-ammonium nitrate solution (UAN or solution 32). This product is designed to protect urea for 7-21 days, giving the urea time to be incorporated by either rainfall or irrigation.

Although there has been published data on ammonia volatilization, losses in pounds per acre on a field scale have not been well documented. The method used in this study allowed us to measure nitrogen loss (lb/a) in the field. Earlier studies could only compare relative nitrogen loss between two products. Knowing lb/a loss allows comparison between nitrogen products to calculate nitrogen savings and economic impact.

The objective of this study was to measure ammonia volatilization from Agrotain treated urea (Agrotain), ammonium sulfate, and urea applied to field burned and unburned Kentucky bluegrass fields in the Columbia Basin in Oregon.

Methods

Research was conducted on four fields of Kentucky bluegrass (*Poa pratensis* L.). Two 125-acre fields that were open field burned after straw was harvested fields near Echo, OR with pH of 6.5 and 5.9, and two 70-acre unburned fields that had straw harvested near Stanfield, OR with pH 7.1 for both fields.

The two fields at the Echo location had 3 surface applied nitrogen treatments: Agrotain (5 qts Agrotain/ton urea), Ammonium Sulfate, and Urea. Nitrogen was applied to a 98 ft diameter circle at a rate of 100 lb nitrogen/acre. The treatments were arranged in a randomized complete block design with three replications. Plots were separated by approximately 230-ft to avoid possible ammonia cross-contamination between treatments. The Stanfield location was set up similarly with 2 treatments: Urea and Agrotain.

Ammonia volatilization losses were measured with a modified passive flux method (Wood et al., 2000), which consists of a rotating ten foot tall mast placed at the center of a circular plot. Ammonia is sampled at five heights (1.47, 2.46, 4.75, 7.38, and 9.84 ft; Leuning et al., 1985). Each passive flux ammonia sampler consisted of a glass tube (each tube 0.28-in i.d. by 7.87 in long), which the inside surface was coated with oxalic acid to trap ammonia out of the air. The mast has a wind vane that keeps the tubes facing into the wind. A background mast was placed upwind of the predominant wind direction. The sampling tubes were initially changed daily, then after a week every other day. Sampling tubes were shaken for 10 minutes with deionized water, then extracted and analyzed colorimetrically for ammonium (NH_4^+) (Sims et al., 1995).

Total ammonia volatilized from applied fertilizer was quantified by subtracting the background ammonia measurements. Vertical flux of ammonia was determined by summing horizontal flux at each measurement height (Wood et al., 2000; Schjoerring et al., 1992).

An Adcon Telemetry weather station was placed at the study area to measure air temperature, soil surface temperature, humidity, rainfall, and wind speed and direction.

Nitrogen loss by ammonia volatilization was subjected to an analysis of variance (Statistix 8, 2003) using LSD for mean separation.

Results and Discussion

Burned Sites

Agrotain reduced ammonia volatilization at both burned fields compared to urea ($p<0.05$). Ammonium sulfate also reduced volatilization compared to urea ($p<0.05$). There was no difference within dates between Agrotain and ammonium sulfate, however there was a difference in cumulative loss ($p=0.08$). Urea lost an average of 10.25 lb/a more ammonia than either Agrotain or ammonium sulfate (Figure 1). Agrotain limited cumulative ammonia loss over time compared to the urea treatment.

Daily ammonia loss from urea at the field burned sites began immediately after application and increased steadily until it reached its maximum daily loss on October 6, daily loss then decreased. Ammonia loss from Agrotain was linear and lost 0.318 lb/a ammonia each day ($r^2 = 0.973$). Ammonia loss from ammonium sulfate was also linear and lost 0.397 lb/a each day (r^2=0.903). Following rain on October 3, 4, 5 (Figure 2), the largest increases in daily loss where measured for the urea treatment. Prior to these rains, urea pellets were still observable. Ammonia loss increased as urea pellets hydrolyzed in addition to the increased urease contact and/or increased urease activity. Subsequent soil profile drying increases ammonia loss as the evaporation process carries ammonium to the soil surface where it is susceptible to volatilization. Ammonium sulfate and Agrotain were unaffected by the rainfall. Agrotain was likely not affected because the urease inhibitor slowed urea hydrolysis even though exposed to the increased urease activity following rainfall. This study demonstrates the importance of getting adequate water to move fertilizer deep enough into the subsoil where it can be held by the soil's cation exchange capacity. Otherwise small amounts of precipitation can increase ammonia loss when urea is surface applied.

Figure 1. Average cumulative nitrogen loss as ammonia on two burned Kentucky bluegrass fields. Bars represent standard error.

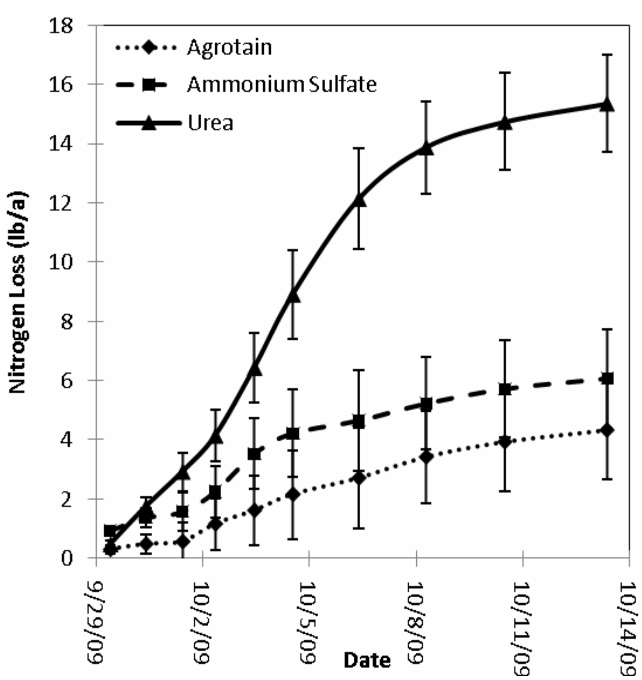
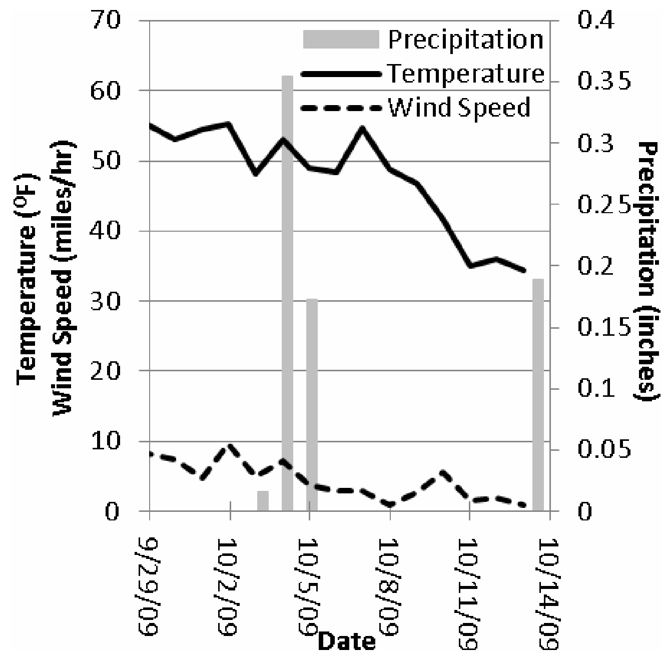


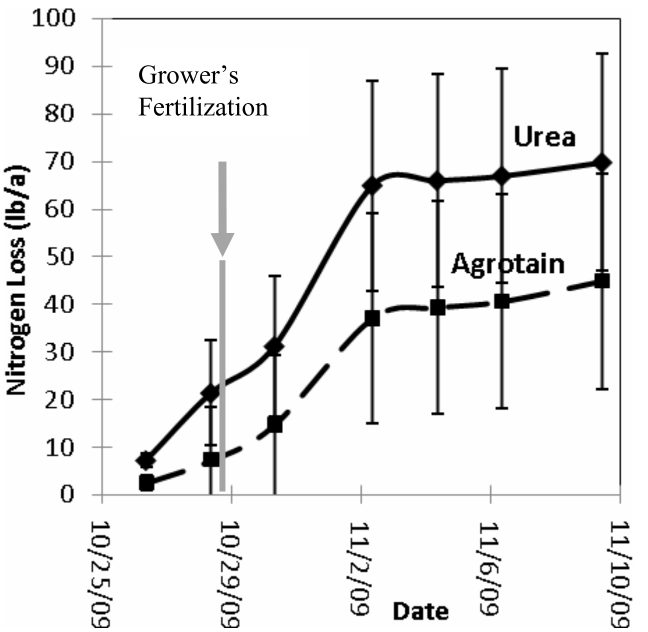
Figure 2. Average daily temperature and wind speed with cumulative precipitation for burned Kentucky bluegrass fields.



Unburned Sites

All data from these locations are confounded by a grower's subsequent fertilizer application. No difference in total ammonia volatilization was observed between urea and Agrotain at either unburned location ($p>0.05$) when comparing individual dates. Ammonia loss differed on total ammonia volatilized only. Ammonia loss started immediately after fertilization and then increased after the first couple days (Figure 3). The large increase on November 2 is due to ammonia from the grower's 150 lb/a nitrogen application that was applied on October 28 and applied over the top of our plots. The grower's fertilization affected ammonia measurements for all treatments. Consequently, after the grower's nitrogen application ammonia measurements were not reflective of the treatments. This makes the data after October 28 misrepresentative of treatment comparison. Only the data prior to the grower's application can be used to determine treatment effects. This leaves only two sampling dates to compare for which there was no difference between treatments. There were also no ammonia volatilization differences in the early sampling at the burned locations. We hypothesize that the time from application to grower fertilization was too short to see a diversion between treatments at the unburned locations. More research on unburned Kentucky bluegrass fields is scheduled in order to quantify the effects of Agrotain on these fields.

Figure 3. Average cumulative nitrogen loss as ammonia on two unburned Kentucky bluegrass fields. Bars represent standard errors.



Ammonia in Smoke

During a preliminary study, a grass seed field burn smoke-event occurred that saturated all the collection devices with ammonia (Table 1). After subtracting background levels, treatment ammonia losses were undetectable for the sampling period. This demonstrated that the ammonia was associated with the smoke. These findings suggest that field burning results in nitrogen being lost from the system as ammonia in the smoke.

Table 1. Average ppm nitrogen (N) as ammonia for the sampling period before (Aug. 6), during (Aug. 7), and after (Aug. 10) the smoke event. Samplers refer to height of ammonia collection.

Height of samplers	Before Aug. 6	Smoke Aug. 7	After Aug. 10
(feet)	------------------- (ppm N) -------------------		
9.84	2.68	1.94	0.92
7.38	1.13	2.20	1.05
4.75	1.79	2.96	0.96
2.46	2.64	6.45	1.47
1.47	5.24	10.97	2.43
Total	13.49	24.51	6.85

Diurnal Ammonia Loss

Also during this preliminary study, ammonia measurements were taken twice a day to measure diurnal ammonia loss. Immediately after fertilizer application a diurnal effect was measured (Figure 4). Ammonia losses peaked in the daylight hours and were lowest during the night. Increased loss is related to higher temperatures, wind speeds, and decreased humidity during the afternoon hours (Table 2).

Figure 4. Average diurnal nitrogen loss as ammonia across treatments on wheat stubble.

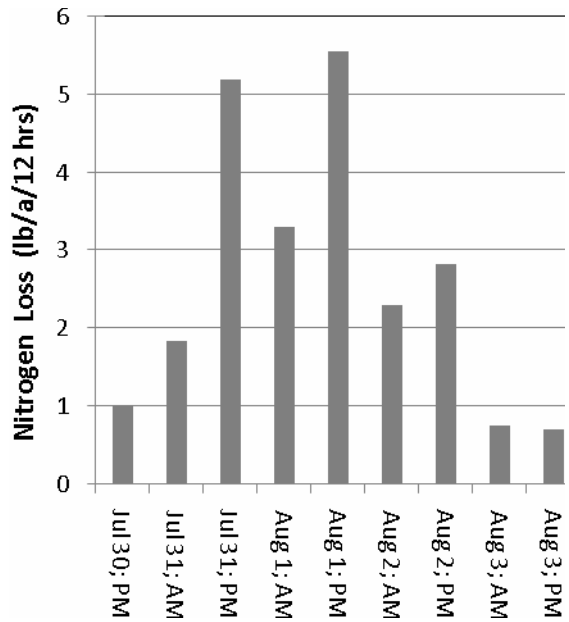


Table 2. Average 12-hour weather data for diurnal wheat stubble data. No precipitation occurred.

Date 2009	Air temp.	Soil temp. at 2 in.	Wind speed	Rel. hum.
	------- (°F) -------		(mi/hr)	(%)
7/30; PM	92.8	89.5	5.2	21.8
7/31; AM	75.5	80.8	2.7	45.6
7/31; PM	95.6	90.3	4.6	21.3
8/1; AM	77.1	81.1	3.1	40.3
8/1; PM	99.9	91.5	3.9	20.1
8/2; AM	82.1	83.7	3.3	39.4
8/2; PM	94.9	92.6	3.5	18.1
8/3; AM	81.0	84.1	5.9	36.5
8/3; PM	91.3	91.4	8.1	18.8

Conclusions

Ammonia loss from urea at the burned field sites accounted for 15.3% of nitrogen applied. Agrotain at the burned field sites accounted for 4.3% of nitrogen applied, which is a 71.8% reduction of ammonia loss compared to urea. Urea that is left on the surface without being incorporated or watered into the soil profile could benefit from the use of Agrotain when just nitrogen loss is considered. However, Agrotain may not be suited for all conditions. Ammonia loss follows a diurnal pattern with more ammonia being lost during the day than at night. Ammonia loss increases during the day as a result of higher temperatures and wind speeds. Preliminary studies also suggest that a substantial amount of nitrogen in smoke from field burning is ammonia; however, this was not quantified. These results confirm the method used is able to measure nitrogen loss (lb/a) and can be used to calculate the value of retained nitrogen compared to the expense of the product being applied, e.g., urea vs. Agrotain.

Acknowledgements

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References

Leuning, R., F.R. Freney, O.T. Denmead, and J.R. Simpson. 1985. A sampler for measuring atmospheric ammonia flux. Atmos. Environ. 19:1117-1124.

Schjoerring, J.; Sommer, S.; Ferm, M. A simple passive sampler for measuring ammonia emission in the field. Water Air Soil Pollut. 1992, 62, 13-24.

Sims, G.K.; Ellsworth, T.R.; Mulvaney, R.L. Microscale determinations of inorganic nitrogen in water and soil extracts. Commun. Soil Sci. Plant Anal. 1995, 26, 303-316.

Statistix 8 Analytical Software. 2003. Statistix 8 User's Manual, Analytical Software, Tallahassee, FL.

Wood, C.W.; Marshal, S.B.; Cabrera, M.L. Improved method for field-scale measurement of ammonia volatilization. Commun. Soil Sci. Plant Anal. 2000, 31 (5), 581-590

EVALUATION OF PALISADE ON FIFTEEN KENTUCKY BLUEGRASS VARIETIES GROWN FOR SEED IN CENTRAL OREGON, 2009

M.D. Butler, R.P. Affeldt, L.L. Samsel and K.J. Marling

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

This research was conducted at the Central Oregon Agricultural Research Center (COARC) near Madras. The fifteen varieties compose the 10-ft by 60-ft main plots, with 10-ft by 20-ft subplots comparing yields for plots treated with the growth regulator Palisade® and untreated plots. Main plots were replicated four times in a randomized complete block design.

Palisade was applied at 24 oz/acre on May 8 when most varieties were in the boot stage. 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 in the first-year field on May 22 and June 3 and in the second-year field on May 27 and June 3. Percent lodging was estimated on July 1. A section 6-ft x 17 ft of each plot was swathed as varieties matured from July 2 to 9. This was followed by combining of the plots at an appropriate timing. Equipment used were a plot-sized swather and Wintersteiger plot combine. Seed samples were transported to the Hyslop Farm near Corvallis where they were debearded, run through a small scale Clipper cleaner, and clean seed weight was determined.

Seed yield on the first year field was significantly higher for 12 of the 15 varieties treated with Palisade, with a trend for all varieties to have increased yields (Table 1). Yield across all varieties averaged 35 percent higher than the untreated check. Average yield for untreated plots across varieties was 1025 lb/acre compared with 1340 lb/acre for those treated with Palisade. The trend was a reduction in plant height of 2.0 inches and 2.6 inches for the two evaluation dates, with a 37 percent reduction in lodging across varieties.

The effect of Palisade on seed yield in the second year trial was not significant. In the establishment year, this field produced an average yield across varieties of 1266 lb/acre for the untreated plots and 1383 lb/acre for plots treated with Palisade. The average yield increase across varieties was 11 percent for Palisade treated plots. The trend was a reduction in plant height of 1.3 inches and a 44 percent reduction in lodging across varieties.

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

					Evaluation dates					
					7/1/09		5/27/09		6/3/09	
	Clean seed yield (lb/acre)				Lodging (%)		Plant ht (in)		Plant ht (in)	
Variety	Check	Palisade	% Check	Signif.[1]	Check	Palisade	Check	Palisade	Check	Palisade
Atlantis	1206	1516	126	***	69	43	15.3	13.3	27.8	25.3
Merit	1305	1602	123	**	66	11	13.0	10.5	23.0	19.0
Rhapsody	888	1101	124	*	26	3	14.0	10.8	24.3	19.3
Valor	776	942	122	NS	63	8	11.3	9.5	19.0	14.0
Bariris	614	1179	192	***	100	93	17.0	16.0	26.5	25.3
Crest	1261	1467	116	*	48	8	12.3	10.0	21.8	19.3
Monte Carlo	743	911	123	NS	50	16	11.3	9.8	19.0	15.8
Shamrock	1682	1918	114	**	83	28	18.0	14.3	27.8	25.5
A00-891	1311	1712	131	***	58	16	14.3	14.0	21.3	21.3
A00-1400	663	1012	153	***	59	31	12.0	10.3	23.0	20.0
Bandera	1060	1190	112	NS	15	3	11.5	9.0	21.3	17.3
Bordeaux	890	1302	146	***	81	13	16.0	11.5	25.0	21.3
Volt	1211	1514	125	***	85	48	19.3	16.5	28.3	26.0
Zinfandel	783	1216	155	***	66	15	14.0	12.5	21.8	19.5
A01-299	981	1529	156	***	46	19	15.5	15.8	22.8	24.3

[1]Comparison with paired t-test: NS = non-significant, * for P = 0.10, ** for P = 0.05, *** for P = 0.01

Table 2. Effect of Palisade® growth regulator on seed yield, lodging, and plant height on a second year field of 15 Kentucky bluegrass varieties planted August, 2007 at COARC, Madras, Oregon.

	Clean seed yield (lb/acre)[1]			Evaluation dates: 7/1/09 Lodging (%)		5/27/09 Plant ht (in)		6/3/09 Plant ht (in)	
Variety	Check	Palisade	% Check	Check	Palisade	Check	Palisade	Check	Palisade
Atlantis	1002	1049	105	23	3	17.0	14.0	25.8	20.5
Merit	860	884	103	13	1	13.3	9.8	21.3	15.8
Rhapsody	412	661	160	15	0	12.0	10.3	18.8	14.8
Valor	487	584	120	31	0	11.3	7.5	17.0	11.3
Bariris	203	344	169	85	60	20.0	14.3	27.0	24.5
Crest	838	708	84	25	0	13.8	10.0	20.8	15.3
Monte Carlo	561	636	113	71	6	11.3	9.5	17.0	13.0
Shamrock	818	928	113	69	14	19.0	14.0	27.0	22.3
A00-891	951	1187	125	30	3	12.5	9.8	21.0	17.3
A00-1400	480	657	137	56	10	12.3	11.3	17.8	15.5
Bandera	655	748	114	24	5	13.8	10.3	20.3	15.8
Bordeaux	751	757	101	53	10	15.0	10.0	24.5	16.5
Volt	950	1133	119	81	10	20.3	16.0	28.0	23.8
Zinfandel	732	980	134	41	16	12.0	9.3	16.8	12.0
A01-299	825	1070	130	33	1	15.0	11.5	19.3	17.3

[1]Comparison of check against Palisade® was not significant.

SOD WEBWORM MANAGEMENT SYSTEM FOR KENTUCKY BLUEGRASS SEED PRODUCTION IN CENTRAL OREGON, 2009

M.D. Butler, L.L. Samsel, K.J. Marling, 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. At that time sod webworms were considered an emerging pest that could have a financial impact on Kentucky bluegrass fields in central Oregon. As a result this project has focused on sod webworm populations and distribution during the 2005 through 2009 seasons. The strategy has been to use pheromone traps that emit a scent to attract males in order to track the number of the sod webworm moths. This has been followed by sod sampling to determine the correlation between moth and larval populations. The objective of this research is to determine whether 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 4 quadrants of 11 commercial Kentucky bluegrass seed production fields in mid-June. Fields with potential insect problems in the Madras and Culver areas were chosen for the project this season. Contents of the traps were collected weekly from June 19 to August 3, with the number of sod webworm and cutworm moths noted.

The overall peak flight of the sod webworm moth was July 6 to July 20 (Table 1). During peak flight the average number of sod webworm moths collected per field per week from the four traps was 102. The total number of sod webworm moths collected per field varied from 71 to 928 over the trapping period. 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 June 26 through July 6, with the average number collected per field per week during this time at 30. The total number of cutworms collected per field ranged from 19 to 188 during the trapping period. The number of cutworms collected is considered relatively low compared to other growing regions. The cutworm life cycle appears to be similar to that of the sod webworm.

It appears that a better strategy for control of sod webworm may be the control of adults at peak flight prior to egg-laying, rather than targeting larvae in the fall. Materials will be evaluated during the 2010 season to determine the effectiveness of this approach. If so, use of pheromone traps will have a direct influence on the need for treatment, rather than being an indicator of potential larvae populations in the fall. There has not been a strong correlation between adult populations in early summer and larval number in the fall.

Table 1. Sod webworm moths collected per field using pheromone traps from June 19 to August 3, 2009, near Madras, Oregon.

Field	Collection dates sod webworm moth							Total
	June 19	June 26	July 6	July 13	July 20	July 27	Aug. 3	
1	77	48	83	15	39	19	7	288
2	70	31	26	9	14	6	9	165
3	1	2	11	20	7	6	4	71
4	55	47	127	12	134	66	7	448
5	93	46	79	47	12	1	0	278
6	---	33	42	34	20	3	2	134
7	---	35	30	6	177	61	6	315
8	88	145	66	124	160	61	3	647
9	---	39	117	228	438	51	55	928
10	---	19	85	218	212	181	117	832
11	---	105	90	172	158	68	1	594
Total	384	550	756	885	1371	523	211	

Table 2. Cutwork moths collected per field using pheromone traps from June 19 to August 3, 2009, near Madras, Oregon.

Field	Collection dates cutworm moth							Total
	June 19	June 26	July 6	July 13	July 20	July 27	Aug. 3	
1	38	27	59	46	17	1	0	188
2	35	38	37	16	6	3	1	136
3	27	19	9	38	21	5	0	119
4	38	34	30	17	1	0	1	121
5	8	29	29	8	17	8	1	100
6	---	35	51	36	32	2	3	159
7	---	30	41	41	4	0	6	122
8	---	19	22	4	2	1	0	48
9	---	3	10	5	1	0	0	19
10	---	52	36	13	3	0	0	104
11	---	27	16	7	1	0	1	52
Total	146	313	340	231	105	20	13	

DEVELOPMENT OF A PHENOLOGICAL MODEL FOR THE DENVER BILLBUG IN CENTRAL OREGON KENTUCKY BLUEGRASS SEED PRODUCTION, 2009

M.D. Butler, G.C. Fisher, S. Rao, L.L. Samsel and K.J. Marling

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

Five commercial bluegrass seed production fields showing moderate to severe billbug damage were selected for sampling during the 2009 season. Eight pitfall traps were placed in field number 4 on April 10, 2009 and eight traps were placed on May 11, 2009 in field numbers 1, 2, 3, and 5. The traps were checked on a weekly basis from April 10, 2009 to June 30, 2009 when they were removed for harvest and placed back into four of the five locations September 25, 2009. Weekly sampling resumed through November 12, 2009.

Eight, 12 inch diameter sod samples, 3 inches in depth, were collected every two weeks from May 26, 2009 through November 24, 2009. Sod samples were not taken during the months of July and August due to harvest. These samples were taken within three to five feet from the pitfall traps and kept refrigerated while waiting for processing. Sod samples were processed for four days using Berlese funnels. Insects were collected and identified. The samples were screened for any non-mobile adults or larvae.

The number of adult billbugs collected in the pitfall traps ranged from 0 to 27 per trap from April 10 thru June 30, 2009. The last week of May and the first week of June saw the highest activity of adults in the pitfall traps, then tapered off through the summer and into the fall (Table 1). With the exception of one field adult numbers for the fall dates were very low compared to the spring numbers (Table 2).

The number of billbug larvae collected from sod samples taken from May 26, 2009 to November 24, 2009 ranged from 0 to 56 per field (Tables 3 & 4). Mid- June saw a high number of small larvae from four locations indicating a newly hatched generation of billbugs. One field showed higher numbers of small larvae during late May and early June. The location of this field is at a lower elevation which may explain why the larvae count was higher earlier in the season compared to mid-June for the other locations. Because of the lower elevation and higher temperatures insect development was one to two weeks ahead of the other locations. It appears that the Denver Billbug overwinters both as adults and larvae.

Random samples of adult billbug and larvae were sent to Sujaya Rao for DNA sampling. The results for the 12 adult billbugs show they were of the Denver Billbug species. The objective of the study was to determine if molecular markers could be identified for separation of three billbug species, *Sphenophorus parvulus* (Bluegrass Billbug), *Sphenophorus cicatristriatus* (Rocky Mountain Billbug) and *Sphenophorus sayi* (currently no common name). The three species are indistinguishable as larvae and current species identification is based on adult characteristics. Based on reports from other parts of the US, the Bluegrass Billbug and the Rocky Mountain Billbug have the potential to cause major economic damage to Oregon's grass seed industry. There are no reports of damage by the third species, *Sphenophorus sayi*. Presently, little is known about the life-cycle of these species in Oregon. Hence, molecular markers that allow identification at the larval stage will facilitate studies on evaluation of the possible risks presented by each species to grass seed farmers in Oregon.

Table 1. Number of adult billbugs collected in pitfall traps from fields located on the Agency plains near Madras, Oregon, during the spring of 2009.

Field	Collection dates								
	April 20	April 27	May 18	May 21	May 27	June 8	June 16	June 22	June 30
	(Adults per field)								
1	--[1]	--	1	3	9	14	7	2	1
2	--	--	1	1	14	17	7	2	0
3	--	--	1	0	6	2	1	4	3
4	0	0	5	--	17	27	4	8	12
5	--	--	6	0	1	3	2	4	--

[1] Traps not collected.

Table 2. Number of adult billbugs collected in pitfall traps from fields located on the Agency plains near Madras, Oregon, during the fall of 2009.

Field	Collection dates						
	Sept. 18	Sept.25	Oct. 2	Oct. 8	Oct. 15	Oct.23	Nov. 5
	(Adults per field)						
1	1	0	0	0	0	0	0
2	--[1]	--	--	--	--	--	--
3	1	0	0	--	--	0	0
4	--	6	9	7	10	6	2
5	0	1	1	0	1	0	--

[1] Traps not collected due to field being removed after harvest.

Table 3. Number of billbug adults and larvae collected from sod samples taken from fields located on the Agency plains near Madras, Oregon during the spring of 2009.

Field	Collection dates							
	May 26	June 9	June 22	July 7	May 26	June 9	June 22	July7
	(Adults per field)				(Larvae per field)			
1	1	0	2	1	1	0	18	7
2	3	6	4	--[1]	17	9	8	--
3	1	1	3	0	0	0	28	0
4	0	6	3	10	37	19	7	16
5	4	0	1	--	2	3	6	--

[1]Sample not collected.

Table 4. Number of billbug adults and larvae collected from sod samples taken from fields located on the Agency plains near Madras, Oregon during the fall of 2009.

	Collection dates									
Field	Sept. 22	Oct. 8	Oct. 23	Nov. 5	Nov. 24	Sept. 22	Oct. 8	Oct.23	Nov.5	Nov. 24
	-----------------(Adults per field)-----------------					------------------(Larvae per field)----------------				
1	1	4	6	3	3	53	56	34	20	11
2	--[1]	--	--	--	--	--	--	--	--	--
3	3	0	0	0	0	12	19	19	16	6
4	10	9	7	4	2	16	2	8	12	1
5	2	1	--	--	--	4	14	--	--	--

[1] Sample not collected due to field being removed after harvest.

EVALUATION OF SIMULATED HAIL DAMAGE TO KENTUCKY BLUEGRASS SEED PRODUCTION IN CENTRAL OREGON, 2009

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. The objective of this three-year project is to determine the impact from timing and severity of hail damage on seed production of Kentucky bluegrass. This information is being generated to assist the National Crop Insurance Service in developing methodology to evaluate hail damage on Kentucky bluegrass.

This is the third 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 second-year field of 'Shamrock' with Macy 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 3-ft alleyways across the front and back of each block of plots. Treatments were made on May 8, May 27, and June 23 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 2, 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.

Yield data from the two previous years were similar, while yields from this year did not follow the same pattern (Table 1). In previous years, damage at head emergence resulted in the greatest reduction in yield, with 33 or 67 percent damage at this stage having a significantly greater effect on seed yield than did other treatment timings. This year damage at the beginning of seed fill resulted in the highest yield reduction, with damage at the boot stage and head emergence being similar.

In previous years 100 percent damage at the boot stage, the plant was able to recover with 50 and 41 percent of yield in the untreated plots. This year seed yield for this treatment timing was 10 percent of the untreated plot. Damage of 100 percent later in plant development, at head emergence or seed fill, consistently eliminates any yield potential.

Table 1. Simulated hail damage on Kentucky bluegrass grown for seed with damage inflicted at boot, head emergence and seed filling prior to harvest on July 2, 2009.

Hail damage		Seed yield		
Growth stage	Damage (%)	Pounds/acre		% Untreated[1]
Boot	33	583	bc[2]	66
	67	559	c	63
	100	90	e	10
Heads emerged	33	701	b	79
	67	577	c	65
	100	0	f	0
Seed fill	33	525	c	59
	67	343	d	39
	100	0	f	0
Untreated	---	890	a	100

[1] The heading "% Untreated" is a comparison of yields from the treated plots with the untreated plots of the same variety.
[2] Mean separation with Least Significant Difference (LSD) at $P \leq 0.05$.

CONTROL OF CLOVER MITE AND WINTER GRAIN MITE IN ORCHARDGRASS HAY FIELDS AND PASTURE, 2009

M.G. Bohle, G.C. Fisher, A.J. Dreves and R.P. Affeldt

Introduction

Clover mite (CLM; *Bryobia praetiosa*), and winter grain mite (WGM; *Penthaleus major*) continue to be pests of grass pastures and hay fields in Deschutes, Jefferson and Crook counties in central OR. Populations of CLM can occur in combination with WGM and are most active during cooler periods of the year (mid-fall to late spring) with peak populations and corresponding damage occurring in late winter and early spring months. Mites feed at night and on cloudy days and are present on the soil surface during the day. They remain active for several months until temperatures routinely exceed 60ºF. Mite injury during spring re-growth results in stunted and chlorotic leaves. Portions of and entire orchardgrass crowns are killed.

Clover Mite Life History: In central Oregon, CLM appear to primarily spend the summer months as eggs either in the soil or in the crowns of pasture grass. These eggs hatch in late September, producing adult mites by the end of October. Some of these mites survive the winter and become active in late February and March. Others produce eggs that will overwinter in the field and hatch the following spring. Clover mite populations build rapidly beginning in late March and peak in April or May, which is when crop damage occurs. Orchardgrass samples from central Oregon pastures consisting of 2.5- inch diameter cores from the crowns have revealed hundreds of mites per sample in April and May. Symptoms of activity in the spring for the clover mite includes little to no spring re-growth, yellowish-chlorotic leaves and dead areas in pastures. Effective products to control CLM have yet to be identified and labeled.

Winter Grain Mite Life History: WGM are most common on grasses and cereals in central Oregon in the fall and late winter. One generation occurs in the fall from eggs that over-summered in the field. A second generation occurs from late winter through early spring. Cereals, grasses and some broadleaf plants are hosts. Eggs hatch in October and resultant mites feed, mature and begin laying eggs in November. This mite can lay 2 to 3 eggs per day and up to 60 eggs in a lifetime. Ideal temperatures for this mite are between 50 to 60 °F. Peak activity usually occurs in late fall and again in February and March. However the mites are present and cause damage through the winter. Feeding by this mite causes grasses to turn silver or dull gray; often the leaf tips brown and die. Winter grain mite has required control measures in grass seed crops, cereals, orchardgrass and timothy pastures and hay fields. Effective products are available to control this pest in most crops, including pasture and hay fields, and should be applied in late October, late winter or early spring when populations build, but before damage is noticeable.

The objective of this trial was to evaluate potential products for the control of these two mites.

Materials and Methods

Three products were evaluated for control of CLM infesting a 4 year old mixed grass species field in the Lower Bridge area (west of Terrebonne), Deschutes County, Oregon. The main grass species in the field was orchardgrass, along with some smooth brome, timothy, bluegrass, and quackgrass present. These other grasses suffered much less damage than the orchardgrass, with Timothy the exception. The pasture was being grazed by horses at the start of the trial, but then the horses were removed from the field on May 15. The field was not fertilized or irrigated.

CLOVER MITE

WINTER GRAIN MITE

DAMAGE

The field trial was designed as a randomized complete block with plots measuring 20 × 20 ft and replicated 4 times. At the time, treatments were applied on April 4, 2009, the orchardgrass had broken dormancy and new leaves were 1 to 3 inches long. Insecticides were delivered with a CO^2 powered backpack sprayer using a 6 nozzle (AM 11002 flat fan) hand held boom that covered a 10 ft swath. Spray pressure was set at 40 psi, and delivered an equivalent of 20 gpa.

Evaluation of plots consisted of extracting three cores for pre-treatment application, and four cores for post treatment. Cores were 2.5 inch diameter cores to a depth of 2 inches from randomly selected orchardgrass crowns. Samples were placed in paper bags and then into plastic zip lock bags. The samples were transported in a cooler to a laboratory in Corvallis where Berlese funnels equipped with 25W bulbs extracted mites and other arthropods from the treated crowns into 70% EOH.. All instar stages of CLM and WGM were counted and recorded for all plots on 9 sampling dates: April 2 (pre-), April 10 (6 Days after treatment (DAT)), April 13 (13 DAT), April 20 (20 DAT), May 1 (27 DAT), May 8 (34 DAT), May 15 (41 DAT), May 29 (55 DAT), and June 5 (62 DAT).

In addition, a visual assessment of mite damage in all plots was made on four sample dates on May 1, 8, 15, and 29. The subjective assessment was based on relative grass height, color, vigor, affected plants, and employed a scale of 1 to 5 (1 representing least regrowth and serious chlorosis; 5 representing greatest regrowth and least chlorosis). This was made more difficult by horses grazing in the trial area.

Each plot was harvested on June 23, 2009 for dry matter yield. A 34-inch x 18 feet swath was cut from the interior of each plot from east to west borders. Excessive growth areas resulting from horse urine and manure were avoided. One half to one pound samples were oven dried at 120°F until there were no changes in weights. Plot weights were converted to per acre DM yields.

Data were subjected to analysis of variance (ANOVA) and means were separated using Fishers LS Means (LSD) test at p-value =.05. All mite number values were transformed using square root transformation to equalize variance.

Results and Discussion

Cobalt® at 26 ounces per acre of product gave excellent control of both CLM and WGM through the duration of the trial, resulted in the least amount of visual damage from these mites, and produced the second greatest yield of dry matter weight, though not significantly different from the other treatments, but significantly greater than the untreated control (Table 1, 2, 3).

None of the other treatments resulted in reduction of CLM that was significantly different from the untreated control. Interestingly, the CLM population in the Brigade 2EC + Exponent 8L treatment tended to increase and persisted one week longer than the untreated check population. The CLM population generally declined from April 2 and then completely crashed between May 29 and June 5. A few mites remained in the Brigade 2EC + Exponent 8L plots (Table 1).

The WGM population started declining after April 10 (6 DAT) and collapsed by May 1 (27 DAT). WGM populations in the Brigade and Brigade plus Exponent® treatments were lower than those in the UTC at 6, 13 and 20 DAT. These reductions, however, were only significantly different at 20 DAT. The addition of Exponent® to Brigade did not improve control over Brigade alone with WGM (Table 2).

Oberon did not control either mite species at the rates evaluated in this trial. Numbers of mites remained statistically similar to those in the untreated control for the duration of the trial. However, there was a trend for fewer mites with the high rate of Oberon compared to the UTC and low rate of Oberon. This trend was noticeable beginning at 13DAT. Visual ratings for damage between the two treatments were similar.

Brigade 2EC and Cobalt treated plots produced the greatest dry matter forage weight of all plots. These differences were statistically different from the dry matter forage weight recorded from the UTC. Plots treated with Cobalt produced the best visual grass rating scores for least amount of visible damage. Interestingly, although CLM numbers remained fairly high in the Brigade 2EC plots, feeding damage was not correspondingly great! The addition of Exponent® to Brigade appeared to reduce CLM control (though not significantly), damage symptoms were significantly increased and dry matter forage weight slightly reduced compared to Brigade alone.

Numerical differences in dry weight yield among treated plots were not great, all were statistically similar. Yields were greatest in Colbalt and Brigade 2EC plots and were significantly greater than the yield in the UTL (Table 3). Small differences in yield could be due to adequate field moisture and fertility combined with even grazing from the horses.

Timely rains and cool weather did help to keep the grass growing relatively well through out the trial period, until the week before harvest.

Acknowledgement:

We gratefully acknowledge the cooperation of Steve and Kathy Simpson for allowing this research to take place on their farm.

Table 1. Mean number of clover mites per 2.5 inch diameter core through orchardgrass crowns to a depth of 2 inches by treatment and date, Deschutes Co., OR in 2009.

		Mean number of clover mites per 2.5-inch grass core[3,4]								
Treatment[1,2]	Rate (fl oz/a)	4/2/09 Pre-	4/10/09 6 DAT	4/17/09 13 DAT	4/24/09 20 DAT	5/01/09 27 DAT	5/8/09 34 DAT	5/15/09 41 DAT	5/29/09 55 DAT	6/5/09 62 DAT
Untreated Check	--	247.3 ±59.5	118.1a ±28.9	84.4a ±22.9	174.6a ±67.3	99.2a ±20.1	46.8a ±4.8	80.8a ±24.1	20.8b ±4.9	0b
Oberon 2SC Low	8	321.0 ±57.6	173.4a ±39.0	94.7a ±23.9	126.8a ±38.8	64.1a ±12.6	36.1a ±19.1	67.4a ±23.1	NA	NA
Oberon 2SC High	12	337.8 ±23.2	112.2a ±26.5	61.9a ±18.9	58.8a ±13.9	35.0a ±8.3	20.6a ±3.9	20.9a ±5.5	NA	NA
Brigade 2EC	6.4	298.0 ±97.3	127.5a ±24.2	95.6a ±24.7	92.8a ±19.4	60.3a ±33.5	34.5a ±4.2	32.8a ±14.5	NA	NA
Brigade 2EC + Exponent 8L	6.4	292.3 ±81.0	145.0a ±33.6	185.9a ±23.7	145.0a ±11.9	52.1a ±12.6	37.6a ±11.6	66.3a ±20.0	62.5a ±18.5	2.0a ±0
Cobalt	26	250.0 ±54.6	13.8b ±3.3	5.3b ±1.9	2.8b ±0.60	1.5b ±0.3	0.5b ±0.1	1.5b ±1.2	NA	NA
F		0.33	15.98	17.94	39.04	23.21	36.78	1.48	19.48	Infty
P-Value		NS	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

[1] Treatments were applied on April 4, 2009.
[2] SuperSpread 7000L was added to all product tank mixes at an equivalent rate of 2 pt /100gal.
[3] Means followed by the same letter are not significantly different ($P = 0.05$; Fishers LS Means Test).
[4] Data were transformed using (Log (x + 0.01)) to reduce variation. Original means are presented in table.
Plots not sampled at 55 DAT and 66 DAT are listed as NA, not applicable.

Table 2. Mean number of live winter grain mites per 2.5 inch diameter core through orchardgrass crowns to a depth of 2 inches by treatment and date, Deschutes Co., OR in 2009.

		Mean number of winter grain mites per 2.5-inch grass core[3,4]						
Treatment[1,2]	Rate (fl oz/a)	4/2/09 Pre-	4/10/09 6 DAT	4/17/09 13 DAT	4/24/09 20 DAT	5/01/09 27 DAT	5/8/09 34 DAT	5/15/09[5] 41 DAT
Untreated Check Check	-	11.3 ±3.0	11.6a ±3.1	8.8ab ±3.1	10.6a ±2.8	0.3a ±0.3	0.1 ±0.1	0.6 ±0.4
Oberon 2SC Low	8	22.0 ±3.8	12.2a ±2.8	13.8a ±2.4	9.1a ±1.6	1.3a ±0.9	0.9 ±0.3	0.1 ±0.1
Oberon 2SC High	12	19.5 ±6.2	6.5a ±2.5	7.5abc ±3.7	7.2a ±2.6	0.8a ±0.1	0.5 ±0.4	0.3 ±0.3
Brigade 2EC	6.4	9.5 ±2.2	2.2ab ±1.4	1.3bc ±1.3	0b	0b	0.1 ±0.1	0
Brigade 2EC + Exponent 8L	6.4	10.8 ±3.3	0.94ab ±0.31	1.3bc ±0.9	0b	0b	0	0
Cobalt	26	13.8 ±4.6	0.31b ±0.31	0c	0b	0b	0	0
F		1.58	5.39	5.98	229.89	4.89	2.27	1.24
P-value		NS	<0.0033	0.0021	0.0059	0.0059	NS	NS

[1] Treatments were applied on April 4, 2009.
[2] SuperSpread 7000L was added to all product tank mixes at an equivalent rate of 2 pt /100gal.
[3] Means followed by the same letter are not significantly different ($P = 0.05$; Fishers LS Means Test).
[4] Data were transformed using (Log (x + 0.01)) to reduce variation. Original means are presented in table.
[5] No winter grain mites were found in samples after 5/15/09.

Table 3. Equivalent per acre dry matter yield of orchardgrass hay and visual ratings of clover mite damage by treatment and date, Deschutes Co., OR 2009.

	Harvest yield[1,2,3,4] (lb/a)	Clover mite damage rating [3,4,5] (0-5; 1 = damage, 5 = no damage)			
Treatment	June 23	May 1	May 8	May 15	May 29
Untreated Check	893.1b ±94.4	1.60c ±0.20	1.88c ±0.18	1.95b ±0.18	1.95b ±0.19
Oberon 2SC Low	1066.3ab ±39.1	1.53c ±0.31	1.78c ±0.21	2.03b ±0.20	2.03b ±0.18
Oberon 2SC High	1030.2ab ±68.1	1.48c ±0.19	1.90c ±0.24	1.70b ±0.18	1.88b ±0.18
Brigade 2EC	1183.8a ±82.9	2.83a ±0.18	3.10a ±0.17	3.35a ±0.37	3.28a ±0.34
Brigade 2EC + Exponent 8L	1049.9ab ±81.6	1.75bc ±0.32	1.93bc ±0.29	2.23b ±0.34	1.95b ±0.26
Cobalt	1139.9a ±57.3	2.43ab ±0.35	2.63ab ±0.31	3.33a ±0.47	3.18a ±0.46
F	1.90	4.38	4.67	5.38	5.29
P-value	NS	< 0.0087	< 0.0066	< 0.0034	< 0.0037

[1] Orchardgrass was harvested on June 23, 2009. Samples were oven dried at 120°F until no further change in weights were observed.
[2] Treatments applied on April 4, 2009.
[3] Means followed by the same letter are not significantly different ($P = 0.05$; Fisher's LSD Mean).
[4] Data were transformed using Logarithm to reduce variation. Original means are presented in table.
[5] A rating of 1(least regrowth, serious chlorosis) to 5 (most regrowth least chlorosis) scale was used to quantify orchardgrass damage.

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Business Address

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

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

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