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**Edited by Andrew Hulting, Nicole Anderson, Darren Walenta, and Michael Flowers**



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**The following authors have contributed to this report.**


**Central Oregon Agricultural Research Center**

G. Sbatella, Assistant Professor, Weed Scientist
S. Twelker, Biological Sciences Research Technician

**Cooperative Extension Service – OSU**

N.P. Anderson, North Valley Extension Field Crops Agent, Washington, Yamhill and Polk Counties
D.L. Walenta, Extension Crops Specialist, Union County

**Department of Crop and Soil Science – OSU**

T.G. Chastain, Associate Professor, Seed Crop Physiology
A.R. Corkery, Technician, Entomology
D.W. Curtis, Faculty Research Assistant, Weed Science
S. Elias, Associate Professor, Senior Research, Seed Science and Technology
A. Garay, Manager of OSU Seed Laboratory
C.J. Garbacik, Senior Faculty Research Assistant, Seed Crop Physiology
R. Hankins, Instructor and Seed Certification Specialist
G.D. Hoffman, Faculty Research Assistant, Integrated Pest Management
A.G. Hulting, Associate Professor, Extension Weeds Specialist
C.A. Mallory-Smith, Professor, Weed Science
S. Rao, Professor, Entomology
K.C. Roerig, Faculty Research Assistant, Weed Science
W.C. Young III, Professor Emeritus, Extension Seed Production

**Department of Horticulture – OSU**

D. Bruck, Courtesy Research Entomologist (USDA-ARS)

**Hermiston Agricultural Research and Extension Center**

P.B. Hamm, Station Director and Professor Emeritus

**Hermiston Experiment Station**

J.K.S. Dung, Postdoctoral Scholar, Plant Pathology

**National Forage Seed Production Research Center - USDA-ARS**

S.C. Alderman, Professor and Research Plant Pathologist
G.M. Banowetz, Research Plant Physiologist and Research Leader
B.L. Barnhart, Research Physical Scientist
S.M. Griffith, Professor and Research Plant Physiologist
G.W. Mueller-Warrant, Associate Professor and Research Agronomist
W. Pfender, Research Plant Pathologist
G.W. Whittaker, Research Hydrologist

**Private Industry**

D. Gady, Engineer, Farm Power, Rockford, WA



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# OCCURRENCE AND TRENDS OF WEED SEED CONTAMINANTS IN FINE FESCUE SEED LOTS IN OREGON[1]

*S.C. Alderman, S. Elias, and A.G. Hulting*

## Introduction

Approximately 60% of fine fescue seed is produced in the foothills of the Cascade Mountains (Silverton Hills) east of Salem, in Marion and northern Linn Counties. An additional 30% of the seed production occurs in the Grand Ronde Valley in the northeastern region of Oregon, near LaGrande, in Union County. The remaining acreage is scattered among counties in the northern half of the state, especially near the eastern end of the Columbia River Gorge.

State and Federal seed laws include lists of prohibited and restricted noxious weed species in order to limit the spread of weeds and the introduction and spread of objectionable weed species. In addition, seed certification programs in each state have their own maximum standards of tolerance for weed seeds in seed lots. Contamination of fine fescue seed with undesirable weed species reduces the value of high quality seed for the end user and increases production costs to control weeds introduced with the seed. However, little is known about the species diversity and frequency of occurrence of weed seed contaminants in fine fescue seed produced in Oregon. An unpublished list of weed contaminants, based on seed lot samples submitted to the Oregon State University Seed Laboratory (OSU Seed Lab) during the period 1986–1995, was prepared for the Oregon Department of Agriculture Field Burning Alternatives Research Program (Dade, 1996). Beyond this, our understanding of the occurrence of weed seeds in fine fescue seed lots is incomplete, and published reports of weed seed occurrence of weed seed contamination in fine fescue seed lots are lacking.

Nearly all fine fescue seed produced in Oregon is certified. Purity analyses for certified seed lots are conducted at the OSU Seed Lab after harvest, as required by OSU's Seed Certification program. During purity analysis, the sample is separated into four components: pure seed, weed seed, inert matter, and other crops. Each component is determined as a percentage by weight. Weed seeds are identified by accredited seed analysts.

The objective of this study was to develop a comprehensive summary of weed seed occurrence in Oregon fine fescue seed lots, based on OSU Seed Lab purity reports between 1986–1995 and 2002–2006.

## Materials and Methods

Data for 1986–1995 were obtained and compiled from a summary report of weed seed occurrence in certified seed samples of chewings fescue, red fescue, and hard fescue, prepared by Dade (1996). Data for 2002–2006 were obtained from the purity records of the OSU Seed Lab. The OSU Seed Lab purity records list weed seed contaminants by common and scientific name, based on the Uniform Classification of Weed and Crop Seeds (AOSA, 2010a). Non-certification records and duplicate records associated with retesting of a given fine fescue seed lot were excluded. Purity samples were drawn according to the AOSA Rules for Testing Seeds (AOSA 2010b). The size of purity sample for fine fescues is 3 g (approximately 2,500 seeds). In addition, a total of 30 g (25,000 seeds) are inspected using the 'all states noxious weed exam' for the presence of prohibited noxious weed seeds, based on official lists of noxious weed seeds in the state of Oregon.

Data were summarized to include the number of years in which each contaminant was found (frequency of occurrence) and the percentage of seed lots in which each contaminant was detected in each

[1] *This report is a condensed version of a paper of the same title published in Seed Technology in 2011, Vol. 33: 7-21.*

year. Common and scientific names used throughout this report were based on the Uniform Classification of Weed and Crop Seeds (AOSA, 2010a).

**Results**

Chewings Fescue

In chewings fescue, 68 weed contaminants were identified to species and 23 to genus (Table 1). The most prevalent contaminant was *Vulpia myuros* L. (rattail fescue), occurring annually in 30% to 61% of samples. Other species occurring annually were*Bromus tectorum* L. (downy brome) in 1.0% to 5.9% of samples, and *Poa annua* L. (annual bluegrass) in 2.0% to 17.1% of samples. All three of the grasses are widespread weeds in Oregon. Most of the other weed species detected in samples occurred infrequently, with 37% occurring in two to four years out of 15, and 36% occurring in only a single year. In 2002–2006, 32% to 58 % of seed lots were free of contaminants and less than 7% of samples had three or more different contaminant species. In most cases, only one to several seeds of any given species was detected in the purity test. The occurrence of new species (or genera), relative to 1986, increased at the rate of 2.6 per year. From 1986 and 2006, the percentage of samples with *Anthoxanthum* spp. (vernal grass) or *Rumex acetosella* L. (sheep sorrel) decreased. *Lolium* spp. (ryegrass) seeds, found in 6.8 to 17.5% of samples in 2002–2006, were not reported in 1986-1995, presumably because ryegrass would have been listed as crop rather than weed in the database used by Dade (1996).

Red Fescue

Seventy-five weed contaminants were identified to species and 18 to genus in red fescue (Table 1). The most common contaminant was *V. myuros*, occurring annually in 24.8% to 58.1% of the samples, depending on year. *P. annua* occurred in 13 out of 15 years in up to 24.2% of the samples. Forty percent of the contaminant species occurred in 2 out of 4 years and 32% in only a single year. In 2002–2006, 35% to 54% of seed samples were free of weed seed contaminants and 38–40% had only a single species contaminant. The occurrence of new species, increased at the rate of 2.8 species per year. *Lolium* spp. seeds, common in 2002–2006 (6.3% to 13.8% of samples) were not reported in 1986–1995. From 1986 to 2006, the percentage of samples with *Anthricus caucalis* M. Bieb. (bur chervil) decreased.

Hard Fescue

Data from Dade (1996) did not include hard fescue, so only data for 2002–2006 are included. Thirty-three weed seed contaminants were identified to species and seven to genus (Table 1). The most common contaminants, occurring in four out of the five years, were *V. myuros* and *Lolium* spp. Seventy-nine percent of the species contaminants occurred in only one of the five years. In 2002–2006, 20.0% to 42.68% of seed lots were free of contaminants and less than 7% of samples had three or more different contaminant species. No trends of increasing or decreasing levels of any of the contaminant species, with respect to time, were detected.

**Discussion**

Results from this study indicate that a great diversity of contaminants can occur in certified fine fescue seed lots, although most contaminants occurred at a low level and in few years. Approximately one third of the contaminant species occurred in only one out of the 15 years included in the study. Few species, such as *V. myuros*, *P. annua*, and *B. tectorum* were prevalent at high levels or in most years.

Predictably, the most commonly occurring contaminants were winter annual grass weeds, including *V. myuros*, *P. annua*, and *B. tectorum*, reflecting the difficulty of selectively managing these species in seedling and established perennial fine fescue crop fields. In perennial grass seed fields in Oregon, *B. tectorum* has been problematic since the 1950's and *V. myuros* since the 1960's (Lee, 1965). A variety of cultural and chemical weed management tactics are employed annually to control these species, but adequate control can be elusive and seed production from weed management escapees often occurs, resulting in contaminated fine fescue seed lots.

*Vulpia myuros* is an increasing problem in grass grown for seed and cereal-based cropping systems across the Pacific Northwest because of its relative tolerance to many of the commonly-applied herbicides used in grass seed and cereal production and its ability to flourish in conservation tillage

production systems (Ball and Hulting, 2009; Ball et al., 2008; Jemmett et al., 2008; Mueller-Warrant et al., 2008). Past chemical management practices have selected for *P. annua* biotypes that are resistant to diuron, ethofumesate or both. At one time these herbicides were standards for selectively controlling annual grass species in seedling (activated carbon-seeding systems) and established perennial grass seed crop fields. Herbicide resistant *P. annua* biotypes are now geographically widespread and result in serious seed contamination issues on an annual basis.

Generally, weed seeds that are similar in size, shape and weight to the crop being cleaned are difficult to separate using air screen machines or similar cleaning equipment, whereas those that are different in size and terminal velocity from the crop can be removed easily. Therefore, producing seeds that are free from weed seed contaminants should start with a successful management program in the field whenever possible. In addition to testing certified seed lots after harvest and cleaning to ensure meeting minimum quality standards for seed lot certification, certified fields also are inspected during the growing season to assure their cleanness from weeds. This may contribute to the relatively low weed contamination incidents in certified seed lots noted in this study.

The sources or mechanisms of weed seed contamination in seed lot samples were not determined and are beyond the scope of this study. We hypothesize that the source of most contaminants was weed populations growing in individual fields, but cannot exclude the possibility of contaminant sources outside the production fields, including wind borne seed contamination or inadvertent introduction of contaminants during transport, storage, or conditioning of seed lots.

As new weed species continue to invade production areas and are increasingly moved around the environment, the number of weed species detected in fine fescue seed lots is expected to continue to increase. Depending on the weed species, this may or may not represent a production problem from a pest management perspective. Management of the more common and persistent contaminants is the focus of ongoing weed science research in fine fescues grown for seed. Most contaminant species will likely fall into the rare or uncommon occurrence categories and will not represent significant management challenges for fine fescue seed production. However, weed seed contamination will continue to pose a problem for seed shipments to domestic and international markets, depending on which contaminant species are restricted or prohibited from entry.

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Table 1. Weed seeds occurring in Oregon chewings fescue (*Festuca rubra* L. subsp. *commutata* Gaudin) red fescue [*Festuca rubra* L. subsp. *rubra*], and hard fescue [*Festuca trachyphylla* (Hack.) Krajina] seed lots, frequency of occurrence, and range of percentage of seed lots contaminated per year. Data summarized for years 1986–1995 and 2002–2006.

| Weed species | Common name | Chewings fescue | | Red fescue | | Hard fescue | |
|---|---|---|---|---|---|---|---|
| | | f[†] | range[‡] | f[†] | range | f[§] | range |
| *Agrostis* L. spp. | bentgrass | 2 | 0-1.2 | 1 | 0-1.4 | 2 | 0-2.5 |
| *Aira* L. spp. | hairgrass | - | - | 4 | 0-1.1 | - | - |
| *Aira caryophyllea* L. | silver hairgrass | 1 | 0-1.0 | 1 | 0-1.6 | - | - |
| *Allium vineale* L. | wild garlic | 4 | 0-2.1 | 3 | 0-6.7 | - | - |
| *Alnus* Mill spp. | alder | 1 | 0-0.7 | - | - | - | - |
| *Alopecurus* L. spp. | foxtail | 1 | 0-0.6 | - | - | - | - |
| *Alopecurus pratensis* L. | meadow foxtail | 3 | 0-1.1 | - | - | - | - |
| *Amaranthus retroflexus* L. | redroot pigweed | 3 | 0-2.0 | 3 | 0-1.6 | 1 | 0-2.1 |
| *Amsinckia* Lehm. spp. | fiddleneck | 2 | 0-0.8 | 5 | 0-3.1 | - | - |
| *Amsinckia intermedia* Fisch. & C. A. Mey | coast fiddleneck | - | - | 2 | 0-1.0 | - | - |
| *Anthemis arvensis* L. | field chamomile | 13 | 0-11.7 | 12 | 0-10.3 | 3 | 0-2.6 |
| *Anthemis cotula* L. | dogfennel | 4 | 0-1.3 | 6 | 0-4.6 | - | - |
| *Anthoxanthum* L. spp. | vernalgrass | 10 | 0-7.6 | 4 | 0-4.8 | - | - |
| *Anthriscus caucalis* M. Bieb. | bur chervil | 11 | 0-3.6 | 9 | 0-4.6 | 2 | 0-7.5 |
| *Apera spica-venti* (L.) P. Beauv. | windgrass | 1 | 0-1.0 | 8 | 0-4.0 | - | - |
| *Avena fatua* L. | wild oat | 3 | 0-5.0 | 3 | 0-4.8 | - | - |
| *Brassica* L. spp. | *Brassica* spp. | 3 | 0-3.0 | 3 | 0-3.0 | - | - |
| *Bromus arvensis* L. | field brome | 1 | 0-0.6 | 2 | 0-2.0 | - | - |
| *Bromus commutatus* Schrad. | hairy chess | 4 | 0-1.0 | 6 | 0-1.1 | 2 | 0-2.6 |
| *Bromus hordeaceus* L. | soft chess | 4 | 0-0.9 | 7 | 0-4.8 | 1 | 0-1.1 |
| *Bromus japonicus* Thunb. | Japanese brome | - | - | 1 | 0-1.9 | - | - |
| *Bromus sterilis* L. | barren chess | - | - | 2 | 0-1.1 | - | - |
| *Bromus tectorum* L. | downy brome | 14 | 1.0-5.9 | 8 | 0-15.1 | 3 | 0-10.0 |
| *Capsella bursa-pastoris* (L.) Medik. | Shepherd's-purse | 5 | 0-0.8 | 1 | 0-1.0 | 2 | 0-2.9 |
| *Carex* L. spp. | sedge | 13 | 0-2.4 | 11 | 0-5.6 | 1 | 0-4.3 |
| *Centaurea cyanus* L. | cornflower, ragged robin | 7 | 0-1.2 | 1 | 0-1.6 | - | - |
| *Cerastium* L. spp. | mouse-ear chickweed | 1 | 0-0.7 | 1 | 0-0.8 | - | - |
| *Cerastium glomeratum* Thuill. | sticky mouse-ear | 2 | 0-0.8 | - | - | - | - |
| *Chenopodium album* L. | common lamb's-quarters | 1 | 0-1.0 | 4 | 0-1.1 | 1 | 0-2.5 |
| *Chorispora tenella* (Pall.) DC. | blue mustard | - | - | - | - | 1 | 0-1.1 |
| *Cirsium arvense* (L.) Scop. | Canada thistle | 5 | 0-2.5 | 4 | 0-1.5 | - | - |
| *Cirsium vulgare* (Savi) Ten. | bull thistle | - | - | 3 | 0-1.1 | - | - |
| *Crepis capillaris* (L.) Wallr. | smooth hawksbeard | 1 | 0-0.4 | - | - | - | - |
| *Cynodon dactylon* (L.) Pers. var. *dactylon* | bermudagrass | - | - | 1 | 0-1.1 | - | - |
| *Dactylis glomerata* L. | orchardgrass | - | - | 1 | 0-0.7 | - | - |
| *Daucus carota* L. subsp. *carota* | wild carrot | 1 | 0-0.7 | 4 | 0-4.0 | - | - |
| *Descurainia sophia* (L.) Webb ex Prantl | flixweed | - | - | 2 | 0-5.2 | - | - |
| *Digitalis purpurea* L. | common foxglove | 1 | 0-0.6 | - | - | - | - |
| *Digitaria sanguinalis* (L.) Scop. | large crabgrass | 3 | 0-1.0 | 2 | 0-2.0 | - | - |
| *Echinochloa crus-galli* (L.) P. Beauv. | barnyardgrass | - | - | 3 | 0-4.2 | 1 | 0-2.5 |
| *Eleocharis obtusa* (Willd.) Schult. | blunt spikerush | 1 | 0-1.0 | - | - | - | - |
| *Elymus* L. spp. | wildrye | 1 | 0-0.6 | - | - | - | - |
| *Elymus repens* (L.) Gould | quackgrass | 7 | 0-7.9 | 5 | 0-2.9 | - | - |
| *Erodium cicutarium* (L.) L'Hér. | redstem filaree | 4 | 0-1.4 | 4 | 0-1.6 | 1 | 0-1.1 |
| *Fallopia convolvulus* (L.) Á. Löve | wild buckwheat | 2 | 0-1.6 | 3 | 0-1.1 | - | - |
| *Festuca arundinacea* Schreb. | tall fescue | 4 | 0-1.0 | 2 | 0-1.1 | 1 | 0-2.1 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Galium* L. spp. | bedstraw | 4 | 0-2.7 | 10 | 0-6.7 | 3 | 0-10.0 |
| *Galium aparine* L. | cleavers | - | - | - | - | 1 | 0-2.9 |
| *Geranium* L. spp. | cranesbill | 1 | 0-0.5 | - | - | - | - |
| *Glyceria* R. Br. spp. | mannagrass | 1 | 0-0.9 | - | - | - | - |
| *Holcus* L. spp. | velvetgrass | 2 | 0-1.8 | 8 | 0-6.2 | - | - |
| *Holcus lanatus* L. | velvetgrass | - | - | 1 | 0-1.1 | - | - |
| *Holcus mollis* L. | German velvetgrass | 2 | 0-0.5 | - | - | - | - |
| *Hordeum* L. spp. | wild barley | - | - | 3 | 0-1.9 | - | - |
| *Hypericum perforatum* L. | common St. John's-wort | 1 | 0-0.5 | - | - | - | - |
| *Hypochaeris radicata* L. | spotted cat's-ear | 12 | 0-5.6 | 10 | 0-6.3 | 1 | 0-6.4 |
| *Juncus bufonius* L. | toad rush | 10 | 0-5.9 | 8 | 0-1.6 | 2 | 0-2.6 |
| *Juncus tenuis* Willd. | path rush | 2 | 0-0.6 | 3 | 0-1.6 | - | - |
| *Lactuca* L. spp. | wild lettuce | - | - | 1 | 0-0.8 | - | - |
| *Lactuca serriola* L. | prickly lettuce | - | - | 1 | 0-1.1 | - | - |
| *Lamium amplexicaule* L. | henbit | 8 | 0-1.0 | 10 | 0-1.8 | 2 | 0-2.6 |
| *Lapsana communis* L. | nipplewort | 6 | 0-0.6 | 5 | 0-2.1 | 1 | 0-2.9 |
| *Leontodon saxatilis* Lam. | rough hawkbit | 6 | 0-1.7 | 4 | 0-3.2 | 1 | 0-2.6 |
| *Lepidium heterophyllum* Benth. | Smith pepperweed | 1 | 0-0.6 | - | - | - | - |
| *Leucanthemum vulgare* Lam. | ox-eye daisy | 3 | 0-1.6 | 1 | 0-1.6 | 1 | 0-2.6 |
| *Lolium* L. spp. | ryegrass | 4 | 0-17.5 | 4 | 0-13.8 | 4 | 7.5-14.7 |
| *Lotus* L. spp. | trefoil | 3 | 0-1.0 | - | - | - | - |
| *Lotus micranthus* Benth. | slender trefoil | 2 | 0-0.8 | 1 | 0-1.9 | - | - |
| *Matricaria chamomilla* L. | sweet false chamomile | 1 | 0-0.9 | 1 | 0-1.6 | - | - |
| *Matricaria discoidea* DC. | pineappleweed | 1 | 0-0.7 | 1 | 0-1.6 | 1 | 0-2.6 |
| *Medicago lupulina* L. | black medic | - | - | 1 | 0-2.0 | - | - |
| *Onopordum acanthium* L. | scotch thistle | - | - | 1 | 0-2.0 | - | - |
| *Panicum capillare* L. | witchweed | 4 | 0-1.0 | 3 | 0-1.4 | - | - |
| *Parentucellia viscosa* (L.) Caruel | parentucellia | - | - | 1 | 0-1.0 | - | - |
| *Persicaria lapathifolia* (L.) Delarbre | pale smartweed | - | - | - | - | 1 | 0-2.5 |
| *Persicaria maculosa* Gray | ladysthumb | 8 | 0-3.6 | 9 | 0-3.0 | - | - |
| *Persicaria pensylvanica* (L.) M. Gómez | Pennsylvania smartweed | 1 | 0-0.4 | - | - | - | - |
| *Phacelia* Juss. spp. | scorpionweed | 3 | 0-0.8 | 2 | 0-1.1 | - | - |
| *Phalaris arundinacea* L. | reed canarygrass | - | - | 2 | 0-1.1 | - | - |
| *Plantago lanceolata* L. | buckhorn plantain | 3 | 0-2.5 | 3 | 0-1.4 | - | - |
| *Poa* L. spp. | bluegrass | 1 | 0-1.0 | 2 | 0-2.0 | - | - |
| *Poa annua* L. | annual bluegrass | 14 | 2.0- 17.1 | 13 | 0-24.2 | 3 | 0-10.0 |
| *Poa bulbosa* L. | bulbous bluegrass | - | - | 8 | 0-4.4 | - | - |
| *Poa compressa* L. | Canada bluegrass | - | - | - | - | 1 | 0-1.1 |
| *Poa pratensis* L. | Kentucky bluegrass | 4 | 0-5.1 | 4 | 0-9.8 | 3 | 0-7.5 |
| *Poa secunda* J. Presl. | big bluegrass | - | | 1 | 0-1.1 | - | - |
| *Poa trivialis* L. | rough bluegrass | 3 | 0-2.0 | 2 | 0-1.1 | 2 | 0-2.9 |
| *Polygonum aviculare* L. | prostrate knotweed | 4 | 0-1.0 | 5 | 0-2.0 | - | - |
| *Populus* L. spp. | poplar | - | - | - | - | 1 | 0-2.6 |
| *Prunella vulgaris* L. | heal all | - | - | 3 | 0-1.4 | - | - |
| *Puccinellia lemmonii* (Vasey) Scribn. | Lemmons alkaligrass | 1 | 0-1.2 | - | - | - | - |
| *Puccinellia nuttalliana* (Schult.) Hitchc. | Nuttail alkaligrass | - | - | 1 | 0-1.0 | - | - |
| *Ranunculus* L. spp. | buttercup | 1 | 0-0.6 | - | - | - | - |
| *Rorippa palustris* (L.) Besser | western yellowcress | 6 | 0-1.1 | 5 | 0-1.4 | 1 | 0-5.0 |
| *Rubus* L. spp. | blackberry; raspberry | - | - | 1 | 0-0.8 | 1 | 0-2.9 |
| *Rumex* L. spp. | dock | 1 | 0-0.5 | - | - | - | - |
| *Rumex acetosella* L. | sheep sorrel | 12 | 0-14.7 | 11 | 0-14.5 | - | - |
| *Rumex crispus* L. | curly dock | 6 | 0-1.8 | 7 | 0-1.6 | - | - |
| *Rumex maritimus* L. var. *persicarioides* (L.) R. S. Mitch. | golden dock | 1 | 0-0.7 | 1 | 0-1.1 | - | - |
| *Rumex obtusifolius* L. | broad dock | - | - | 1 | 0-1.0 | - | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| *Salsola* L. spp. | Russian-thistle | 1 | 0-1.0 | | - | - | - |
| *Scleranthus annuus* L. | knawel | 5 | 0-1.9 | 5 | 0-3.0 | - | - |
| *Senecio* L. spp. | groundsel | 1 | 0-0.6 | - | - | - | - |
| *Senecio vulgaris* L. | common groundsel | 2 | 0-0.6 | 3 | 0-1.8 | 1 | 0-2.1 |
| *Sherardia arvensis* L. | field madder | 5 | 0-0.6 | 1 | 0-1.0 | - | - |
| *Silene vulgaris* (Moench) Garcke subsp. *vulgaris* | bladder campion | 3 | 0-1.5 | - | - | - | - |
| *Sisymbrium altissimum* L. | tumble mustard | - | - | 4 | 0-3.1 | - | - |
| *Sisymbrium officinale* (L.) Scop. | hedge mustard | - | - | 2 | 0-3.1 | - | - |
| *Solanum nigrum* L. | black nightshade | - | - | 1 | 0-1.4 | - | - |
| *Solanum villosum* Mill. | hairy nightshade | - | - | 1 | 0-1.1 | 1 | 0-2.5 |
| *Sonchus* L. spp. | sowthistle | - | - | 1 | 0-1.1 | - | - |
| *Sonchus asper* (L.) Hill | spiny sow-thistle | 5 | 0-1.9 | 1 | 0-1.1 | 1 | 0-1.1 |
| *Spergula arvensis* L. | corn spurry | 8 | 0-6.7 | 9 | 0-6.4 | - | - |
| *Spergularia rubra* (L.) J. Presl & C. Presl | red sandspurry | 1 | 0-0.4 | 1 | 0-1.6 | 1 | 0-1.1 |
| *Stellaria media* (L.) Vill. | common chickweed | 3 | 0-0.6 | 6 | 0-3.1 | - | - |
| *Taraxacum officinale* F. H. Wigg. aggr. | dandelion | 2 | 0-0.5 | - | - | 1 | 0-2.6 |
| *Thlaspi arvense* L. | field pennycress | 2 | 0-1.1 | 10 | 0-4.7 | 1 | 0-2.6 |
| *Torilis* Adans. spp. | hedge-parsley | 1 | 0-1.7 | - | - | - | - |
| *Trifolium aureum* Pollich | hop clover | 1 | 0-1.1 | 3 | 0-2.9 | - | - |
| *Ventenata dubia* (Leers) Cross. | ventenata | 1 | 0-0.5 | 2 | 0-1.1 | - | - |
| *Veronica* L. spp. | speedwell | - | - | 1 | 0-1.4 | - | - |
| *Vicia sativa* L. subsp. *nigra* (L.) Ehrh. | narrowleaf vetch | 1 | 0-0.4 | - | - | - | - |
| *Viola* L. spp. | violet | 1 | 0-1.7 | 2 | 0-1.4 | 1 | 0-2.5 |
| *Viola tricolor* L. | pansy | 1 | 0-0.6 | - | - | - | - |
| *Vulpia myuros* (L.) C.C. Gmel. | rattail fescue | 14 | 30.1-61.1 | 14 | 24.8-58.1 | 4 | 41.0-45.0 |

[†]Frequency of occurrence, years out of 15.

[‡]Frequency of occurrence, years out of 5.

[§]Range of percentage of samples per year in which weed seeds of the given species were identified.

# EFFECT OF STROBILURIN FUNGICIDES APPLIED AT TWO TIMINGS ON SEED YIELD IN TALL FESCUE

*N.P. Anderson and T.G. Chastain*

## Introduction

Stem rust is frequently a serious problem in tall fescue grown for seed in the Willamette Valley. Depending on the age of the stand, the variety, and seasonal weather patterns, fields receive 1 to 4 fungicide applications per year. Under severe rust pressure, seed yields can be reduced over 70% when rust is not controlled. Although a significant production expense, excellent stem rust control can be obtained with available fungicides.

The newer class of strobilurin fungicides (Quilt Xcel®, Absolute®, Stratego®, Headline®) has been reported to provide a yield boost beyond that from disease control in winter wheat crops (Zhang et al., 2010). Positive effects on yield in other crops have been attributed to physiological effects on plants resulting in better nitrogen metabolism (Glaab and Kaiser, 1999). Thus, many grass seed producers in the Willamette Valley have begun integrating an early application of a strobilurin fungicide at 2-3 nodes (BBCH stage 32-33) into their crop production plans, mostly through tank mixing with a plant growth regulator (PGR).

Oregon grass seed growers spend approximately $15 to $20 million annually for rust control, making stem rust the most costly disease in Pacific Northwest grass seed production. The cost of treating tall fescue with a strobilurin fungicide is approximately $20 to $30 per acre. Results from a 7-year study on early fungicide treatments (with PGR) in perennial ryegrass indicated an increase in seed yield in only 4 of 13 site years (Gingrich and Mellbye, 2006). These results suggest a benefit to early strobilurin fungicide applications only under severe and early rust pressure in perennial ryegrass.

This study was conducted to determine if and under what circumstances an early strobilurin treatment at 2-3 nodes (with PGR) increases tall fescue seed yield compared to a standard fungicide treatment applied later in the season when stem rust begins to develop.

## Methods

Results in this report were obtained from large scale, on-farm yield trials conducted on five turf-type tall fescue fields in three years, 2010 – 2012. Study sites were located at: (2010) a 2nd-year field located near Banks (`Padre`), (2011) a 2nd-year field in the Carlton area (`Sidewinder`) and a 3rd-year field near North Plains (`Padre`), and (2012) two 1st-year fields near Independence (`Van Gogh`) and Rickreall (`Inferno`).

The experimental design for the on-farm trials was a split-plot with treatments arranged in three randomized complete blocks. Main-plots were farm research sites and sub-plots were strobilurin fungicide timing and rate. Treatments were compared to an untreated control. Individual plot size was approximately 24 feet wide and 300-400 feet in length. Treatments included:

1. **Control:** no fungicide
2. **Early:** 10 oz/acre Quilt Xcel (azoxystrobin + propiconazole) applied at 2- 3 nodes (BBCH stage 32-33)
3. **Late:** 12 oz/acre Quilt Xcel applied at early flowering (BBCH stage 59)
4. **Early + Late:** 10 oz/acre Quilt Xcel applied at 2-3 and 12 oz/acre Quilt Xcel applied at early flowering.

All plots were treated with 1 pt/a of Palisade EC plant growth regulator at 2-3 nodes. Plots were harvested and a weigh wagon was used to measure yields from each plot. Sub-samples from the harvested seed were collected and cleaned to determine percent cleanout and thousand seed weight. Nitrogen concentration in flag leaf tissue was determined on samples taken from each of the farm site locations. Total above-ground biomass and tissue N concentration were measured in 2012.

## Results and Discussion

Large variation in seed yield, seed weight, and flag leaf N was noted among the on-farm sites (Table 1). This was expected since the five on-farm sites represented not only the inherent soil and

management conditions present at these locations but also five different cultivars of tall fescue, three stand ages, and three crop years. Seed yield and seed weight were affected by the fungicide treatments but not flag leaf N. There were no interactions of farm sites and fungicides for any of the characteristics measured.

Strobilurin fungicide treatments increased tall fescue seed yield by an average of 17% over the untreated control across sites and years (Table 2). The incidence and severity of stem rust was much greater in 2012 than in either 2010 or 2011. Consequently, the greatest individual increases in seed yield among the farm sites were noted in 2012 with seed yield increases ranging from 36% (Early) to 52% (Early + Late). Applying the strobilurin fungicide early at the normal timing for PGR applications produced lower seed yields than either the Late or Early + Late timings under high rust pressure. Tall fescue seed yield was increased by 7% when the stem rust pressure was low only if the fungicide was applied at both Early and Late timings. Mellbye and Gingrich (2004) found that strobilurin fungicides significantly increased seed yield in perennial ryegrass in a low rust pressure year.

The increase in seed yield due to strobilurin fungicide treatments was, in part, attributable to increased seed weight (Table 2). The greatest seed weight was observed when the fungicide treatment was made at both the early and late timings. Strobilurin fungicides have been reported to delay senescence of leaves (Grossmann et al., 1999) and thus might have aided carbon partitioning to seed thereby contributing to the increased seed weight. Zhang et al. (2010) showed that strobilurin fungicides (azoxystrobin) increased seed weight in wheat and the number of seeds per spike. Tall fescue seed number per acre was also increased by the fungicide treatments, making further contributions to the observed seed yield increases (data not shown).

Total above-ground biomass and tissue N concentrations were not influenced by the fungicide treatments as measured at the farm sites in 2012 (data not shown). The reported effects of strobilurin fungicides on increased nitrate reductase activity were not sufficient to increase flag leaf or whole-plant tissue N concentrations in tall fescue.

The results of this study suggest that early strobilurin fungicide application is beneficial in tall fescue; however, the best results are obtained under severe and early rust pressure. A well timed fungicide program is a good investment for tall fescue seed producers in western Oregon.

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**Appreciation**

*Appreciation is extended to the cooperation of the growers who allowed us to use their fields and assist with seed harvest.*

Table 1. Analysis of variance for strobilurin fungicide treatments in on-farm trials with tall fescue grown for seed. On-farm trials were conducted at one farm in 2010, and two farms each in 2011 and 2012.

| Source of variation | Seed yield | Seed weight | Flag leaf N |
|---|---|---|---|
| Farms (A) | * | *** | *** |
| Fungicide (B) | ** | *** | NS |
| A x B | NS† | NS | NS |

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

Table 2. Effect of strobilurin fungicide treatment timing and rate on seed production of tall fescue across all sites and years. Low rust pressure years are the average of 2010 and 2011 and moderate to severe rust pressure was encountered in 2012.

| Treatment | Seed yield | Seed weight | Flag leaf N | Low rust | Moderate to severe rust |
|---|---|---|---|---|---|
| | lbs/acre | mg | % | seed yield % of control | |
| Control | 1593 a† | 2.53 a | 1.72 a | 100 | 100 |
| Early | 1807 b | 2.61 b | 1.87 a | 101 | 136 |
| Late | 1848 b | 2.60 b | 1.74 a | 102 | 143 |
| Early + Late | 1947 b | 2.67 c | 1.83 a | 107 | 152 |

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

# IRRIGATION AND PGR EFFECTS ON RED CLOVER SEED PRODUCTION

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

## Introduction

Red clover is the most widely grown legume seed crop in the Willamette Valley. Red clover seed yields have roughly doubled since the mid-1970s and our recent work on use of plant growth regulators (PGRs) in red clover seed crops suggests that further improvement in seed yield is possible.

Oliva et al. (1994) showed that irrigation strategically timed to coincide with flowering increased seed yield over non-irrigated red clover. Foliar applied PGRs have been widely used on grass seed crops in Oregon and other parts of the world because of well documented seed yield increases and reduction in lodging (Zapiola et al., 2006). Two acylcyclohexanedione PGRs are registered for use as lodging control agents in grass seed crops in Oregon - trinexapac-ethyl (TE) and prohexamide-calcium (PC).

Very little research has been conducted on the use of PGRs on legume seed crops. In Norway, red clover seed yield was increased when TE was applied at stem elongation (Øverland and Aamlid, 2007). Anderson et al. (2012) conducted three years of on-farm investigations that revealed that TE applications increased seed yield of red clover seed crops in Oregon. There is nothing in the literature regarding the application of PC PGR on red clover seed crops. Furthermore, it is unclear what the combination of irrigation and PGR application might have on seed yield, yield components, and lodging control in red clover.

The objective of this study is to quantify the impact of irrigation and its potential interaction with PGR use on red clover seed production under Willamette Valley conditions.

## Methods

Two plantings (2011 and 2012) of red clover seed crops were established in the fall at Hyslop Crop Science Research Farm near Corvallis and each will be followed over a two-year period to examine the effects of irrigation and PGR use. PGR treatment subplots (11 ft x 50 ft) were randomly allocated within irrigated and non-irrigated main plots in a split-plot arrangement of treatments in randomized block experimental design. Trials were replicated in four blocks. The following PGR treatments were made on the subplots:

1. Untreated Control
2. Trinexapac-ethyl (TE) PGR applied at 1 pint/acre at stem elongation
3. TE PGR applied at 2 pints/acre at stem elongation
4. TE PGR applied at 3 pints/acre at stem elongation
5. TE PGR applied at 4 pints/acre at stem elongation
6. TE PGR applied at 1 pint/acre at bud emergence
7. TE PGR applied at 2 pints/acre at bud emergence
8. TE PGR applied at 3 pints/acre at bud emergence
9. TE PGR applied at 4 pints/acre at bud emergence
10. Prohexamide-calcium (PC) PGR applied at 7.4 oz/acre at stem elongation
11. PC applied at 14.8oz/acre at stem elongation

The red clover seed crop was flailed in mid-May (prior to bud emergence) and residue was left on the field. Once regrowth occurred, approximately four inches of irrigation water was applied to the main plots at late bud emergence (BBCH growth stage 55) by using a custom-designed Pierce AcreMaster linear system equipped with minimum-drift Nelson sprinklers. This single irrigation was strategically timed to coincide with first flowering (BBCH 60 growth stage). TE and PC PGRs were applied at the rates listed above to subplots at stem elongation (BBCH growth stage 32) and bud emergence (BBCH growth stage 50). Seed was harvested with a small-plot swather (modified JD 2280) and threshed with a Hege 180 small-plot combine. Harvested seed was processed with a M2-B Clipper cleaner and clean seed yield was determined.

Plots were sampled at peak bloom (BBCH growth stage 65) to determine the number of heads (inflorescences) and florets within the heads, primary stems, and above-ground biomass. Harvest index was determined for each plot based on harvested seed yield and above-ground biomass. Seed weight was measured by counting two 1000 seed samples from harvested, cleaned seed and determining the weight. Seed number was calculated based on seed yield and 1000-seed weight values obtained from each plot.

**Results and Discussion**

Rainfall for the July through September period was 37% of the average. Only 10 of the past 123 years have been this dry or drier during summer in the Willamette Valley. These dry conditions were preceded by a very wet and cool spring, so soil moisture was greater than normal as summer approached.

Above-ground biomass, stem number, and harvest index were not influenced by either irrigation or PGR treatment, nor by the interaction of the two (Table 1). There were no interactions of irrigation and PGR for any of the seed production characteristics presented in this report.

Irrigation had significant effects on seed yield, seed weight, and several other characteristics (Table 1). Seed yield was increased by 10% in the 1$^{st}$-year stand by irrigation over the non-irrigated crop (Table 2). The most likely reasons for the increase in seed yield attributable to irrigation were increased seed weight and a greater number of seeds/floret than the non-irrigated red clover. This increase in yield was evident despite the reduction in heads/ft$^2$ and florets/ft$^2$ by irrigation. While not significant, there was a trend for increased vegetative plant growth with irrigation and this might have altered the resource partitioning of the crop so that there were fewer flowers and more vegetation.

There was a trend for increased seed yield when TE was applied at stem elongation. However, unlike our previous work (Anderson et al., 2012), the PGR treatments did not significantly increase seed yield in 2012 (Table 3). There were several possible explanations for this observation. TE applications reduced seed weight over the untreated control regardless of rate of application or the timing of the application, and this reduction was greater than previously noted in our on-farm trials. The largest reductions in seed weight were found among the higher TE application rates and were more pronounced with the bud emergence timing. On the other hand, TE mostly increased the number of seeds produced but was not sufficient to offset the reduced seed weight and thus seed yield was not increased by TE. PC did not reduce seed weight like TE but also did not increase seed number and so seed yield was also not increased. The florets/head tended to be increased by some applications of TE at the stem elongation timing while PC had no effect on florets/head. Anderson et al. (2012) found some minor reductions in seed weight by using certain TE treatment application timings but not to the degree observed in this 1$^{st}$-year stand of red clover. Moreover, the prior trials results showed that heads/ft$^2$ were increased by TE, a phenomenon not evident in the present work.

This is the first of a series of reports on irrigation and PGR effects in red clover seed production. Future updates will continue to follow the results of the two experimental red clover seed fields as they age as well as research on effect of PGR on seed quality and crop maturity.

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Table 1. Analysis of variance for effects of irrigation and PGR on red clover seed production 2012.

| Characteristic | Source of variation | | |
|---|---|---|---|
| | Irrigation (I) | PGR (P) | I x P |
| Above-ground biomass | NS | NS | NS |
| Stem number | NS | NS | NS |
| Harvest index | NS | NS | NS |
| Seed yield | * | NS | NS |
| Seed weight | ** | *** | NS |
| Heads/ft$^2$ | * | NS | NS |
| Florets/head | NS | * | NS |
| Florets/ft$^2$ | * | NS | NS |
| Seeds/ft$^2$ | NS | *** | NS |
| Seeds/floret | * | NS | NS |

* $P \leq 0.05$
** $P \leq 0.01$
*** $P \leq 0.001$

Table 2. Irrigation effects on a 1$^{st}$-year red clover seed crop in 2012.

| Characteristic | Treatment | |
|---|---|---|
| | Irrigated | Non-Irrigated |
| Seed yield (lbs/acre) | 867 b† | 786 a |
| Seed weight (mg) | 1.73 b | 1.64 a |
| Heads/ft$^2$ | 65 a | 80 b |
| Florets/ft$^2$ | 7752 a | 9635 b |
| Seeds/floret | 0.80 b | 0.59 a |

†Means in rows followed by the same letter are not significantly different ($P = 0.05$).

Table 3. Effects of trinexapac-ethyl (TE) and prohexamide-calcium (PC) PGR treatments on red clover seed production characteristics in a 1st-year stand in 2012.

| PGR | PGR rate and timing | Seed yield | Seed weight | Florets/head | Seeds/$m^2$ |
|---|---|---|---|---|---|
| | pts/A (TE) or oz/A (PC) | lbs/acre | mg | no. | no. x $10^4$ |
| Control | | 818 | 1.77 a† | 113 ab | 5.18 a |
| TE | 1 Stem elongation | 829 | 1.71 b | 125 d | 5.43 ab |
| | 2 Stem elongation | 860 | 1.69 b | 121 bcd | 5.70 b |
| | 3 Stem elongation | 852 | 1.69 b | 122 cd | 5.64 b |
| | 4 Stem elongation | 844 | 1.66 c | 120 bcd | 5.73 bc |
| TE | 1 Bud emergence | 795 | 1.69 b | 115 abc | 5.25 a |
| | 2 Bud emergence | 831 | 1.64 cd | 119 bcd | 5.69 b |
| | 3 Bud emergence | 815 | 1.61 d | 121 bcd | 5.69 b |
| | 4 Bud emergence | 829 | 1.54 e | 119bcd | 6.04 c |
| PC | 7.4 Stem elongation | 812 | 1.76 a | 110 a | 5.17 a |
| | 14.8 Stem elongation | 807 | 1.75 a | 114 ab | 5.16 a |

†Means in columns followed by the same letter are not significantly different ($P = 0.05$).

# INTERACTION OF TRINEXAPAC-ETHYL AND APPLIED NITROGEN INCREASES SEED YIELD IN PERENNIAL RYEGRASS AND TALL FESCUE

*T.G. Chastain, C.J. Garbacik, and W.C. Young III*

## Introduction

Trinexapac-ethyl (TE) is a plant growth regulator (PGR) which has been widely adopted for use as a lodging control agent in grass seed production. Under certain growing conditions especially accompanied with high nitrogen (N) availability in spring, the structure of the stem cannot support the increasing weight of the developing inflorescence and seed. As a result, the tiller together with the inflorescence that it supports lodges or falls to the ground under its own weight. Lodging affects pollination and seed development, and consequently, seed yield is reduced.

Previous studies have found that an earlier PGR used for lodging control - paclobutrazol, increased seed yield of perennial ryegrass regardless of N application rate (Hampton et al., 1983). In other words, there was no interaction of the PGR and applied N for seed yield evident in this study. Young et al. (1999) found interactions of paclobutrazol and N in Chewing's fescue and tall fescue but not in orchardgrass under conditions in the Willamette Valley. In more recent studies with TE, Borm and van den Berg (2008) similarly found no interaction of TE PGR and applied N for seed yield in perennial ryegrass.

Since lodging is exacerbated in the high N environment present in grass seed production systems, further work was needed to determine the possibility of interactions of TE PGRfor lodging control and spring-applied N under Oregon conditions. The objectives of this study were to determine how TE and spring-applied N treatment affects seed production characteristics and seed yield in perennial ryegrass and tall fescue.

## Methods

Field trials were conducted at Hyslop Crop Science Research Farm near Corvallis, OR, to characterize the effects of TE and spring-applied N on seed yield and other seed production characteristics in 'Evening Shade' perennial ryegrass and 'Falcon IV' tall fescue. The trials were conducted over three harvest years, 2010 to 2012.

The trials were designed to manipulate partitioning within the crop through the following management treatments:

1. Spring applied N (160 lbs/acre – perennial ryegrass, 120 lbs/acre – tall fescue)
2. TE PGR (1.5 pts/acre)
3. Control (no spring N, no PGR)

Spring N was applied in March of each of the three years with an orbit air spreader system. The TE PGR treatment (Palisade®) was applied at BBCH stage 32-33 to control lodging. Above-ground dry weight and fertile tiller number were determined on samples collected from each plot near peak anthesis of perennial ryegrass and tall fescue in June. The seed crops were cut with a small-plot swather and threshed by a small-plot combine in July of each of the study years. The seed was cleaned, and seed yield and seed weight were determined. Harvest index was determined as the proportion of total above-ground dry matter represented by seed yield.

## Results and Discussion

Interactions of TE PGR and spring-applied N governed seed yield of perennial ryegrass in all three harvest years and was evident in tall fescue in two of the three harvest years, but the responses differed among the two species. For perennial ryegrass, the PGR had no positive effect on seed yield unless N was applied (Figure 1). Perennial ryegrass seed yields were greatest with the combination of TE and N in each of the three harvest years. In tall fescue, there was no interaction of TE and N for seed yield in 2010, but seed yield interactions were evident in both 2011 and 2012 where the combination of N and TE PGR produced the greatest seed yields (Figure 2).

There were no interactions of TE and N for the seed yield components, fertile tillers and seed weight, in any of the harvest years for both perennial ryegrass

and tall fescue. Likewise, there were no interactions of TE and N for above-ground dry weight or for harvest index in both perennial ryegrass and tall fescue. The influence of TE and N on seed yield components and other seed production characteristics were independent of one another.

The application of spring N consistently increased the above-ground dry weight observed in both seed crop species over the life of the study (Table 1). An increase in the number of fertile tillers resulting from N application accompanied the increased dry weight in perennial ryegrass, but increased fertile tiller production was observed in only one of three years in tall fescue as a result of N application. Nitrogen increased seed weight for both perennial ryegrass and tall fescue. Mixed effects of N on harvest index were noted for both perennial ryegrass and tall fescue. Harvest index was most often reduced by N application, but was also increased or not affected by N. Spring-applied N increased the size of the crop canopy (above-ground dry weight) in both species thereby enabling greater solar energy capture and partitioning of carbon (derived from atmospheric $CO_2$) to the seed (seed weight) increasing seed yield.

The application of TE tended to reduce above-ground dry weight, but these effects were neither consistent nor were they always statistically significant (Table 2). Effects of the TE application were largely not evident in fertile tiller numbers as has been noted in previous studies. Applications of TE mostly increased harvest index in perennial ryegrass and tall fescue, and even when not significant, the trend was for increased harvest index with the PGR application. Mixed effects of the TE PGR were observed for seed weight; application of the PGR reduced seed weight, increased seed weight, or had no effect on seed weight.

The results of this study increases our understanding of how TE and applied spring N work in affecting seed yield in perennial ryegrass and tall fescue and this information can be used to improve the economic and biological efficiency of TE applications. Spring N applications greatly increased lodging in perennial ryegrass and to a lesser extent in tall fescue. Nitrogen-induced lodging was mitigated by the application of the TE PGR in both species. For best results in increasing seed yield when using TE in perennial ryegrass and tall fescue, the PGR should be applied in conjunction with the recommended rates of spring N for these crops.

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Table 1. Spring-applied N effects on harvest characteristics in perennial ryegrass and tall fescue seed crops.

| Crop and Year | Treatment | Dry weight | Fertile tillers | Harvest index | Seed weight |
|---|---|---|---|---|---|
| | | kg ha$^{-1}$ | no m$^{-2}$ | | mg |
| Perennial Ryegrass | | | | | |
| 2010 | No N | 6485a† | 1927a | 13.2b | -- |
| | Spring N | 16405b | 3100b | 10.2a | -- |
| 2011 | No N | 4723a | 1841a | 10.0a | 1.80a |
| | Spring N | 10303b | 2487b | 11.1b | 1.93b |
| 2012 | No N | 4221a | 1765a | 15.4b | 1.72a |
| | Spring N | 10659b | 2454b | 13.3a | 2.82b |
| Tall Fescue | | | | | |
| 2010 | No N | 19734a | 1281a | 3.7a | -- |
| | Spring N | 20626b | 1281a | 3.2a | -- |
| 2011 | No N | 7953a | 743a | 11.8a | 2.49a |
| | Spring N | 12663b | 872a | 12.1a | 2.59b |
| 2012 | No N | 4304a | 474a | 19.6b | 2.47a |
| | Spring N | 10959b | 710b | 11.6a | 2.69b |

†Means within columns and years that are followed by the same letter are not significantly different ($P$ = 0.05)

Table 2. Trinexapac-ethyl PGR treatment effects on harvest characteristics in perennial ryegrass and tall fescue seed crops.

| Crop and Year | Treatment | Dry weight | Fertile tillers | Harvest index | Seed weight |
|---|---|---|---|---|---|
| | | kg ha$^{-1}$ | no m$^{-2}$ | | mg |
| Perennial Ryegrass | | | | | |
| 2010 | No PGR | 11650a† | 2551a | 11.2a | -- |
| | PGR | 11240a | 2487a | 12.2a | -- |
| 2011 | No PGR | 8376b | 2306b | 9.4a | 1.79a |
| | PGR | 6649a | 2034a | 11.8b | 1.93b |
| 2012 | No PGR | 7715a | 2099a | 13.3a | 1.79a |
| | PGR | 7167a | 2121a | 15.4b | 1.76a |
| Tall Fescue | | | | | |
| 2010 | No PGR | 20261a | 1302a | 2.6a | -- |
| | PGR | 20098a | 1259a | 4.3b | -- |
| 2011 | No PGR | 12031b | 883b | 10.5a | 2.62b |
| | PGR | 8586a | 732a | 13.4a | 2.46a |
| 2012 | No PGR | 7865a | 549a | 11.7a | 2.61b |
| | PGR | 7398a | 635a | 19.8b | 2.56a |

†Means within columns and years that are followed by the same letter are not significantly different ($P$ = 0.05)

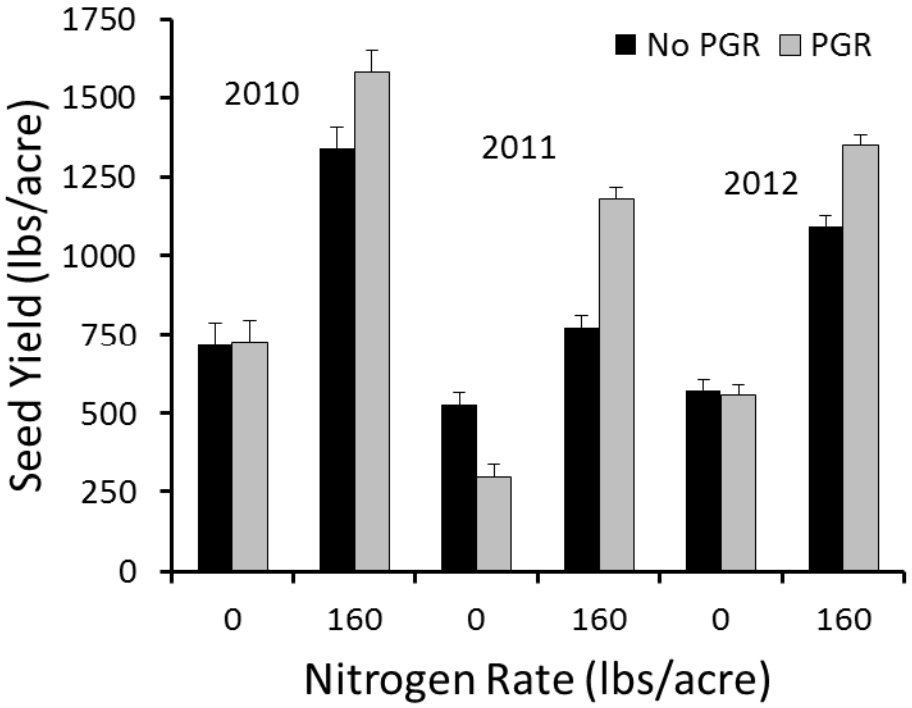


Figure 1. Interaction effects of trinexapac-ethyl PGR and spring-applied nitrogen on seed yield of perennial ryegrass over a three-year period. Bars represent standard error of the mean difference values for comparing means within years ($P$ = 0.05)

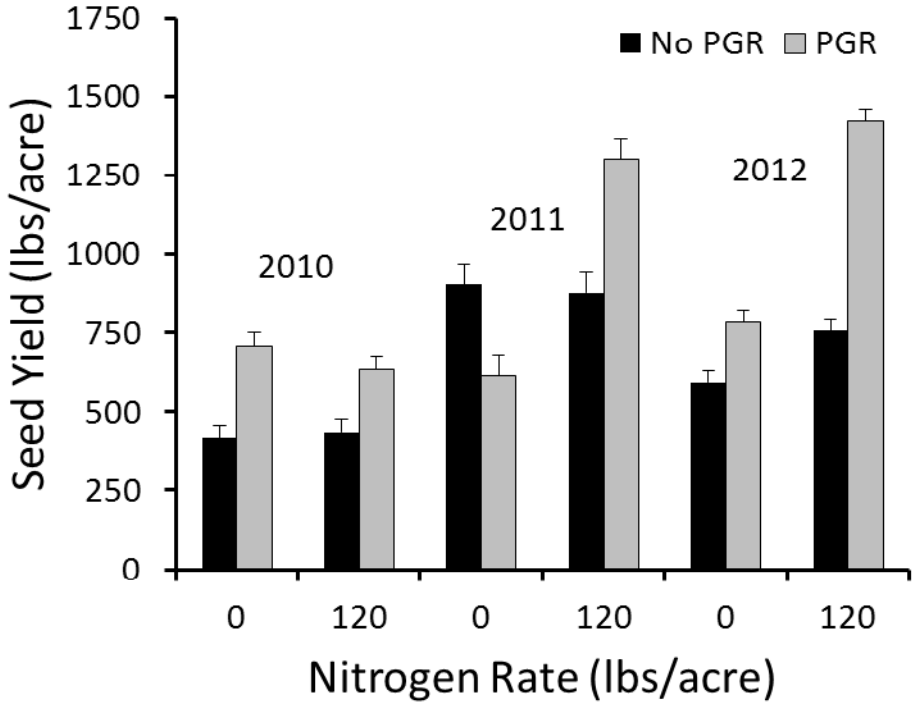


Figure 2. Interaction effects of trinexapac-ethyl PGR and spring-applied nitrogen on seed yield in tall fescue over a three-year period. Bars represent standard error of the mean difference values for comparing means within years ($P$ = 0.05)

# ANNUAL BLUEGRASS MANAGEMENT WITH PYROXASULFONE AND FLUMIOXAZIN IN PERENNIAL RYEGRASS AND TALL FESCUE GROWN FOR SEED

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

## Introduction

Annual bluegrass (*Poa annua*) contamination in grass grown for seed continues to be a major production challenge with significant economic ramifications for growers. Cool season grasses grown for seed are swathed into windrows, allowed to dry and then threshed with a combine equipped with a pick-up header. Weed seeds present in the crop are inherently harvested along with the crop seed in this production system. Oregon seed certification allows contamination of only 0.3% annual bluegrass seed by weight in tall and fescue crops and 0.5% by weight in perennial ryegrass crops (2012 Oregon Certified Seed Handbook). Many seed companies have a zero tolerance. Thus, annual bluegrass seed contamination in cool season grass seed production is a major weed management consideration for growers. Research results from field experiments utilizing flumioxazin and pyroxasulfone herbicides for annual bluegrass control in established and spring planted perennial ryegrass and tall fescue are presented here. Cole et al. (2003) documented poor control of annual bluegrass with flumioxazin and diuron in carbon seeded perennial ryegrass, but good annual bluegrass control was documented by Curtis et al. (2011) with pyroxasulfone in carbon seeded perennial ryegrass. Neither flumioxazin nor pyroxasulfone are currently registered for use in grasses grown for seed.

## Methods

Field experiments were conducted from 2009-2012 to examine weed control efficacy and crop tolerance of grasses grown for seed to pyroxasulfone and flumioxazin. These experiments were located at the Oregon State University Hyslop Research Farm near Corvallis, OR. All studies utilized a randomized complete block design with four replications. Visual evaluations of annual bluegrass control along with crop injury ratings were taken following herbicide applications. Seed was harvested, cleaned and yields were quantified. Data were analyzed using ANOVA and means separated by LSD.

## Results

In early January, 2009, treatments of pyroxasulfone applied at 0.09 lb ai/A and flumioxazin applied at 0.1 lb ai/A to an established stand of perennial ryegrass infested with diuron resistant annual bluegrass resulted in control of 90% or greater with pyroxasulfone and 48% with flumioxazin (Table 1). Perennial ryegrass yields were not significantly different than the untreated control.

Table 1. Established Perennial Ryegrass Tolerance to Herbicides

| Treatment | Rate | Annual bluegrass | Yield clean seed |
|---|---|---|---|
| | lb ai/A | % control | lb/A |
| check | 0 | 0 | 1569 |
| flufenacet | 0.34 | 100 | 1327 |
| pyroxasulfone | 0.09 | 90 | 1207 |
| oxyfluorfen | 0.25 | 23 | 1403 |
| flumioxazin | 0.1 | 48 | 1440 |
| LSD P = 0.05% | | 29 | NS |
| CV | | 36 | 14 |

planted 9/25/2007
applied 1/13/2009
evaluated 4/24/2009

A study initiated in the fall of 2009 documented crop safety and diuron resistant annual bluegrass control with pyroxasulfone and flumioxazin in spring planted perennial ryegrass. Pyroxasulfone was applied at 0.053, 0.106 and 0.213 lb ai/A preemergence to annual bluegrass which had been overseeded across a bare ground area in each plot. The diuron resistant annual bluegrass was controlled 90% or greater with all three application rates (Table 2). In this same study, a flumioxazin treatment applied preemergence to the annual bluegrass at 0.063 lb ai/A controlled 83% of the diuron resistant annual bluegrass. Perennial ryegrass yields were not significantly affected by these treatments.

Table 2. Spring Planted Perennial Ryegrass Tolerance to Herbicides

| Treatment | Rate | Annual bluegrass | Yield clean seed |
|---|---|---|---|
| | lb ai/A | % control | lb/A |
| check | 0 | 0 | 628 |
| pyroxasulfone | 0.53 | 98 | 856 |
| pyroxasulfone | 0.106 | 100 | 1034 |
| pyroxasulfone | 0.213 | 100 | 625 |
| flumioxazin | 0.063 | 90 | 734 |
| flufenacet-metribuzin | 0.425 | 100 | 734 |
| LSD P = 0.05% | | 3 | NS |
| CV | | 3 | 29 |

planted 4/7/2009
applied 10/1/2009
evaluated 6/14/2010

Two additional studies were conducted during the 2010-2011 growing season, one in established perennial ryegrass and one in established tall fescue, with four rates of a pre-mix combination of flumioxazin plus pyroxasulfone. The objectives of these studies were to evaluate tolerance and annual bluegrass control efficacy in perennial ryegrass and tall fescue seed crops to the pre-mix formulation of flumioxazin plus pyroxasulfone. Flumioxazin plus pyroxasulfone was applied preemergence to diuron resistant annual bluegrass at 0.095, 0.143, 0.19 and 0.285 lb ai/A.

Table 3. Control of Diuron Resistant Annual Bluegrass in Established Perennial Ryegrass

| Treatment | Rate | Annual bluegrass | Yield clean seed |
|---|---|---|---|
| | lb ai/A | % control | lb/A |
| check | 0 | 0 | 552 |
| flumioxazin-pyroxasulfone | 106 | 75 | 693 |
| flumioxazin-pyroxasulfone | 160 | 90 | 583 |
| flumioxazin-pyroxasulfone | 212 | 90 | 674 |
| flumioxazin-pyroxasulfone | 319 | 100 | 731 |
| flufenacet-metribuzin | 476 | 88 | 748 |
| LSD P = 0.05% | | 7 | NS |
| CV | | 6 | 31 |

planted 9/06/2009
applied 9/16/2010
evaluated 4/22/2011

Table 4. Control of Diuron Resistant Annual Bluegrass in Established Tall Fescue

| Treatment | Rate | Annual bluegrass | Crop injury | Yield clean seed |
|---|---|---|---|---|
| | lb ai/A | % control | % injury | lb/A |
| check | 0 | 0 | 0 | 1110 |
| flumioxazin-pyroxasulfone | 0.095 | 90 | 5 | 1292 |
| flumioxazin-pyroxasulfone | 0.143 | 100 | 18 | 1227 |
| flumioxazin-pyroxasulfone | 0.19 | 100 | 25 | 1364 |
| flumioxazin-pyroxasulfone | 0.285 | 100 | 45 | 1180 |
| flufenacet-metribuzin | 0.425 | 100 | 8 | 1419 |
| LSD P = 0.05% | | 0 | 7 | NS |
| CV | | 0 | 28 | 14 |

planted 4/23/2010
applied 10/8/2010
evaluated 4/22/2011

In the perennial ryegrass study, diuron resistant annual bluegrass was controlled 90% or greater with the three higher rates of flumioxazin plus pyroxasulfone (Table 3). In the tall fescue study, flumioxazin plus pyroxasulfone controlled the diuron resistant annual bluegrass 90% at the lowest rate and 100% at the highest three rates (Table 4). There was considerable visible injury in the tall fescue study which initially showed up as slight tissue necrosis and later as stunting. This injury increased with increasing rate. Tall fescue yield was not affected despite the injury.

**Discussion**

This series of studies indicates that pyroxasulfone and combinations of pyroxasulfone and flumioxazin control diuron resistant biotypes of annual bluegrass with adequate crop safety in perennial ryegrass and tall fescue seed production. These data were used to initiate an IR-4 project in 2012-13 in an effort to seek registration of Fierce™ herbicide (a combination of pyroxasulfone plus flumioxazin marketed by Valent U.S.A.) since this product is not currently registered for use in grasses grown for seed in Oregon. Additional research is underway to evaluate applications rates which minimize potential for crop injury, improve annual bluegrass control, and to determine if these herbicides can be utilized in carbon-seeding systems to improve weed management in seedling grasses.

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# SPATIAL PATTERNS OF *CLAVICEPS PURPUREA* IN KENTUCKY BLUEGRASS AND PERENNIAL RYEGRASS GROWN FOR SEED AND EFFECT OF SOIL-APPLIED FUNGICIDES ON GERMINATION OF ERGOT SCLEROTIA

*J.K.S. Dung, D.L. Walenta, S.C. Alderman, and P.B. Hamm*

## Introduction

Ergot, caused by the fungus *Claviceps purpurea*, is an important floral disease of grasses that significantly impacts Kentucky bluegrass (KBG) and perennial ryegrass (PRG) seed production in the Pacific Northwest (PNW). The fungus infects unfertilized ovaries and replaces seed with elongated black fungal bodies called sclerotia, which overwinter in the soil and germinate to produce airborne ascospores in the spring. In addition to yield losses from ergot, the repeated cleanings required to remove ergot sclerotia to achieve seed certification standards result in additional seed loss as well as extra costs in time and labor.

Although ergot is a persistent problem in PNW grass seed production, the incidence and intensity of ergot epidemics can vary regionally, locally, and from year to year. Several studies have investigated the occurrence and distribution of ergot in different production areas of Oregon, but little is known about the spatial patterns of ergot epidemics within large commercial fields. Understanding the spatial patterns of ergot in grass grown for seed can provide important information that can be used to improve ergot sampling and assessment, identify and target sources of inoculum, and develop more effective management tactics.

Germinating sclerotia of *C. purpurea* are considered to be the source of primary inoculum for ergot epidemics in grass seed fields. Although some sclerotia are removed with seed during harvest or with plant debris during the cutting and baling of straw, sclerotia are often dislodged from infected inflorescences and returned to the field during mechanical harvest. Sclerotia that remain in the field following harvest can overwinter and increase the amount of primary inoculum available for the next year, especially in perennial grass seed crops (Alderman *et al*. 1993).

Ergot control in grass seed production in the PNW has been improved in recent years, but multiple protective fungicide applications are required during anthesis. Some growers experience severe ergot issues even after four fungicide applications. A limited number of fungicides are currently available and new products or application strategies need to be evaluated. In addition to timing fungicides during anthesis, when flowers are susceptible to infection, it may be possible to apply fungicides to sclerotia in the field during the fall and/or as they begin to germinate in the spring before they release spores. Soil-applied fungicides may reduce sclerotia germination and spore production, limiting the production of primary inoculum and subsequent ergot infection (Hardison 1975).

The objectives of this study were to: 1) quantify and describe the spatial patterns of ergot epidemics in commercial KBG and PRG fields in Oregon and Washington; 2) quantify the number of sclerotia left in fields after harvest and post-harvest management operations; and 3) investigate the effectiveness of soil-applied fungicides at reducing the germination of ergot sclerotia *in vitro*. Together, this research should provide a better understanding of *C. purpurea* inoculum sources, the etiology and development of ergot epidemics in commercial fields, and additional options for the chemical control of ergot.

## Materials and Methods

### Fields

Three 125 acre commercial PRG fields (cultivars ‘Pavilion’, ‘Provocative’, and ‘Top Hat II’) near Hermiston, OR were included in the study. All three fields were in the first year of production, under center pivot irrigation, and subjected to similar cultural practices. Two commercial KBG fields located near Paterson, WA (R-1 and BH-6) and four commercial KBG fields located near LaGrande, OR were also included. Both fields near Paterson, WA were first-year, 125 acre fields (cultivar ‘Midnight’) under center pivot irrigation. Fields near LaGrande, OR were between 2 and 4 years old and of varying cultivars and acreages (Table 1). All fields near

LaGrande were under hand or wheel line irrigation except the field of cultivar 'Kelly', which was irrigated under a one-half center pivot.

Disease Assessment and Spatial Analyses

Fields were surveyed about one week prior to harvest. Sample points were located along wheel tracks and consisted of quadrats approximately 10 $ft^2$ in size spaced 30 to 100 ft apart. Quadrats were located 6.5 ft away from the wheel track and were mapped using a GPS unit. Inflorescences were arbitrarily collected from each quadrat for evaluation in the lab. The number of sclerotia was counted in each inflorescence to determine incidence and severity at each quadrat. Spatial autocorrelation and aggregation of disease severity were determined using Moran's I and the SADIE indices of aggregation, patch clusters, and gap clusters. Patch and gap clusters are defined as regions with relatively large or small counts in close proximity to each other, respectively, and the SADIE indices measure the degree to which each quadrat contributes to a patch or cluster. These statistics were used to determine if the intensity of ergot was evenly distributed throughout the field or if the disease tended to occur in patches, or foci.

Postharvest Collection and Quantification of Sclerotia

Samples of crop debris, soil, sclerotia, and seed were collected following harvest and residue management operations. Samples were collected from the three commercial PRG fields near Hermiston, OR and three of the commercial KBG fields near LaGrande, OR (cultivars 'Baron', 'Kelly' and 'Right') described in Objective 2. Postharvest residue was baled and removed from PRG fields, while KBG fields near La Grande were propane flamed. A commercial vacuum-sweeper, towed at approximately 1 mph, was used to collect samples from 20 to 24 plots per field. Each plot was approximately 6.5 ft wide and 16 or 32 ft long. Seed and sclerotia were separated from soil and plant residues using an air screen machine, indent cylinder, air column separator, and hand screens. A stereo microscope was used to identify and count sclerotia.

Effect of Soil-applied Fungicides on Sclerotia Germination

Fresh sclerotia from KBG and PRG were obtained from seed cleaning facilities in August. Sclerotia from both hosts were used since sclerotia from KBG are typically much smaller (≤ 1 mg) than those from PRG (4 to 70+ mg) and may respond differently to soil-applied fungicides. A total of four replicate plates, each containing 25 sclerotia, were used for each combination of sclerotia type and fungicide treatment. The experiment was arranged in a randomized complete block design. Treatments were intended to simulate a spring application, so sclerotia were preconditioned in moist sterile soil at 41°F for six weeks prior to fungicide treatments. Eight fungicides, including Endura (boscalid at 5.6 lb a.i./gallon), Botran 5F (dicloran at 5 lb a.i./gallon), Omega 500F (fluazinam at 4.2 lb a.i./gallon), Blocker 10G (PCNB at 75% a.i. w/w), Quilt Xcel (azoxystrobin+propiconazole at 2.2 lb a.i./gallon), Propulse (fluopyram+prothioconazole at 3.4 lb a.i./gallon), DPX-PZX74 (picoxystrobin+cyproconazole at 2.3 lb a.i./gallon), and Priaxor (pyraclostrobin+fluxapyroxad at 4.2 lb a.i./gallon), onion oil (2.4 and 0.24 gallon/acre), onion compost (24.5 gallon/acre), and a sterile water control were tested. Tween, a nonionic surfactant, was added to the onion oil and fluopyram+prothioconazole treatments (1 qt/100 gal) as recommended by the manufacturer. Treatments were applied directly to ergot sclerotia using a handheld sprayer calibrated to dispense 750 µl/plate, equivalent to 100 gallon/acre. Sclerotia were subsequently placed in a 60°F incubator for seven weeks. The number of germinating sclerotia and capitula (spore-producing fruiting bodies) were recorded weekly. Germination ratios were calculated by dividing the total number of germinated sclerotia for each experimental unit by the mean number of germinated sclerotia of the sterile water control treatment. A germination ratio < 1 indicates reduced germination compared with the mean germination ratio of the water-treated control. Data were subjected to ANOVA and treatments were compared using Dunnett's test to determine if any were significantly different than the control.

**Results and Discussion**

Disease Assessment and Spatial Analyses

A total of 1433 and 1613 quadrats were examined in the three PRG and six KBG fields, respectively. The percentage of quadrats containing at least one

inflorescence bearing sclerotia ranged from 59 to 90% in the PRG fields. The percentage of quadrats with sclerotia in KBG fields ranged between 0 and 49%. Sclerotia were not observed in field R-1, but 36% of quadrats contained at least one inflorescence exhibiting honeydew. The mean incidence of inflorescences bearing sclerotia ranged between 1.9 and 25.3%, while mean severity, or the mean number of ergot bodies per 10 to 30 inflorescences, ranged from 0.68 to 4.13. Results are summarized in Table 1.

Surveys and plots of disease intensity indicated that although ergot incidence was widespread within the fields, disease severity was not evenly distributed throughout (Fig. 1). Significant ($P \leq 0.002$) clustering of disease severity was observed in all three PRG fields and bluegrass field BH-6 using Moran's I and SADIE indices. Foci of high ergot severity in fields may be caused by secondary spread within and among neighboring plants via honeydew, focused sources of primary inoculum, or a combination of environmental and biological factors. In contrast, ergot was randomly distributed in bluegrass field of cultivar 'Baron', which was in its fourth year of production. Negative binomial regression analysis indicated that ergot severity in PRG fields H-3, H-7, and RC-2 significantly ($P < 0.006$) decreased with increasing distance from established, nearby PRG fields, and especially PRG fields located upwind. These results suggest that older PRG seed fields may be important sources of inoculum for neighboring first-year fields. However, the contribution of infected weeds, volunteers, or native plants to ergot epidemics also requires further investigation.

Postharvest Collection and Quantification of Sclerotia

Sclerotia remaining in the field post-harvest varied among the three PRG fields, with mean sclerotia/ft$^2$ at 0.41, 0.35 and 1.42 for fields H-3, H-7 and RC-2, respectively. In fields H-3 and H-7, 77% of plots had 5 or fewer sclerotia/10 ft$^2$. High sclerotia levels were found in the RC-2 field, with more than 10 sclerotia/10 ft$^2$ recovered from 50% of the sites and one site contributing over 70 sclerotia/10 ft$^2$. Post-harvest assessments of ergot from the KBG fields were not completed due to difficulties in identifying sclerotia among the burned surface residues.

Effect of Soil-applied Fungicides on Sclerotia Germination

A significant ($P \leq 0.05$) reduction in germination ratio was observed in KBG and PRG sclerotia treated with picoxystrobin+cyproconazole or azoxystrobin+propiconazole and in KBG sclerotia treated with pyraclostrobin+fluxapyroxad or fluopyram+prothioconazole compared to water-treated controls (Fig. 2). Reduced capitula production was also observed. Pyraclostrobin+fluxapyroxad, picoxystrobin+cyproconazole, and azoxystrobin+propiconazole delayed PRG sclerotia germination by at least 2 weeks. Pyraclostrobin+fluxapyroxad also delayed KBG sclerotia germination by two weeks, while picoxystrobin+cyproconazole and azoxystrobin+propiconazole prevented germination of KBG sclerotia for the entire 7-week period. These results indicate that soil-applied fungicides have the potential to reduce or delay the germination of overwintered ergot sclerotia, preventing the release of ascospores during anthesis and disrupting the ergot disease cycle. Future studies performed in the lab and in the field will focus on the most efficacious chemistries and the impacts of single and multiple fungicide applications on sclerotia germination and capitula development.

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**Acknowledgements**

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Registration, the Washington Turfgrass Seed Commission, and the USDA for providing project funding; BASF Corporation, Bayer CropScience, DuPont, Gowan Company, Syngenta Crop Protection, and Top Onions USA for providing fungicides and essential oils used in this study; and Javier Almaguer, Jesika Holcomb, and Phil Rogers for technical assistance.

**Table 1.** The number of quadrats examined, ergot incidence and the mean incidence of infected inflorescences and ergot severity in three fields of perennial ryegrass and six fields of Kentucky bluegrass grown for seed.

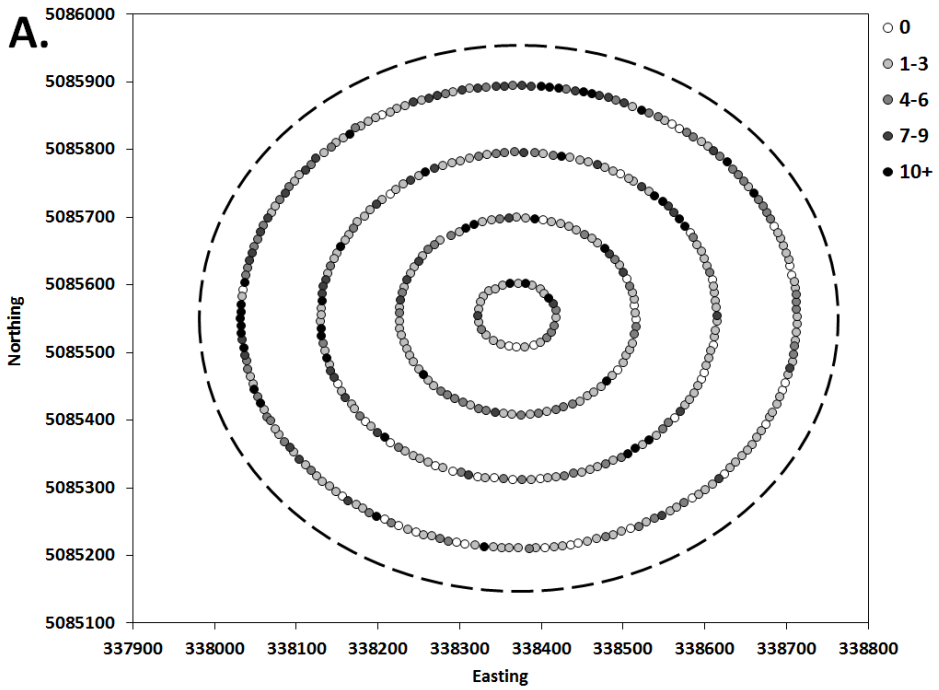
| Grass | Field | Cultivar | Acres | Years cropped to grass seed | No. quadrats[a] | Quadrats with ergot (%)[b] | Mean incidence of infected inflorescences (%)[c] | Mean Severity[d] |
|---|---|---|---|---|---|---|---|---|
| Perennial ryegrass | H-7 | Provocative | 125 | 1 | 454 | 90 | 25.3 | 4.13 |
| | H-3 | Pavilion | 125 | 1 | 492 | 84 | 20.5 | 2.86 |
| | RC-2 | Top Hat II | 125 | 1 | 487 | 59 | 12.7 | 1.79 |
| Kentucky bluegrass | BH-6 | Midnight | 125 | 1 | 589 | 29 | 1.9 | 0.68 |
| | R-1 | Midnight | 125 | 1 | 483 | 0 | 0.0 | 0.00 |
| | BR-20 | Baron | 32 | 4 | 115 | 49 | 23.3 | 0.38 |
| | 08-651 | Kelly | 65 | 4 | 185 | < 1 | < 0.1 | < 0.01 |
| | 10-06 | Wildhorse | 40 | 2 | 139 | 0 | 0.0 | 0.00 |
| | 10-02 | Right | 77 | 2 | 102 | 0 | 0.0 | 0.00 |

[a] Quadrats were approximately 10 $ft^2$ in size and approximately 30 to 100 ft apart. Quadrats were located at approximately 6.5 ft outside of every other pivot wheel track. At least 10 inflorescences were collected from each quadrat.

[b] Percentage of quadrats with at least one inflorescence bearing sclerotia.

[c] Mean percentage of inflorescences bearing sclerotia per quadrat.

[d] Mean number of ergot bodies per quadrat.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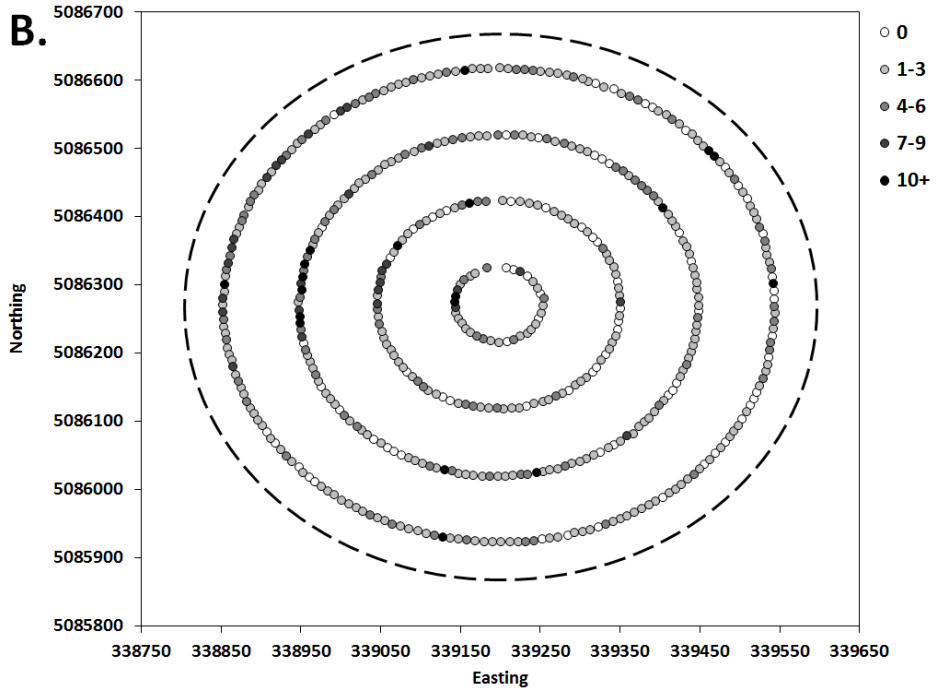
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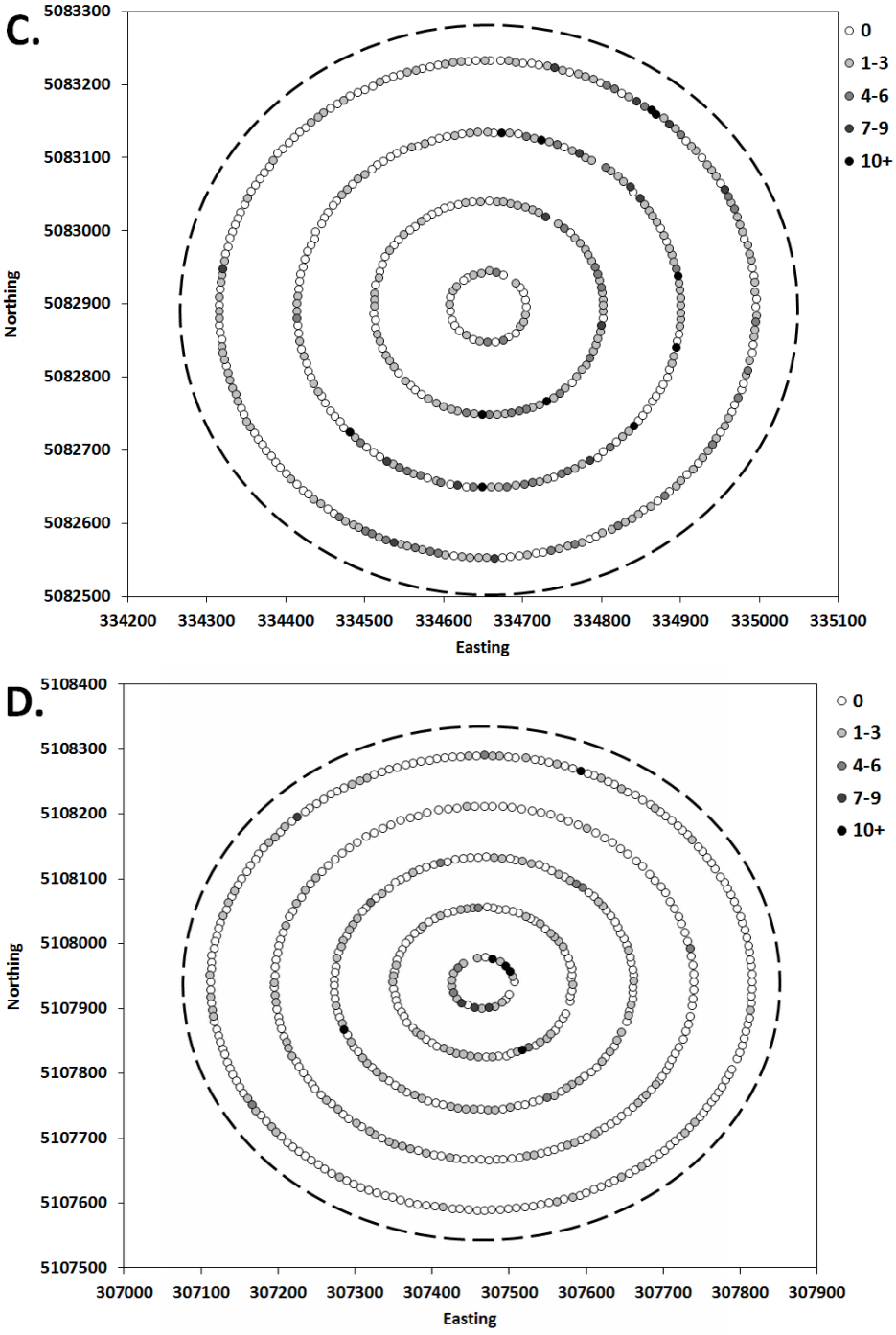


**Fig. 1.** Dot plots of ergot severity in perennial ryegrass fields A) H-7; B) H-3; C) RC-2; and D) Kentucky bluegrass field BH-6. Values represent the total number of sclerotia in ten inflorescences collected from sampled quadrats located 30 ft apart and following alternating center pivot wheel tracks. Field boundaries are indicated by dashed lines.

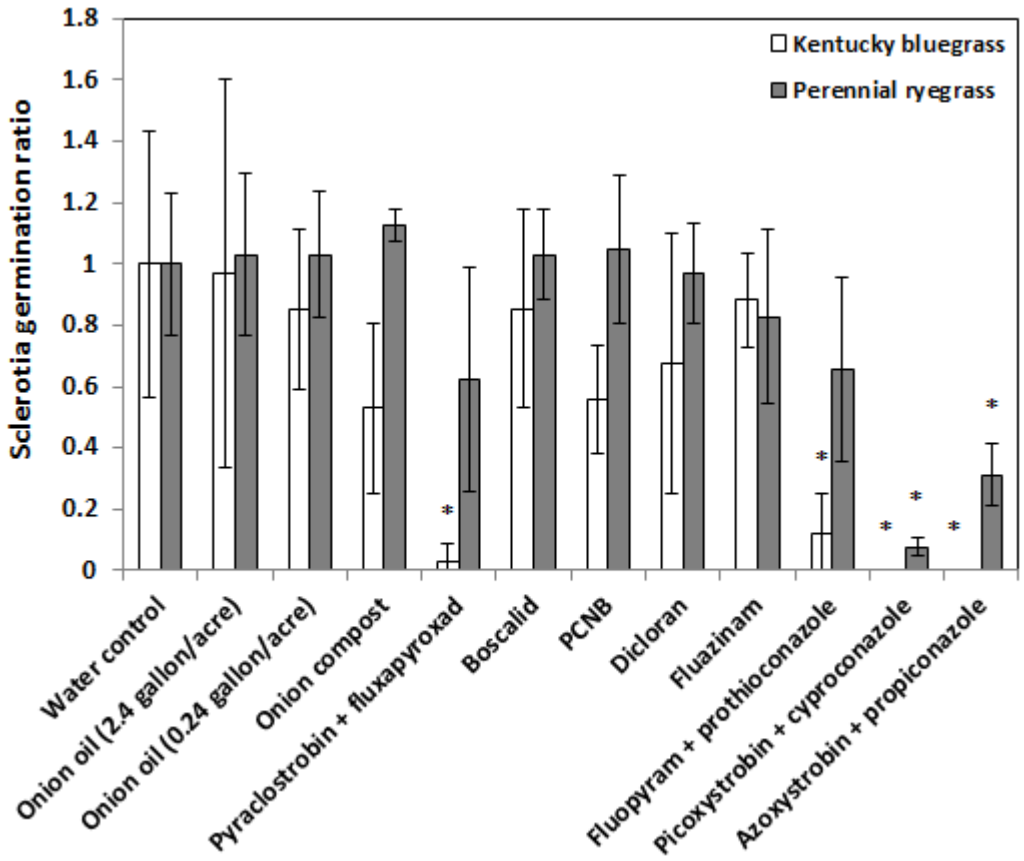


**Fig. 2.** Effect of onion oil, onion compost, and various fungicides on the germination of ergot sclerotia collected from Kentucky bluegrass and perennial ryegrass. Sclerotia germination ratio values were calculated by dividing the mean of each observation by the overall mean of the control treatments. Error bars represent standard deviations. Treatments labeled with an asterisk are significantly different than the water control using Dunnett's test at $P = 0.05$. Products used above are not registered for use in grass seed production and/or as soil applications. Always rely on the product label for complete details.

# EXPRESSION OF GERMINATION AND FLUORESCENCE IN ANNUAL RYEGRASS SAMPLES AFTER SEVEN AND FOURTEEN DAY GERMINATION PERIODS

*S. Elias and A. Garay*

## Introduction

Samples from seed lots of recently harvested annual ryegrass (*Lolium multiflorum* L.) (ARG) possess varying levels of dormancy, depending on the variety and the growing conditions. The Rules for Testing Seeds of the Association of Official Seed Analysts (AOSA) indicate that dormant seeds have to receive pre-chilling treatment to overcome dormancy and allow the seeds to germinate (AOSA, 2012). Samples from seed lots harvested in Oregon in early summer (i.e., early July) are typically chilled through the end of the summer (i.e., September). Starting in early fall, ARG samples are no longer chilled as seed dormancy gradually disappears over time. This occurs through a process known as 'after-ripening' a series of physiological changes that allow dormant seeds to germinate (Copeland and McDonald, 2001).

The AOSA Rules for Testing Seeds indicate that germination tests may end when a sample has reached its maximum germination potential (AOSA, 2012, vol. 1. sec. 6.9d.3). However, in case of ryegrasses, the AOSA Cultivar Purity Testing Handbook (AOSA, 2008) indicates that fluorescence test may not end before the 14-day prescribed germination period regardless of whether or not a sample has reached its maximum germination. It has been observed over years that many ARG samples reach maximum germination after one week of pre-chilling treatment and one week of germination testing at 15-25°C (data not shown). To date, research has not been conducted to systematically evaluate germination and fluorescence patterns exhibited by ARG and determine the feasibility of reducing the germination test period from 14 to 7 days.

The ryegrass seed industry is genuinely concerned about the justification for waiting an additional seven days even if a sample reached maximum germination at the first count (7-days). ARG is usually harvested in July and seeds have to be cleaned, tested, labeled and shipped by the end of August in most cases. This short window of time requires that every activity from cleaning seeds to testing and tagging has to be performed efficiently and effectively, including germination and fluorescence testing. Any delays during this process create missed opportunities for ARG sales. Many members in the seed industry consider the 21-day period currently needed to complete the germination-fluorescence test excessive. It is worthy to note that in 2011 the AOSA agreed that evaluation of ARG germination and fluorescence tests could be completed and reported before the 14$^{th}$ day, as long as the seed analyst is positive that the sample had reached maximum germination. The hypothesis of the study is that if an ARG samples reached maximum germination, it also expresses maximum fluorescence, and waiting additional time will not affect the final results of neither germination nor fluorescence. Therefore, the objectives of this study were to: 1) determine the germination and fluorescence test results of 112 freshly harvested (dormant) ARG samples at 7 and 14 days; and 2) determine the frequency of samples that reach maximum potential germination and fluorescence before 14 days.

## Materials and Methods

Data were collected in the summer of 2010 to determine the germination and fluorescence results of 112 freshly harvested seeds of certified seed samples representing 23 ARG varieties. The germination and fluorescence results were collected systematically at 7-day count (first count) and 14-day count (final count) at the Oregon State University Seed Laboratory. Because these samples had been freshly harvested in early summer, they were chilled at 10°C for seven days prior to the warm germination at 15-25°C for 7 and 14 days. All germination and fluorescence tests were conducted according to the AOSA Rules for Testing Seeds (AOSA). For simplicity in representing the research

findings, the fluorescence test results were rounded to whole numbers.

**Results and Discussion**

Germination Test Results: 7-day versus 14-day

The results of 7 and 14-day germination testing of 112 ARG samples are presented in Figure 1. The mean test results of the 112 samples was 96.16% at the first count after 7 days and was 96.52% at the final count after 14 days. The standard deviation of the 112 samples from their means in the 7-day count was similar at 2.30 in the first count and 2.13 in the final count. The germination data in Figure 1 has been ranked from the highest to the lowest value, based on 7-day count. The results showed that a vast majority of samples expressed high germination, 90% or higher, in the first count, which was similar to that of the final count. Those samples that had achieved high germination in the first count did not change, or had a slight increase between 7 and 14 days counts. This indicates that the majority of samples reached maximum potential germination in the first count and that the germination tests could therefore be ended after 7 days. Leaving the sample in the germinator for extra 7 days did not affect the final results, and may cause an unnecessary delay in test results.

At the lower end of the germination in Figure 1, a few samples showed lower germination results in first count compared to the final count indicating these samples do need to germinate for the full 14-day germination test period to achieve maximum potential germination. The magnitude of variation between first and final counts depends on varietal differences, environmental influence under which the crop developed and matured, the physiological quality of each seed lot, the age of seeds, and whether seeds were subjected to pre-chilling treatment before the germination test. It is reported that pre-chilling treatments break dormancy and speed up germination for ryegrass (Elias and Garay, 2008).

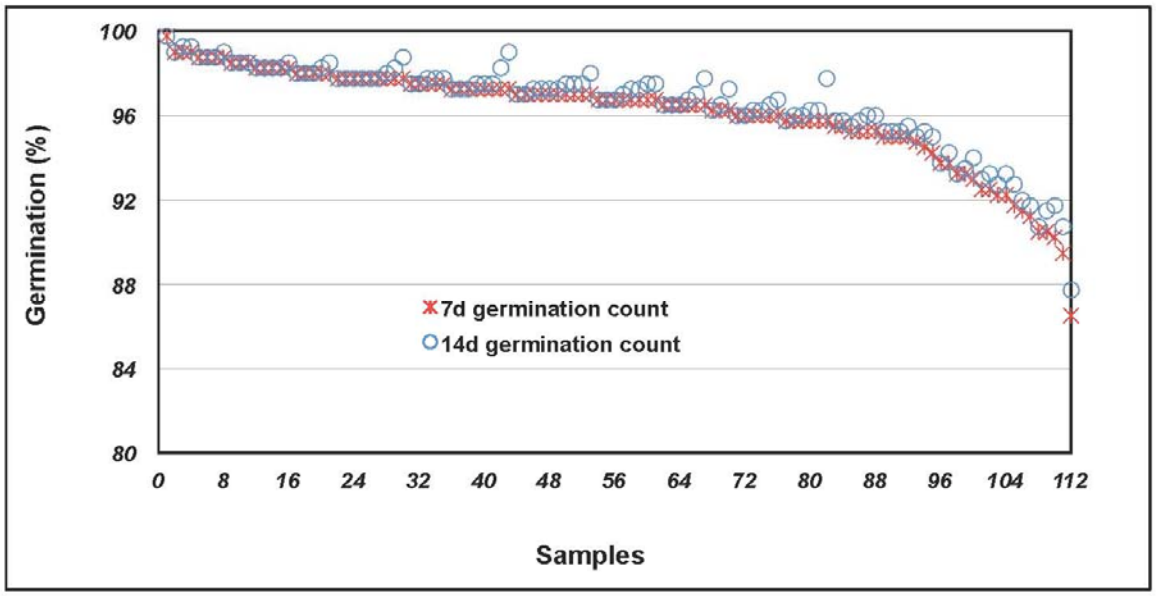


Figure 1. Germination results of 7-day and 14-day counts of 112 ARG samples tested at the OSU Seed Laboratory.

Maximum Germination Frequency: 7-day versus 14-day

The frequency of samples that reached maximum germination in 7 days compared to 14 days is presented in Figure 2. Results showed that a large number of samples had the same germination level in the first and the final counts. In 72 of the 112 samples tested (64%) there was no difference in germination percentage between the first and the final counts (Fig. 2). Those samples had already expressed their maximum germination in the first count. In this case, waiting an extra 7 days did not

improve the final results, but caused unnecessary delay in delivering the results in a timely manner. Likewise, the germination percentage of approximately one-third of the samples increased in the final count (14 days) only by 1% compared to the first count after 7 days (Fig. 2). This increase is minimal and is smaller than the typical random sampling variation of two subsamples drawn from the same seed lot. The germination of a small number of samples (3%) increased in germination in the final count by 2%. This increase is still small, which confirms that most samples achieve maximum germination potential in the first count, and thus the germination tests of those samples could be ended in 7 days rather than 14 days without affecting the accuracy of the results. It is not unusual that 36% of ARG samples did not achieve maximum germination at 7-days. Among the reasons that affect the speed of germination are differences among varieties, growing conditions, dormancy levels, seed vigor, as well as random sampling variation.

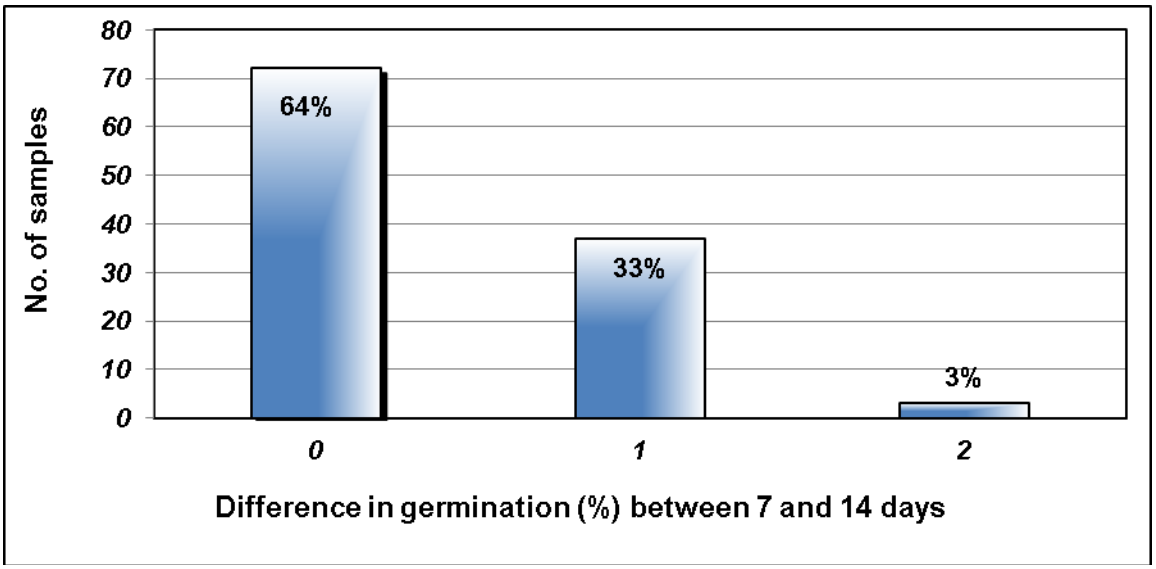


Figure 2. Frequency of samples that reach maximum germination in 7 days compared to 14 days of 112 ARG samples tested at the OSU Seed Laboratory.

Fluorescence Test Results: 7-day versus 14-day.
The fluorescence test results in the first count at day 7 and in the final count at day 14 of the 112 samples are presented in Figure 3. The mean of the 112 samples was 99.31% at the first count after 7 days and was 99.78% at the final count after 14 days. The standard deviations of the 112 samples from their means in both the first and the final counts were small at 1.16 and 0.48, respectively. The fluorescence data has been ranked from the highest to the lowest based on 7-day count (Fig. 3). The results indicated that the vast majority of samples (over 87%) have already expressed the typical high fluorescence of annual ryegrass (i.e., 99-100%) in the first count. Samples that had achieved high fluorescence in the first count either did not increase or slightly increased compared to the final count after14 days. These results indicated that the fluorescence evaluation in such samples could be ended in the first count and that waiting extra seven days would cause unnecessary delay in delivering the results. These results are not surprising because as long as the samples reach maximum germination and developed normal root system, the fluorescence expression is expected to reach full potential. At the lower end of the curve in Figure 3, some samples showed relatively lower fluorescence in the first count compared to the final count, and would therefore need the full 14-day test period before the test is ended.

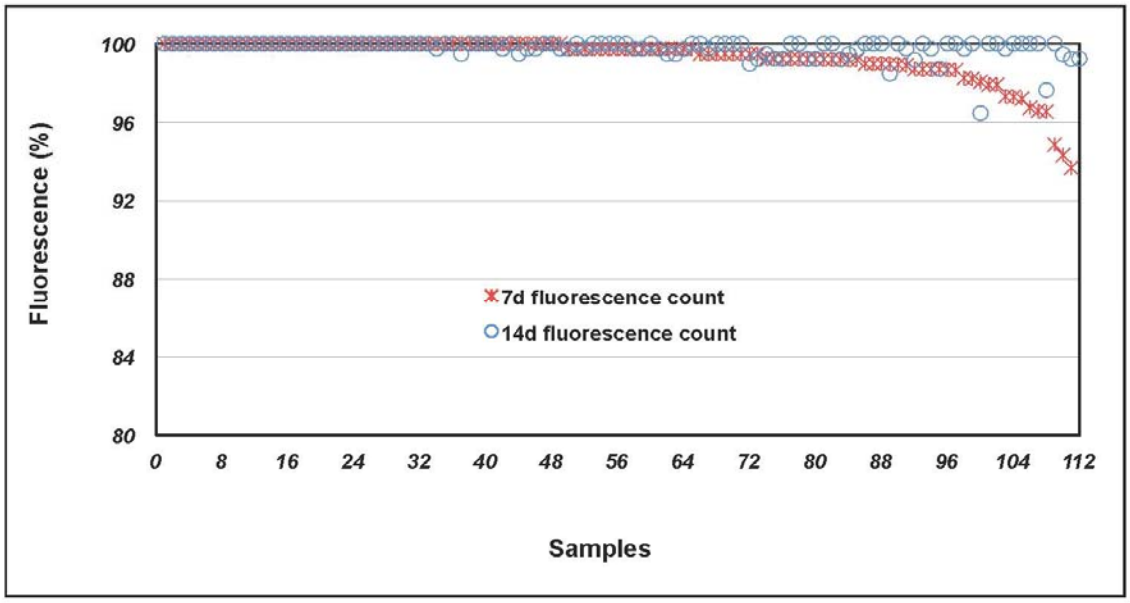


Figure 3. Fluorescence results of 7-day and 14-day counts of 112 ARG samples tested at the OSU Seed Laboratory.

Maximum Fluorescence Frequency: 7-day versus 14-day

The frequency of samples that reached maximum fluorescence in 7 days compared to 14 days is presented in Figure 4. The results indicated that the fluorescence test results of 70% of the 112 samples did not change from the first to the final count, and 19% of the samples changed by only 1% (Fig. 4). The majority of samples (89%) had expressed maximum fluorescence in the first count or had a slight change from the first to the final count. These results indicate that a great number of samples had expressed maximum fluorescence at the first count without the need to extend the test for an additional 7 days.

Feasibility of 7-day Germination and Fluorescence Testing Period.

The results presented in this study confirm previous observations made by germination analysts in many laboratories for several years. These results indicated that over 80% of ARG samples did reach both maximum germination and fluorescence expression in the first count in 7 days and the additional week of test period required by the AOSA rules appears unnecessary. The study also determined that a small percentage of samples increased in germination and fluorescence only by 1% which does not justify waiting an additional 7 days, Such a small increase in germination and fluorescence is insignificant and could be attributed to random sampling variation if the test is to be repeated. These findings indicate the potential for seed analysts to end ARG germination and fluorescence tests when maximum germination is attained at 7-days without compromising accuracy of results. In addition, the results from this study would support a proposed change in AOSA testing protocol, thus, increasing ARG seed testing efficiency by releasing results in a more timely fashion. The small percentage of ARG samples that do not express maximum germination and/or fluorescence in the first count because of dormancy or any other reason do need to germinate for the full 14-day period to make the final evaluation. The seed analyst has the discretion to determine whether a sample reached maximum germination potential on a case-by-case basis.

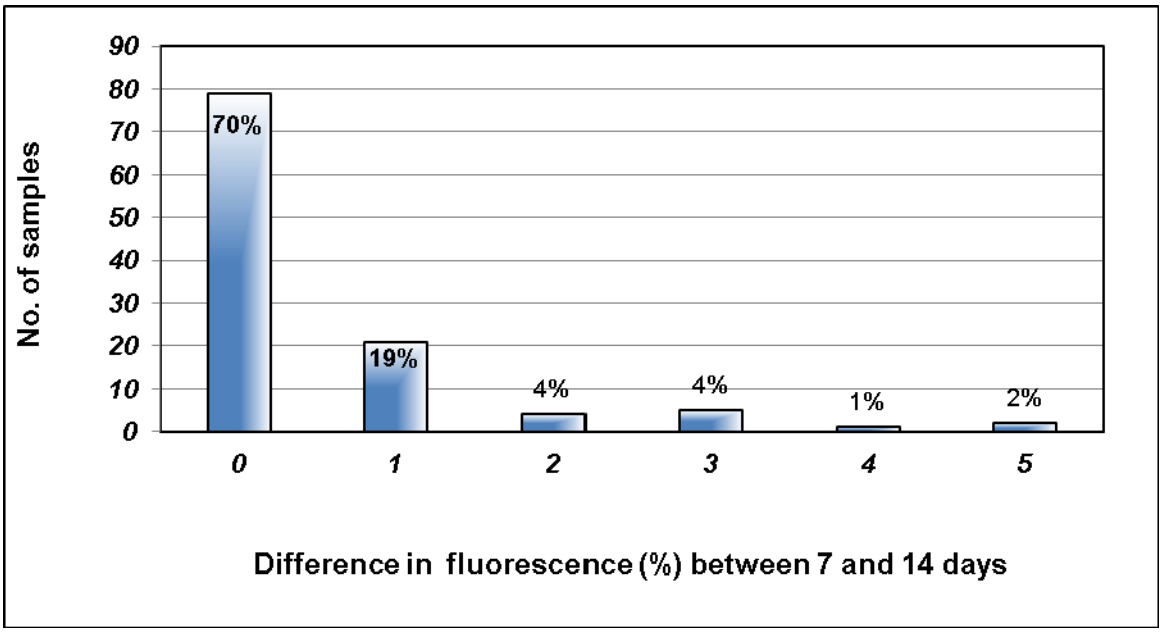


Figure 4. Frequency of samples that reach maximum fluorescence in 7 days compared to 14 days of 112 ARG samples tested at the OSU Seed Laboratory.

**Conclusions**

- With pre-chilling treatment (7 days at 10°C), the majority of ARG samples reached maximum germination and fluorescence in the first count after 7 days, or changed only by a small magnitude (i.e., 1-2%) after 14 days. The germination and fluorescence tests in such samples could be ended at the first count, thus increasing the timeliness of reporting test results to the industry, without sacrificing accuracy.

- Samples that do not reach maximum germination and/or fluorescence in the first count need to be germinated for the full 14 days before ending the test.

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# FEASIBILITY OF REDUCING THE DURATION OF GERMINATION AND FLUORESCENCE TESTS FOR PERENNIAL RYEGRASS (*LOLIUM PERENNE* L.)

*S. Elias and A. Garay*

## Introduction

Germination and fluorescence tests are required for labeling certified seed lots of perennial ryegrass. The standard germination test indicates the percentage of viable seeds in a sample, and the fluorescence test quantifies the amount of annual ryegrass contamination in perennial samples which is used to calculate purity test results. The roots of annual type fluoresce upon exposure to UV light, while the roots of perennial type do not fluoresce.

Perennial ryegrass (PRG) is harvested in August and must be shipped to worldwide markets by the end of September in order to arrive on time for fall planting. After seed harvest is completed, the time frame for cleaning, sampling, testing, tagging and shipping is very short. Any delays during this process can lead to missed opportunities for PRG sales.

Germination and fluorescence testing conducted on freshly harvested PRG seeds under the current Association of Official Seed Analysts (AOSA) Rule for Testing Seeds requires pre-chilling treatment at 5-10ºC followed by 14 days of warm germination (15-25ºC). However, previous observations have indicated that the full 14 days of warm germination might not be necessary to achieve maximum germination in all samples and leads to unnecessary delay in delivering final test results. It is true that the chilling period to break dormancy cannot be avoided, however the warm germination period may be shortened. Observations in many labs have indicated that many freshly harvested PRG seeds, when properly chilled, show complete germination in the first count after seven days, and that the resulting seedlings have well-developed roots for full expression of fluorescence (Fig. 1).

In 2011, the AOSA agreed that official evaluation of annual ryegrass (ARG) germination and fluorescent test results could be completed and reported before the 14$^{th}$ day, provided the seed analyst is positive that the sample has reached maximum germination capacity. This change was accepted based on studies, which demonstrated that the majority (over 80%) of ARG samples reach maximum germination and fluorescence at 7 days (first count) on chilled samples (unpublished data by the authors, 2010). This change has allowed seed labs to successfully deliver timely and accurate test results to the seed industry over the last two years, thus, increasing the efficiency of shipping certified ARG seed to global markets. As a result, many seed industry members have asked the Oregon State University Seed Laboratory (OSUSL) to conduct similar studies to determine whether or not germination and fluorescence tests for PRG can be ended at 7-day count rather than enduring the entire 14-day testing period. The potential benefit to PRG would be similar to the improved process utilized for ARG testing and subsequent shipment. Therefore, the objective of this study was to compare the percentage of germination and fluorescence of chilled PRG samples after 7 and 14 days to assess the feasibility of reducing the duration of germination and fluorescence tests for perennial ryegrass.

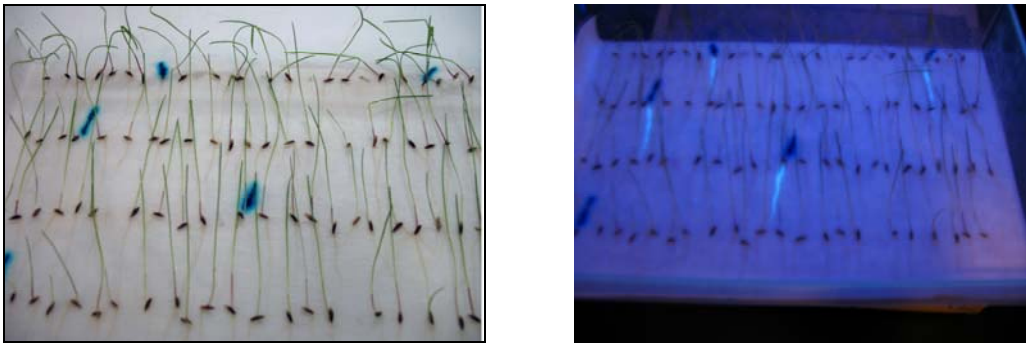

Figure 1. A perennial ryegrass sample showing well developed seedlings and maximum germination capacity and fluorescence expression at the first count (7-day pre-chill + 7-day germination).

**Methods**

Data from germination and fluorescence test results were collected from the Oregon State University Seed Services database on 2242 PRG samples, representing 203 varieties that were produced and tested in 2011. All samples received pre-chilling treatments before germination.

Samples were germinated according to the AOSA Rules for Testing Seeds, vol. 1. Samples were pre-chilled at 10ºC for 7 days and then transferred to growth chambers for germination at 15-25ºC. Four replications of 100 seeds each were planted for each test. The first germination count was conducted at 7 days and the final count at 14 days. Fluorescence was evaluated at 7 and 14 days as well. Means and standard deviations were calculated to make comparisons between 7 and 14-day test results.

**Results and Discussion**

Germination Test Results: 7-day versus 14-day

The average germination of the 2242 samples tested in first count (7 days) was 93%, and was 94% at the final count after 14 days (Fig. 2). For practical purpose, these results are comparable and statistically similar. The vast majority of samples had already reached over 90% germination by the first count at 7-days (Fig. 2). This means that the germination level is already above the standard required by certification and meets the needs of most industry customers.

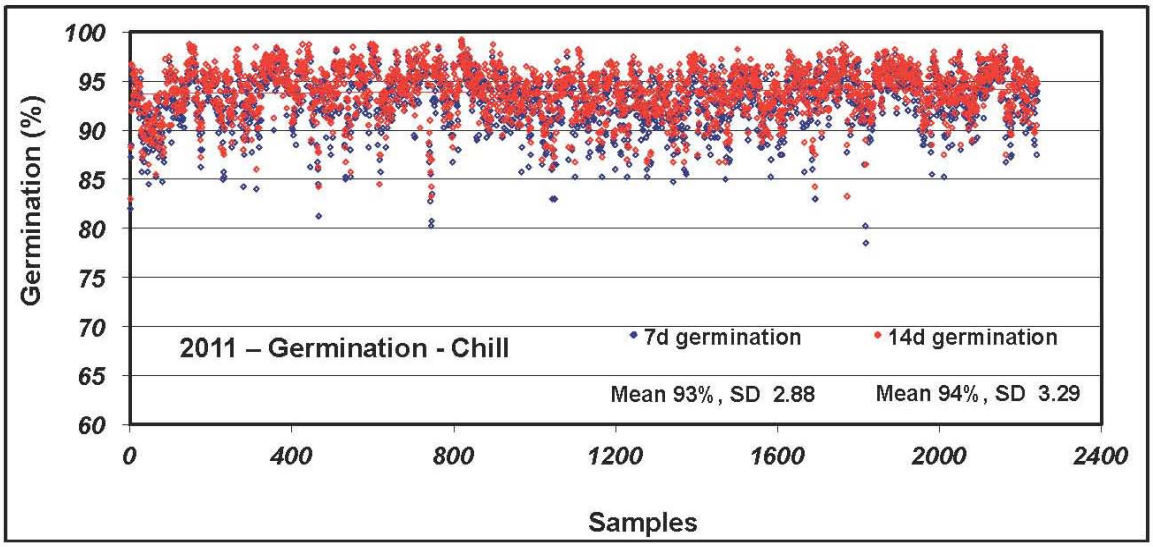


Figure 2. Comparison between 7-day and 14-day germination test results of 2242 perennial ryegrass samples tested with pre-chilling treatments in 2011.

Figure 3 presents the magnitude of change in germination between the first count at day 7 and the final count at day 14. In 35% of the samples, the germination percentage did not increase from the first to the final count. Additionally, 61% of the samples increased only by 1-2%, which is less than the variance that is expected due to random sampling variation. Such variation is negligible for most customers when the germination of the sample is above 90%. These results indicate that 96% of the 2242 samples reached maximum germination first count (7-days) and it was unnecessary to continue testing for an additional 7 days as the current AOSA Rules require.

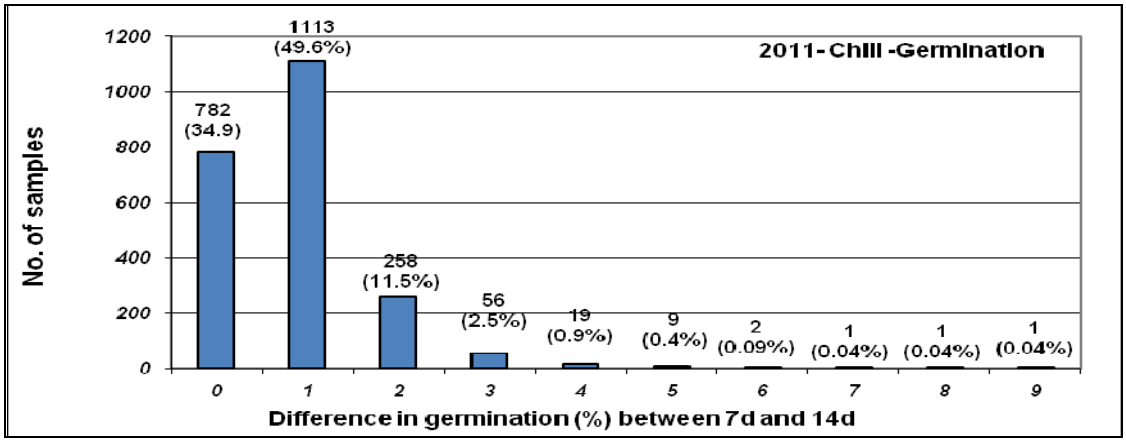


Figure 3. Change in germination test results between the first count at 7 days and the final count at 14 days for 2242 perennial ryegrass samples tested in 2011.

Conversely, in 4% of the 2242 samples the germination results increased by more than 2% between the first and the final counts. Such samples do require the additional 7 days (for a total of 14 day germination) for reach maximum germination. The magnitude of variation between first and final counts depends on varietal differences, environmental influence under which the crop developed and matured, the physiological quality of each seed lot, the age of seeds, and whether seeds were subjected to pre-chilling treatment before the germination test.

Fluorescence Test Results: 7-day versus 14-day

The average difference between the first and the final counts for the fluorescence test results of the 2242 samples did not exceed 0.27% (Fig. 4). This variation in fluorescence is smaller than a typical variation of two subsamples drawn from the same seed lot. It is also worthy to note that the 3% tolerance value for fluorescence in the Oregon Seed Certification Program is greater than this 0.27% difference between the first and final count results detected in this study.

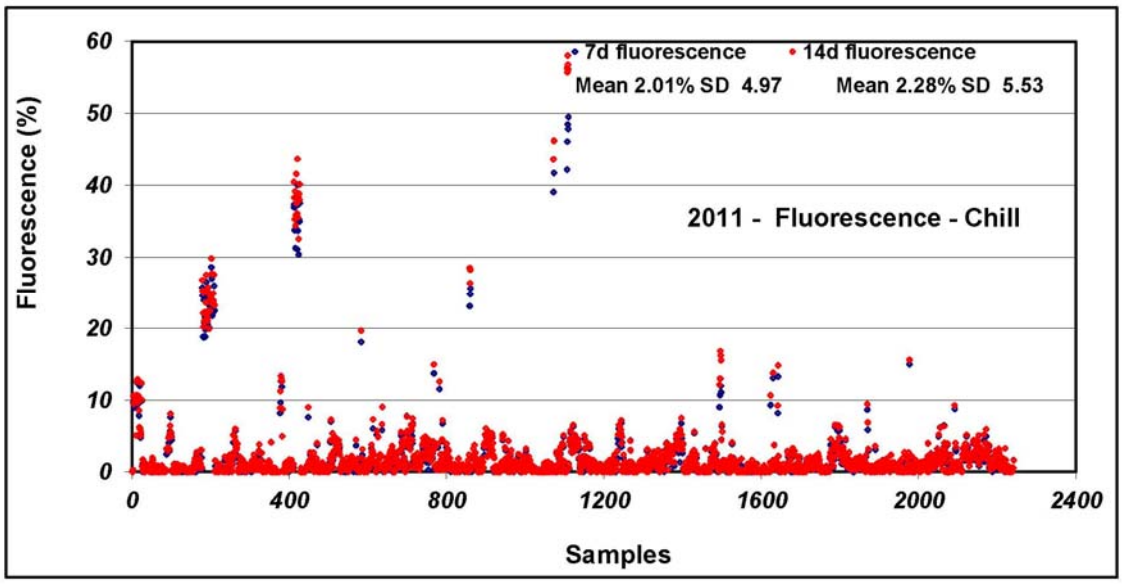


Figure 4. Comparison of fluorescence test results of 2242 perennial ryegrass samples germinated for 7 days and 14 days, with pre-chilling treatment in 2011.

For 54% of the samples, the fluorescence level did not increase from the first to the final count. Additionally, the fluorescence increased only by 1% from the first to the final count in approximately 40% of PRG samples. Overall, the increase in fluorescence level from the first count to the final count did not exceed 1% for a total of 93.5% of all PRG samples tested in 2011 (Fig. 5). Furthermore, for 99% of the total samples tested, the increase in fluorescence level from the first count to the final count did not exceed the 3% tolerance level set by the Oregon certification program (Fig. 5).

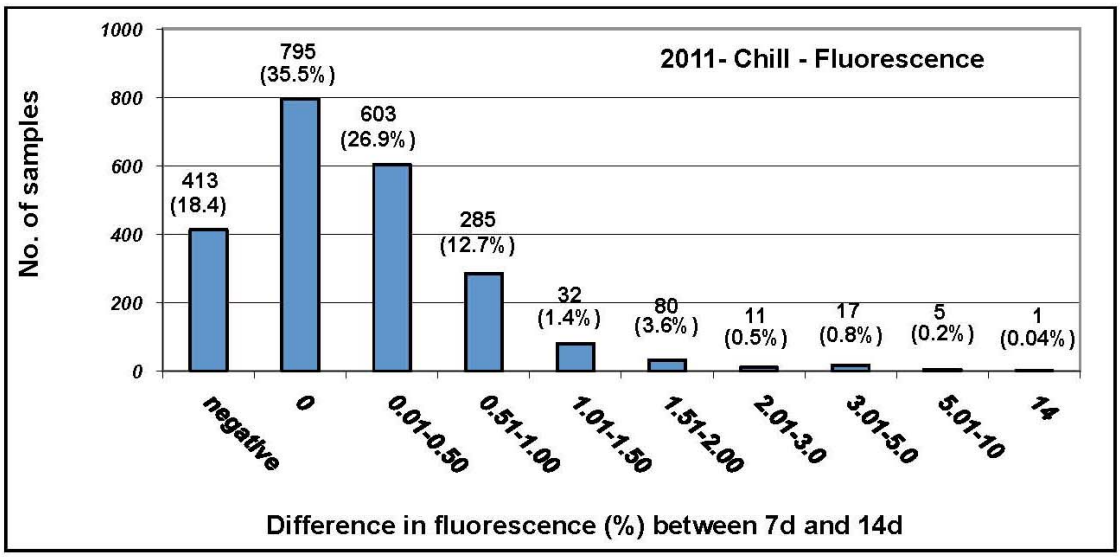


Figure 5. Change in fluorescence test results for 2242 perennial ryegrass samples from the first count at 7 days to the final count at 14 days in 2011.

These results indicate that the expression of fluorescence reached its maximum level at the first count in the vast majority of samples. Generally, if seedlings of annual ryegrass (ARG) developed normal root system after 7 days, they fluoresce upon exposure to UV light and no extra germination time is needed. The roots of ARG possess naturally occurring chemicals called annuoline $[C_{17}H_{10}ON(OCH_3)_3]^2$, a fluorescent pigment that fluoresce when exposed to ultraviolet light. Practical observations also indicate that the change in fluorescence level due to random sampling variation among subsamples from the same seed lot can be more than the changes detected between the first and the final counts in this study. In addition, these changes are smaller than the 3% tolerance allowed by the Oregon Seed Certification Program. The high expression of fluorescence found in this study by the first count can be explained by the high germination that was achieved by first count.

**Conclusions**

- The majority of freshly harvested PRG samples that have been chilled reached maximum germination and fluorescence by the first count (7-day).
- Sample results that have reached maximum germination by the first count (7-day) can be reported without affecting the final results.
- Samples that did not reach maximum germination in the first count (7-day) should be germinated for full 14 days before ending the test.
- Based on the results, it is appropriate to clarify in the AOSA Cultivar Purity Testing Handbook that ending the germination and fluorescence tests of PRG before 14 days should be allowed, provided the analyst is positive that the sample has reached maximum germination potential.

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# CHAR-AMENDED ACID FARM SOILS – EFFECTS ON SOIL CHEMISTRY AND WHEAT GROWTH

*S.M. Griffith, G.M. Banowetz, and D. Gady*

## Introduction

On-farm gasification of agricultural residues, the non-food byproducts from crop harvests, could provide a means to generate value-added income from the production of fuel or electrical generation. The ash-like combustion by-product, char, produced during the process also has potential value as a soil amendment for a variety of purposes including field crop production or even as a sorbent.

Char produced from gasification is different from biochar produced by pyrolysis because gasification is conducted in the presence of a restricted amount of oxygen, which promotes partial combustion at temperatures of 650 to 800°C or higher. In contrast, pyrolysis is conducted under anaerobic to extremely low oxygen conditions at temperatures between 400 and 500°C. Relative to the current knowledge of the chemical bio-characteristics and utility of biochar produced from pyrolysis, there is a scarcity of data concerning char produced from the gasification of biomass, especially with respect to its use as a soil amendment.

Due to the lack of data characterizing char produced from herbaceous biomass, particularly with regards to its use as a soil amendment and subsequent effects on soil chemistry and plant growth, this study characterized char produced by gasification of Kentucky bluegrass seed screenings (KBss) and compared it to char produced from wood biomass. Wood char was included because it's the most commonly studied type of char and the potential for producing wood char in the Pacific Northwest with its abundant horticultural and forest industries. KBss char used in this study was produced in a farm-scale gasifier where the biomass was converted to a syngas containing methane, carbon monoxide, and hydrogen. The syngas was used to partially fuel a diesel generator to produce electricity. We recognize that the high surface to mass ratio KBss char byproduct could have utility as a soil amendment if it had characteristics which protected against damaging acid soil conditions, provided crop nutrients, sequestered C, or helped trap and conserve soil water under dryland farming conditions, or be used as a chemical sorbent. If demonstrated under controlled conditions, we reasoned that this utility could enhance farm profit, soil quality, and resource conservation.

The objective of the study was to determine the effect of char as a soil amendment on wheat growth and identify various soil parameters that might explain measured growth effects.

## Materials and Methods

A replicated greenhouse pot study was conducted using wheat. Single plants of wheat (Triticum aestivum L. cv. Madsen; a widely planted cultivar in the state of Washington, U.S.A.) were grown for 74 days (wheat Feekes stage 5) in 650 $cm^3$ black plastic pots, containing either a Freeman or Bernhill soil (acid farm soil, Spokane, WA, U.S.A) with different percentages of either KBss or wood char (0, 2.6, 6.7, 14.4, and 33.7 % by volume). Due to slight differences KBss and wood char density, the final mass concentration of KBss char to soil was 0, 4, 12, 25, and 58 g $kg^{-1}$ and for wood char, 0, 7, 17, 37, and 86 g $kg^{-1}$. The KBss char was produced at 600 to 650 °C and the wood char produced from conifer tree cuttings in a downdraft gasifier at 1200 ºC. The gasifiers were small-scale units located on-farm.

## Results and Discussion

Wheat shoot dry mass accumulation significantly ($P$<0.05) increased with increasing concentrations of soil amended wood or KBss char. At the highest concentration of KBss char (58 g $kg^{-1}$) shoot dry mass increased by 1.68-fold in the Freeman soil, but root dry mass was unaffected. Amended Bernhill soil with 58 g $kg^{-1}$ KBss char increased shoot dry mass 1.94-fold and root dry mass 1.46-fold. In contrast, amendment of Freeman soil with wood char at 86 g $kg^{-1}$ enhanced shoot dry mass by 2.78-fold and root dry mass 2.06-fold. This same level of amendment of Bernhill soil with KBss char increased shoot and root dry mass by 2.43- and 2.79-fold, respectively.

Wood and KBss char amendments did not significantly ($P$<0.05) affect wheat seedling emergence when mixed with Freeman or Bernhill soils. Plants grown in the Freeman soil-wood char mixtures had higher leaf chlorophyll content (SPAD readings) over plants grown in Freeman soil alone, whereas KBss char had no affect on leaf chlorophyll concentration over either soil alone.

We measured wheat root and shoot tissue concentration of ten plant nutrients of after 74 days of growth to determine the effect of added char on elemental uptake. We found that the addition of increasing concentrations of KBss char to Freeman or Bernhill soil consistently enhanced shoot K, P, S, Zn, and Mg, and to some extent S, and significantly reduced Ca content compared to plants grown in soil alone.

Wood char mixed with Freeman or Bernhill soil had consistently higher concentrations of K, P, and Mn (Bernhill soil only), and P but had lower Ca, Cu, and S concentrations. Iron concentrations were highest in roots over shoots in all treatments and root Fe concentrations were lower with increasing char concentrations. The inverse was true for Ca. Calcium shoot concentrations exceeded root Ca concentrations and Ca concentrations declined in shoot with increased char concentrations, but not in roots. Addition of char lowered Al uptake by wheat in both soils.

The KBss and wood chars alone had a pH of about 11 while the pH of the two soils was approximately 4.5. The electrical conductivity (EC) of the chars alone was about 53-fold greater than the soils (~70 uS), with a cation exchange capacity (CEC) of 55 meq $100g^{-}1$, about five-fold greater than the soils. Increasing char concentrations in soils raised soil pH in a linear fashion. Amended soil pH increased from 4.5 (soil alone) to a maximum of 7.0 after char was added to the soil at a concentration of 86 g $kg^{-1}$. This was probably the greatest contributing factor favoring improved growth of wheat by improving soil nutrient availability and root uptake.

**Conclusion**

Findings of this study are the first showing the effects of KBss and wood char on the growth of wheat. Greenhouse grown wheat in soil amended with char showed a dramatic increase in growth with increasing soil char concentrations. Mineral nutrition was significantly enhanced which most likely resulted from a “liming” effect by the added char. The rise in soil pH with added char most likely contributed reduced soil Al availability to plant roots, thus limiting Al root uptake and potential plant Al toxicity common in low acid soils. Low farm soil pH and associated crop Al toxicity is a current concern on eastern Washington and western Idaho farmland that were historically covered with forest vegetation (Koenig et al., 2011).

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# COMPARISON OF PURITY TEST RESULTS OF VARIOUS GRASS SPECIES USING AUTOMATIC SAMPLER VS. PROBE SAMPLING

*R. Hankins and S. Elias*

## Introduction

A sample is a small quantity of a seed lot intended to show the quality of the whole lot. Increasing accuracy and precision in seed testing is highly correlated with the precision of sampling procedure. No matter how carefully and accurately a seed test is performed, it shows only the quality of the sample submitted for testing (AOSA, 2012). Thus, it is imperative that samples be properly drawn and adequately represents the quality of the seed lot from which it is sampled. If taken with carelessness or biased procedures, all subsequent tests or analyses may not be representative of the quality of the seed lot and are of little value. Any compromise or disregard of the principles of good sampling risks a bias in results and does a disservice to both the seed producer and the consumer (Elias et al., 2012).

Proper and representative sampling is only possible if the sampled seed lot is sufficiently uniform, which makes the distribution of the contaminants within the seed lot as even as possible. The rule of the thumb is that the cleaner the seed lot, the more uniform it is. The level of contaminants in the field from which seed is harvested, as well as post-harvest operations, contribute to seed lot heterogeneity. However, a seed lot must be sufficiently uniform if subsamples are to represent the overall lot quality. Samples drawn from heterogeneous seed lots do not represent the true quality of the lot (Elias et al., 2012).

Recently, a question was raised about the effect of automatic sampling and probe sampling on the final results of a seed purity test. Automated sampler is a portable unit that can be programmed to collect discrete sequential samples, time-composite samples or flow-composite samples (WCD, 2007). In the automatic sampler, samples are taken at equal increments of time and are composited proportional to the flow rate at the time each sample is taken. Samples are drawn from the seed stream automatically in the final step of the cleaning process at specified time intervals. Thus, automatic sampling does not involve human subjectivity in drawing samples. On the other hand, probe sampling is an approved sampling method where samples is drawn from a seed lot by a trained sampler using certain procedures, thus it involves human subjectivity. To ensure a representative sample using probe sampling, proper procedure should be followed. Such procedures include sampling equal portions from evenly distributed parts of a seed lot with appropriate probes (also called triers) of sufficient length to reach all areas in a seed bag or a bin. Following this sampling methodology, individual primary samples taken from bags or bins from well-distributed locations throughout the seed lot are combined into one composite sample. In both sampling methods, a composite sample that comprises the primary samples taken from a seed lot is collected and submitted to a seed laboratory for testing.

There are no published reports available on the accuracy and precision of automatic sampling compared to probe sampling in grass seeds. The objective of this study was to measure the effect of using automated sampling and probe sampling on purity test results of various grass species. Our hypothesis was that if the purity test results of samples drawn by the automated sampling method were comparable (i.e., within tolerance) to the results of the samples drawn by probe sampling, then either sampling method may be used without affecting the results of purity testing.

## Materials and Methods

Seed warehouses in Clackamas, Marion, Washington, Polk, Yamhill, Linn, Lane, and Benton counties in Oregon, with automatic samplers, were asked to provide one or two grass seed lots representing eight grass species including, tall fescue, annual, intermediate, and perennial ryegrass, orchardgrass, red fescue, chewing fescue, bentgrass, and Kentucky bluegrass. The seed lots provided by the warehouses represented four growing seasons from 2008 to 2011. One hundred and twenty four official certification samples were drawn using the automatic samplers and were randomly selected for

the comparison study with the probe sampling method.

An official sampler from the Oregon Seed Certification Program used an 11" rice trier (probe), as specified in the OSCS guide for samplers and tagging, to collect samples from the same 124 seed lots provided by the warehouses for the comparison with the automated sampling method. The OSU Seed Laboratory compared the official purity test results from the 124 samples drawn by the automated sampling method with parallel purity tests on the samples drawn by the probe sampling method.

The data were subjected to statistical analysis to compare the difference in purity test results between each two parallel samples drawn by automated vs. probe sampling method. The tolerance Table 14B in the AOSA Rules for Testing Seeds, Vol. 1 were used to detect whether the difference between each two parallel test results drawn by automated vs. probe sampling method is significant or due to random sampling variation (AOSA, 2012).

**Results and Discussion**

Sampling method did not significantly affect ($P \leq 0.05$) purity test results in 103 (83%) of the 124 samples included in the study according to the AOSA (2012). The majority of purity test results were comparable regardless of the sampling method (Fig. 1).

However, the results also indicated that purity test results were significantly different ($P \leq 0.05$), i.e., out of tolerance, in 21 (17%) out of the 124 samples tested. Neither the automated nor the probe sampling methods had consistently higher or lower purity results. Of the 21 samples that differed significantly in purity results, 18 had lower purities from the probe sampling method, and 3 had lower purities from the automated sampling method. It should be noted that even though the samples were out of tolerance it does not mean that they did not meet certification standards. In this study, sampling method did not affect the certification status in 97.6% of the samples. Generally, as the purity level of samples increases, the tolerated difference value between two tests decreases.

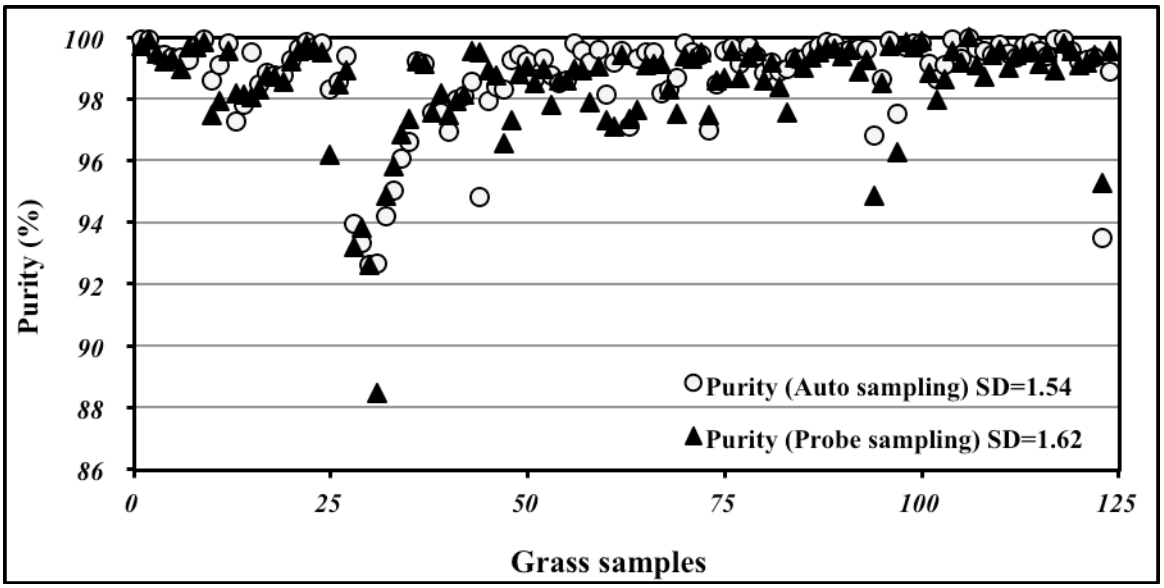


**Figure 1.** Comparison of purity test results of 124 grass seed samples drawn by automated and probe sampling methods tested at Oregon State University Seed Laboratory.

In the 21 samples that showed out of tolerance results in purity tests between the two methods of sampling, random sampling variation contributed to the accumulative effect of variation. Random sampling variation represents the random distribution of contaminants (i.e., weed seed, other crops and inert matter) in a seed lot. This type of variation cannot be avoided (Elias, et al. 2012). In general, random sampling variation increases in heterogeneous and in unclean seed lots or samples.

The overall standard deviation values, 1.54 and 1.62, respectively, for the purity results of the 124 samples tested using the automated and the probe sampling methods was similar. The comparable standard deviations of all samples means neither sampling method caused drastic change in the purity results.

Table 1 indicates the individual standard deviations for the purity tests of eight grass species using the automated and the probe sampling methods. Orchardgrass and Kentucky bluegrass had the largest difference in standard deviations between the automatic sampler and the probe sampling method, and it was larger when probe sampling was used (Table 1). This result indicates that the automatic sampler was more consistent in drawing samples from the seed lots for these two species than the probe sampling method.

**Table 1.** Means and Standard deviations of purity tests conducted on samples drawn by automated and probe sampling methods of eight grass species.

| Crop | Automatic Sampler | Probe Sample |
|---|---|---|
| | Mean (SD) | |
| Bentgrass | 98.84 (0.35) | 97.68 (0.33) |
| Orchardgrass | 94.30 (1.49) | 94.12 (2.83) |
| Kentucky bluegrass | 98.75 (0.57) | 97.85 (1.46) |
| Annual ryegrass | 99.57 (0.27) | 99.52 (0.32) |
| Intermediate ryegrass | 99.76 (0.08) | 99.60 (0.13) |
| Perennial ryegrass | 98.50 (1.08) | 98.47 (0.76) |
| Fine fescue | 98.75 (0.85) | 98.38 (0.82) |
| Tall fescue | 99.18 (1.00) | 99.83 (1.0) |

The overall small values of standard deviations confirmed the importance of seed lot homogeneity and cleanness in reducing sampling variability regardless of whether automatic sampler or probe sampling method is used. Variability among subsamples drawn from a seed lot is expected to be low for seed lots that are cleaned thoroughly, regardless of the sampling methods. Thus, variability of purity test results among laboratories is also reduced for cleaned seed samples compared to uncleaned samples.

Whether using automated or probe sampling, utilizing proper sampling procedures and ensuring seed lot homogeneity increase uniformity among subsamples drawn from the same seed lot. Consequently, these factors decrease variability between two seed purity tests of subsamples drawn

from the same seed lot, whether they were tested in the same laboratory or in two different laboratories.

**Conclusions**

Similar purity test results for the grass seed species used in this study were obtained whether the automatic sampler or the probe sampling method is used, with some exceptions. No consistent pattern of high or low purity results was associated with the automatic or the probe sampling method. Therefore, either sampling technique may be used, as long as the proper sampling procedures are followed.

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# CHOKE STROMA EXPRESSION IN ORCHARDGRASS WITH DIFFERENT NITROGEN APPLICATION RATES AND TIMINGS

*G.D. Hoffman and S. Rao*

## Introduction

Choke disease in orchardgrass seed production fields in the Willamette Valley is caused by a fungus, *Epichloë typhina*, that mostly grows unobserved within the plant. The fungus, native to Europe, was inadvertently introduced into cultivated orchardgrass fields in western Oregon in the late 1990s (Alderman et al. 1997). In the presence of an abundance of host plants in close proximity, the fungus spread rapidly. By 2000, approximately 90% of orchardgrass seed production fields in Oregon were host to the fungus (Pfender and Alderman 2006). It appears that seed yield loss is proportional to the percentage of flowering tillers choked (Large 1954, Pfender and Alderman 2006).

During vegetative growth of the orchardgrass the fungus develops internally. However, when the plant switches to the flowering phase, the fungus proliferates externally forming stromata. This occurs at the tip of the tiller where the leaves are folded together. Stromata are about 1.5 to 2.5 inches in length and are greenish-white when immature, white after fertilization, and burnt-orange when the mature ascospores (infective spores) are ready to be released. The fungal hyphae of the stroma 'cement' together the folded leaves of the upper tiller and prevent the inflorescence from growing upwards. As a result, no seeds are produced on the affected tillers; hence the expression of the pathogen is called choke disease (Sampson and Western 1954).

There does not appear to be anyway to eliminate the choke pathogen from orchardgrass once the plant is infected. Efforts at control have focused on reducing the spread of newly infected plants by reducing the number of infective ascospores released each spring. Eleven different fungicides were tested to determine whether they could reduce the amount of stromata surface producing ascospores. While several fungicides did inhibit fertilization to some degree, the decline was not believed to be great enough to have an impact on ascospore numbers (Alderman et al. 2008). A similar approach explored the use of the fungus *Dicyma pulvinata*, which grows on the fungal stromata of choke. This fungus was very effective in greenhouse studies in reducing the percent of perithecia (ascospore producing structures) on sprayed stromata, but was much less effective in field trials (Alderman *et al*. 2009). Another possible mechanism of limiting the spread of choke is to use an insecticide to kill the fly *Botanophilla labata*, whose feeding and egg laying behaviors lead to the cross fertilization of the stromata from plants infected with the two alternate mating type strains (Bultman *et al*. 1998). An initial insecticide trial conducted in Oregon was inconclusive (Alderman *et al*. 2008). It is now thought that because of the multiple ways fertilization of stromata can occur (Rao *et al*. 2012), interrupting only one mechanism of fertilization is not adequate to limit the production of ascospores.

Ongoing orchardgrass variety trials show some promise in identifying choke resistant orchardgrass lines, but breeding this material from its Mediterranean (dry habitat) adapted sources into varieties suitable for the orchardgrass growing regions in the US, will be a long term project.

Thus, for now, orchardgrass seed farmers in the Willamette Valley will continue to live with the problem of choke. This means taking out fields after 5-6 years, rather than the decades that were once common. In the current study, we examined whether manipulating late winter fertilization practices could reduce the severity of choke expression, and perhaps extend the productive life of orchardgrass fields by a few years. Not all tillers of an infected plant are choked each year, and there is considerable variation between years in the percentage of tillers choked. Our hypothesis was that early and quick tiller growth would allow the flowering tillers to outgrow the development of the fungus and the production of stromata. We manipulated the nitrogen (N) environment of the orchardgrass by varying the amount of late winter applied N, and also compared single versus split applications. We were particularly interested in

seeing if the split application would lead to a reduction in the percentage of tillers with stromata.

**Methods**

The study was initiated in the fall of 2009 using six year old orchard grass plots that developed stromata three years earlier. During the previous three years the plots had been surveyed for the presence of choke disease and the choke fly. The orchardgrass plots received minimal amounts of nitrogen fertilizer during previous years.

At the onset of this study, plots received 40 lbs of N/acre in the form of urea each fall when the plants began to grow with the commencement of fall rains. Soil test phosphorus and potassium levels were moderate to high because of previous fertilizer applications.

Year 2010. The randomized complete block design had 5 late winter N application entries comprised of varying application rates and timings (single versus split). Split applications were made at early (early February) and typical (late February- early March) timings. In 2010 the early date was Feb. 4, and the typical date was Feb. 25. There were three single application entries at the typical date: 80; 120; 160 lbs N/acre. There were two split application entries: 120 lbs- with 40 lbs applied early plus 80 lbs typical; and 160 lbs- with 60 lbs early plus 100 lbs typical. The sixth entry was 120 lbs typical plus a gibberellic acid formulation (ProGibb 40%). The ProGibb rate was 20 gm AI/acre, sprayed on April 20. The sulfur coated urea fertilizer (40-0-0-5.6) was applied with a drop spreader.

Years 2011 and 2012. The experiment was conducted for a second and third year; N entries were laid on the same entry plots from the previous year. The exception was that an additional high N rate (80 lbs early and 120 lbs typical) replaced the ProGibb plots from the previous year since the ProGibb treatment had no effect during the first year of field trials or in a separate potted plant study. In 2011 the early application date was February 7, and the typical was March 4. In 2012 the early application date was February 2, and the typical was March 4.

In all years, we assessed the trial for the effectiveness of the N treatment in reducing choke severity in early June. In each plot two 5-adjacent plant subsamples were selected, and the number of tillers with stromata, the number of flowered tillers, and total tillers, were counted for each 5-plant subsample. The three variables were analyzed using Proc GLM (SAS 9.92), with N application entry as the main effect, and the single versus split applications compared using a contrast statement.

**Results**

Over the course of the three years of the N rate and timing trial there were small but significant differences in the entries for some of the variables. For proper interpretation of the results the following aspects of the methods are important to consider. 1) The trial was initiated in plots that had for several years been receiving less fertilizer than typical production practices. Therefore, soil and mineralizable N were low compared to typical production fields at the beginning of the study. 2) Individual fertilizer entries were applied to the same plots each year. Therefore, there was likely a buildup of soil and mineralizable N in the higher N entries over the course of the study. The exception was the 2010 ProGibb (growth regulator) entry which we changed to the highest N entry (80 lbs N early, 120 lbs N typical) in 2011 and 2012.

In 2010 there were no differences in N rates or between single and split applications (Table 1). This may have been a result of the previously low N applications, which may also have been the cause of the low total number of tillers per plant recorded that year.

In 2011 there were a smaller proportion of choked tillers in the entries with higher N (Table 2). The contrast for single versus split applications was also significant; with split applications having a higher proportion of choked tillers. There was a trend in higher numbers of flowering tillers in the higher N treatments but this was not significant (Table 2). There was no difference in the number of total tillers.

In 2012 there were again a smaller proportion of choked tillers in the high N entries (Table 3). In this year the split versus single application contrast was

not significant. The very high rainfall after the early February application could have washed some of the early applied N out of the system. The patterns in the number of flowering tillers and total tillers in 2012 were the same as in 2011. There was a trend in a higher number of flowering tillers in the high N entries ($P$=0.0855), no difference in total number of tillers, and no significant single versus split application contrast (Table 3).

**Discussion**

The results do not support the hypothesis, that an early application of nitrogen may give the orchardgrass plant a tiller growth advantage over the process of tiller fungal infection. One possible reason for this is that the early N may be washed from the system before it can be taken up by the plants, resulting in lower total N uptake in these entries. Virtually all the orchardgrass plants in the trial plots had tillers that were choked. Commercial production fields are typically replanted to another crop once the incidence of choked tillers reaches 10 – 20%. Our findings may have been different if trial was conducted in a less infected field.

Higher total N rates did result in a lower proportion of choked tillers, but this did not translate into significantly greater number of flowering (yield producing) tillers. However, there was a consistent trend in this direction in the last two years. The differences between the lowest and highest values were rather large, 63% in 2011, and 120% in 2012; but high variances limited the significance of the statistical tests.

Yield samples were not taken from the plots so we do not know exactly how the N rate and timing entries affected seed yield. In 2010 on-farm field trials, only one of the three fields responded to a supplemental early application of N (40 lbs/A) with an increase in seed yield (Mellbye [OSU], Boren and Cacha [Crop Protection Services], unpublished data).

These data suggest there is no strong benefit to an early application of N to reduce the severity of choke. Any reduction in choke severity, and increased seed yield, would need to offset the additional cost of the fertilizer application. Higher rates of total N fertilizer appear to confer some advantage in reducing choke expression, but the highest rates were not significantly better than the medium rates typically used in production fields.

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Table 1. Incidence of choke, and number of tillers per plant at the Hyslop Experiment Station nitrogen-choke incidence trial in 2010.

| Fertilizer Treatment [1,2] | Proportion of stroma/plant | No. of flowering tillers/plant | Total no. of tillers/plant |
|---|---|---|---|
| *P*-value = | 0.9247 | 0.8358 | 0.3060 |
| 160 | 0.47 ± 0.05 | 7.8 ± 1.62 | 14.3 ± 2.4 |
| 120 + PG | 0.49 ± 0.05 | 7.5 ± 1.28 | 14.2 ± 1.6 |
| 40 + 80 | 0.49 ± 0.02 | 6.4 ± 0.67 | 13.6 ± 1.5 |
| 60 + 100 | 0.50 ± 0.03 | 8.8 ± 1.44 | 18.3 ± 2.3 |
| 120 | 0.52 ± 0.09 | 8.0 ± 1.96 | 16.0 ± 2.5 |
| 80 | 0.56 ± 0.08 | 7.1 ± 0.82 | 17.0 ± 1.2 |
| Split vs. Single Application | | | |
| *P*-value = | 0.9929 | 0.8147 | 0.6233 |

[1] Rank of treatments in table based on proportion of tillers with stroma.
[2] Rate in pounds of N per acre, PG = ProGibb

Table 2. Incidence of choke, and number of tillers per plant at the Hyslop Experiment Station nitrogen-choke incidence trial in 2011.

| Fertilizer Treatment [1,2] | Proportion of stroma/plant | No. of flowering tillers/plant | Total no. of tillers/plant |
|---|---|---|---|
| *P*-value = | 0.0495 | 0.1357 | 0.9845 |
| 40+80 | 0.71 ± 0.02 a | 11.0 ± 0.7 a | 41.2 ± 2.9 a |
| 80 | 0.70 ± 0.06 a | 13.8 ± 3.5 a | 41.0 ± 1.0 a |
| 60+100 | 0.62 ± 0.05ab | 16.4 ± 2.9 a | 43.0 ± 1.9 a |
| 120 | 0.61 ± 0.07ab | 14.8 ± 2.5 a | 42.1 ± 3.3 a |
| 160 | 0.54 ± 0.08 b | 17.3 ± 2.9 a | 38.9 ± 2.9 a |
| 80+120 | 0.54 ± 0.07 b | 18.0 ± 2.5 a | 37.7 ± 0.9 a |
| Split vs. Single Application | | | |
| *P*-value = | 0.0485 | 0.2440 | 0.8653 |

Mean values in the same column followed by different letters differ significantly (LSD $P<0.05$).
[1] Rank of treatments in table based on proportion of tillers with stroma.
[2] Rate in pounds of N per acre

Table 3. Incidence of choke, and number of tillers per plant at the Hyslop Experiment Station nitrogen-choke incidence trial in 2012.

| Fertilizer Treatment [1,2] | Proportion of stroma/plant | No. of flowering tillers/plant | Total no. of tillers/plant |
|---|---|---|---|
| *P*-value = | 0.0078 | 0.0855 | 0.2439 |
| 80 | 0.78 ± 0.02 a | 4.3 ± 0.7 | 20.1 ± 1.5 |
| 40+80 | 0.71 ± 0.06 ab | 5.8 ± 0.9 | 19.7 ± 1.2 |
| 120 | 0.69 ± 0.05 abc | 5.0 ± 2.1 | 18.4 ± 3.3 |
| 160 | 0.63 ± 0.03 bcd | 7.5 ± 0.5 | 23.7 ± 2.7 |
| 80+120 | 0.60 ± 0.03 cd | 9.5 ± 1.5 | 24.5 ± 0.7 |
| 60+100 | 0.59 ± 0.03 d | 8.1 ± 0.6 | 21.1 ± 2.1 |
| Split vs. Single Application | | | |
| *P*-value = | 0.6811 | 0.5895 | 0.7429 |

Mean values (mean and SE) in the same column followed by different letters differ significantly (LSD:*P*<0.05). Without block 3.
[1] Rank of treatments in table based on proportion of tillers with stroma.
[2] Rate in pounds of N per acre

# IDENTIFYING WESTERN OREGON CROPS BY SATELLITE IMAGERY IN THE ABSENCE CURRENT YEAR GROUND-TRUTH DATA

*G.W. Mueller-Warrant, G.W. Whittaker, G.M. Banowetz, S.M. Griffith, and B.L. Barnhart*

## Introduction

Few can argue the urgency of improving the sustainability of modern agricultural production. Controversy abounds, however, on the subject of how to best try to achieve sustainability due to a wide variety of factors, including both differences in perspective among individual protagonists in the discussions and complexity of the processes that must ultimately define the long-term limits to humankind's ability to provision itself with adequate food, fiber, and other natural resources. Perhaps the most important question that should be asked in the search for agricultural sustainability is simply how robust/stable our current production systems truly are. Central to any attempts to begin to answer such questions is detailed knowledge of which crops are currently being grown, what inputs they receive/require, and what offsite impacts occur in their production. Successful acquisition of such information for the present and recent past would allow us to measure the slope/change and the acceleration (change in change) of factors ranging from economic viability to water quality to availability of high quality wildlife habitat. Unfortunately, such information is seldom collected for minor crops and only partially tracked even for major ones such as wheat, corn, and soybeans. A useful step forward in evaluating the sustainability of western Oregon crop production systems would be development of a detailed historical record of which crops have been grown at what locations over a period of several decades. Combining this information with models such as the Soil Water Assessment Tool (SWAT) and data such as synoptic water quality samples, wildlife diversity/abundance surveys, and USDA Census of Agriculture summary production statistics should help elevate the discussion of agricultural sustainability to more of an outcome-based approach and less of a debate of lofty principles and general philosophies, i.e., organic versus conventional agriculture, prohibition versus embracing of GMOs, locally grown food versus lowest-cost-no-matter-where production, etc.

## Methods

Starting with the 2004-05 growing season, we systematically collected information on crops produced on several thousand western Oregon fields visible from public roads in a series of fall and spring drive-by surveys, including annual and perennial agricultural and horticultural crops, stand establishment status, planting methods, and post-harvest residue management of grass seed crops. Information for the first three harvest years has already been used as ground-truth data for successful remote sensing classification of Landsat and MODIS satellite imagery for 16 major agricultural crops in western Oregon. We have now elaborated on these methods to cover seven years and 57 landuses, including 19 classes of annually disturbed agriculture, 20 classes of perennial crops, 13 classes of forests and other natural landscape components, and five categories of urban development (Tables 1a, 1b, 1c). Data from the National Land Cover Dataset were used to define most of the forest and urban development landuse classes, though we also directly identified several such classes in our drive-by surveys.

## Results and Discussion

The four broad categories of landuse (annual agriculture, perennial agriculture, forest, urban) were separated from each other at 97 to 98% overall accuracy, with most of the 2 to 3% error involving misclassification of some of the perennial agriculture classes. Not unexpectedly, forests were the most reliably identified landuse. The 39 classes of annual or perennial agriculture defined by our ground-truth data represented 99% of all field area surveyed. While the results satisfied our goal of being able to accurately define nearly all landuse across western Oregon, they can really only cover the time period of our ground-truth, drive-by survey, i.e., the 2004-05 cropping year on up until whenever we decide to quit expending the labor needed to conduct the survey for yet another year. The lack of ground-truth data prior to the 2005 harvest year along with the potential future termination of the survey led us to

question whether it might be possible to extend our remote sensing classification results backward or forward in time through creation of synthetic ground-truth data from the period for which we have conducted drive-by surveys and successfully classified landuse in western Oregon. To test this idea, we first conducted a series of remote sensing classifications in which the ground-truth data actually came either from the year prior to or the year following the satellite images and production of the crops we wished to classify. Because we had already conducted a normal remote sensing classification using actual current-year ground-truth data, we were able to test the validity of our shift-year results against several alternatives. For annual crops such as Italian ryegrass, the shift-year method should work well since the vast majority of Italian ryegrass crops are actually grown year-after-year on the very same fields. The other extreme would be fields of fall- or spring-planted new grass seed stands, which would generally transition into a status of established perennial grass seed crops by the following year and only rarely represent a second year's replanting when the first year's planting had failed to establish.

Using subsequent-year ground-truth data to classify the previous year's landuse was about as successful as normal, same-year classification methods in two out of six cases (2006 and 2009 harvest years), moderately successful in one other case (2011 harvest year), and less successful in the remaining three cases (Table 2). Using prior-year ground-truth data to classify the subsequent year's landuse was more successful than normal, same-year classification in two out of six cases (2006 and 2008 harvest years), about as successful in three cases (2007, 2010, and 2011 harvest years), and less successful in the final case (Table 3). The most successful use of subsequent year ground-truth data to classify prior year landuse occurred for the combination of 2009 harvest year images with 2010 ground-truth. This classification had an overall accuracy of 93.4% relative to pixels where both the original (normal method) classification and the shift-year ground-truth data matched. This accuracy was achieved despite omission of 10 entire classes, four of which were also absent from the normal same-year classification. Accuracy of this shift-year classification was 96.5% when measured relative to the four large groups (annual agriculture, perennial agriculture, forests, urban development). All six of the additional landuse classes lost during shift-year classification were annually disturbed crops grown on relatively few fields.

For the five cases in which subsequent and previous year ground-truth methods can be directly compared, subsequent year ground-truth produced more accurate classifications in two cases while previous year ground-truth produced more accurate classifications in three cases (Tables 2 and 3). Based on our fairly successful results of using shift-year ground-truth data to classify individual images for years in which we also had current year ground-truth data, we conducted a full series of classifications over all available images for the 2003-2004 cropping year, one for which we did not have comprehensive ground-truth data. Our first step was to create a synthetic ground-truth dataset from the classified rasters of the following seven years. The method we chose to create the synthetic ground-truth data started with selection of all pixels that had been identically classified in all seven years, a method which gave us an adequately sized sample for 19 of the 57 desired classes. We then added five more classes from pixels that had been identical over the first 5 growing seasons of our ground-truth survey. The next groups of 11 and 5 classes came from pixels that were identical for the first three or two years of the survey, respectively. We obtained six more classes based solely on the 2004-05 cropping year. This left 11 classes that could not be added to the synthetic ground-truth data because they either were entirely absent from the original 2004-05 cropping year classification or were present at too small a number to provide satisfactory training sets. Our general cut-off was to view 1000 pixels as the minimum number required to include a given category in remote sensing classifications. This 46-class synthetic ground-truth data combined with 66 remote sensing image bands to produce training and test validation 57-category accuracies of 87.6 and 93.5% for the 2003-04 cropping year, better than that achieved in any of the normal, same year classifications. The 11 classes of annually disturbed agriculture missing from our 2003-04 cropping year remote sensing classification using synthetic ground-truth data were replaced by increases in area classified in three of the remaining annual crops: (1)

bare ground in the fall not otherwise classified as a specific crop, (2) fallow, and (3) *Brassicaceae* seed crops. Before unambiguously declaring success for our shift-year classification procedure using synthetic ground-truth data from subsequent years, we still need to validate our results using other resources such as county-wide crop production estimates. However, these initial results give us reason to believe that we will be able to eventually define where most of the crops grown in the past 20 to 30 years in western Oregon have been grown.

Table 1a. Landuse category descriptions for 19 classes of annually disturbed agriculture along with corresponding areas of remotely sensed classifications in each of eight cropping years.

| No. | Description | 2003-2004† | 2004-2005 | 2005-2006 | 2006-2007 | 2007-2008 | 2008-2009 | 2009-2010 | 2010-2011 | 7-year mean§ |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (mile$^2$) | | | | | | | | |
| **19 classes annually disturbed agriculture** | | | | | | | | | | |
| 1 | Bare ground in fall not any other class | 415 | 241 | 234 | 219 | 317 | 3 | 78 | 86 | 168 |
| 2 | Full straw Italian ryegrass | 14 | 73 | 65 | 86 | 52 | 18 | 112 | 31 | 63 |
| 3 | Spring-plant new grass seed stands | NA‡ | 45 | 36 | 40 | 43 | 57 | 12 | 2 | 34 |
| 12 | Fall-plant Italian ryegrass | 191 | 116 | 146 | 147 | 156 | 354 | 208 | 273 | 200 |
| 13 | Fall-plant perennial ryegrass | 80 | 75 | 58 | 83 | 49 | 3 | 4 | 3 | 39 |
| 14 | Fall-plant tall fescue | NA | 2213 | 7 | 8 | 6 | 0 | 0 | 0 | 319 |
| 15 | Fall-plant clover | NA | 3 | 23 | 14 | 17 | 9 | 5 | 2 | 10 |
| 16 | Wheat and oats | 19 | 189 | 46 | 56 | 152 | 436 | 261 | 325 | 209 |
| 17 | Meadowfoam | 2 | 3 | 9 | 9 | 3 | 2 | 7 | 6 | 5 |
| 27 | Corn and sudangrass | NA | 0 | NA | NA | 0 | NA | NA | 8 | 1 |
| 30 | Fallow | 212 | 49 | 40 | 32 | 47 | 0 | 21 | 9 | 28 |
| 35 | Beans | NA | 1 | 20 | 162 | 5 | NA | 6 | 0 | 28 |
| 36 | Flowers | NA | 1 | 2 | 2 | 1 | 0 | 0 | 0 | 1 |
| 40 | Other fall-plant/no-till grass seed crops | NA | 2 | 2 | 2 | 1 | 2 | 6 | 1 | 2 |
| 41 | Spring-plant peas or other unidentified | NA | NA | 46 | 22 | 2 | 10 | 4 | 3 | 12 |
| 42 | New planting hops, filberts, blueberries | NA | 238 | 0 | 0 | 0 | 0 | 1 | 0 | 34 |
| 43 | New planting alfalfa or vetch | NA | 1 | 0 | 2 | 1 | 0 | 1 | 7 | 2 |
| 44 | Volunteer Italian ryegrass as pasture | NA | 2 | 11 | 28 | 0 | NA | 0 | 11 | 7 |
| 55 | Brassicaceae | 292 | 23 | 14 | 6 | 0 | 0 | 3 | 4 | 7 |
| Group totals | | 1225 | 3275 | 761 | 919 | 852 | 894 | 729 | 771 | 1171 |

†Classification based on synthetic ground-truth data developed from most common landuse classes over the next 7 years.
‡ NA denotes classes with no members in a given year's remote sensing classification. Values of 0 simply denote classes with total areas of greater than 0 and less than 0.5 square miles.
§Means cover 2005, 2006, 2007, 2008, 2009, 2010, and 2011 harvest years, the period over which full ground-truth data existed.

Table 1b. Landuse category descriptions for 20 classes of established perennial agriculture along with corresponding areas of remotely sensed classifications in each of eight cropping years.

| No. | Description | 2003-2004 | 2004-2005 | 2005-2006 | 2006-2007 | 2007-2008 | 2008-2009 | 2009-2010 | 2010-2011 | 7-year mean |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (mile$^2$) | | | | | | | | |
| **20 classes established perennial agriculture** | | | | | | | | | | |
| 4 | Established perennial ryegrass | 12 | 149 | 167 | 137 | 152 | 41 | 78 | 91 | 116 |
| 5 | Established orchardgrass | 27 | 25 | 39 | 47 | 27 | 53 | 26 | 28 | 35 |
| 6 | Established tall fescue | 83 | 96 | 183 | 215 | 220 | 154 | 124 | 112 | 158 |
| 7 | Pasture | 608 | 422 | 415 | 340 | 856 | 854 | 880 | 1185 | 707 |
| 8 | Established clover | 53 | 14 | 11 | 25 | 17 | 33 | 35 | 11 | 21 |
| 9 | Established mint | 10 | 13 | 14 | 3 | 1 | 1 | 3 | 2 | 5 |
| 10 | Haycrop | 303 | 312 | 261 | 235 | 129 | 63 | 58 | 51 | 158 |
| 18 | Established bentgrass | 53 | 50 | 17 | 26 | 8 | 0 | 0 | 0 | 15 |
| 19 | Established fine fescue | 73 | 55 | 47 | 148 | 67 | 31 | 95 | 41 | 69 |
| 21 | Wildrice lagoons | 0 | 0 | 0 | 0 | 1 | 3 | 22 | 18 | 6 |
| 22 | Wetland restoration | 0 | 0 | 0 | 0 | 3 | 4 | 27 | 3 | 5 |
| 23 | Established alfalfa | 20 | 3 | 6 | 0 | 0 | NA | 5 | 5 | 3 |
| 24 | Established blueberries | 3 | 0 | 2 | 1 | 2 | 0 | 0 | 3 | 1 |
| 25 | Filbert orchards | 85 | 17 | 81 | 38 | 88 | 73 | 234 | 118 | 93 |
| 26 | Caneberry | 149 | 26 | 36 | 25 | 39 | 0 | 3 | 1 | 19 |
| 28 | Nursery crops | 1 | 91 | 164 | 117 | 125 | 1 | 3 | 2 | 72 |
| 29 | Apple and cherry orchards | 27 | 10 | 27 | 12 | 25 | 1 | 58 | 33 | 24 |
| 32 | Vineyards | 47 | 283 | 112 | 81 | 61 | 12 | 41 | 53 | 92 |
| 38 | Hops | 2 | 10 | 17 | 7 | 5 | 7 | 23 | 29 | 14 |
| 56 | Strawberry | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Group totals | | 1557 | 1576 | 1598 | 1457 | 1826 | 1332 | 1714 | 1788 | 1613 |

Table 1c. Landuse category descriptions for 13 classes of forests and other natural landscapes and 5 classes of urban development, along with corresponding areas of remotely sensed classifications in each of eight cropping years.

| No. | Description | 2003-2004 | 2004-2005 | 2005-2006 | 2006-2007 | 2007-2008 | 2008-2009 | 2009-2010 | 2010-2011 | 7-year mean |
|---|---|---|---|---|---|---|---|---|---|---|
| | | (mile$^2$) | | | | | | | | |
| **13 classes forests/other natural landscapes** | | | | | | | | | | |
| 11 | Poplars | 2 | 0 | 11 | 2 | 1 | 0 | 2 | 0 | 2 |
| 20 | Christmas tree plantations | 364 | 1669 | 681 | 506 | 818 | 14 | 661 | 258 | 658 |
| 33 | Reforestation projects | 165 | 3 | 3056 | 1840 | 1807 | 0 | 27 | 20 | 965 |
| 34 | Assorted other lowland forest | 1957 | 851 | 946 | 749 | 479 | 0 | 0 | 4 | 433 |
| 37 | Oaks | 1 | 0 | 22 | 21 | 27 | 42 | 279 | 214 | 86 |
| 39 | Shrubs and wildlife refuges | 2 | 1 | 17 | 15 | 8 | 0 | 1 | 0 | 6 |
| 45 | NLCD 11 open water | 36 | 31 | 49 | 44 | 33 | 64 | 83 | 83 | 55 |
| 46 | NLCD 90 woody wetlands | 73 | 61 | 97 | 66 | 85 | 242 | 125 | 147 | 117 |
| 47 | NLCD 95 herbaceous wetlands | 10 | 10 | 13 | 14 | 11 | 70 | 85 | 63 | 38 |
| 51 | NLCD 41 deciduous forest | 441 | 870 | 309 | 497 | 356 | 108 | 148 | 173 | 351 |
| 52 | NLCD 43 evergreen forest | 2204 | 587 | 653 | 2185 | 1070 | 1743 | 2739 | 2863 | 1692 |
| 53 | NLCD 44 mixed forest | 251 | 136 | 676 | 378 | 1217 | 2611 | 271 | 274 | 795 |
| 54 | NLCD 53 scrub/shrub | 512 | 37 | 58 | 154 | 195 | 914 | 1639 | 1789 | 684 |
| Group totals | | 6020 | 4257 | 6588 | 6470 | 6107 | 5809 | 6059 | 5888 | 5883 |
| **5 classes urban development** | | | | | | | | | | |
| 31 | Mixed grass and buildings | 276 | 134 | 84 | 125 | 144 | 0 | 0 | 0 | 69 |
| 48 | Developed open space (NLC 21) | 23 | 4 | 5 | 228 | 90 | 855 | 316 | 337 | 262 |
| 49 | Developed low intensity (NLC 22) | 356 | 256 | 415 | 159 | 374 | 429 | 496 | 641 | 396 |
| 50 | Developed medium intensity (NLC 23) | 244 | 214 | 260 | 317 | 273 | 374 | 378 | 250 | 295 |
| 57 | Developed high intensity (NLC 24) | 68 | 55 | 58 | 96 | 103 | 76 | 76 | 94 | 80 |
| Group totals | | 966 | 663 | 823 | 925 | 984 | 1734 | 1268 | 1322 | 1103 |
| Totals for all 57 classes | | 9770 | 9770 | 9770 | 9770 | 9770 | 9770 | 9770 | 9770 | 9770 |

Table 2. Classification accuracies, kappa statistics, and omitted classes when subsequent year ground-truth was used on the best set of previous year image bands. Shift year accuracy was measured relative to all classified pixels for subsequent year rather than training/validation sets.

| Ground-truth source cropping year | Image raster properties | | Number missing classes and identification of the omitted classes from the original 57 categories | Normal same year training set best single-run results | | Shift year classification tested with original classified rasters matching in both years | |
|---|---|---|---|---|---|---|---|
| | Cropping year | Bands present | | Accuracy | Kappa | Accuracy | Kappa |
| | | (No.) | | (%) | (Fraction) | (%) | (Fraction) |
| 2005-2006 | 2004-2005 | 62 | 6 (# 21, 27, 40-43) | 52.4 | 0.505 | 39.6 | 0.371 |
| 2006-2007 | 2005-2006 | 42 | 3 (# 27, 40, 42) | 57.9 | 0.560 | 89.3 | 0.876 |
| 2007-2008 | 2006-2007 | 68 | 18 (# 20-23, 33, 35-38, 40-42, 44-45, 47, 54-56) | 66.4 | 0.640 | 48.4 | 0.437 |
| 2008-2009 | 2007-2008 | 58 | 10 (# 14, 23, 27, 30, 34, 35, 40, 42-44) | 69.1 | 0.675 | 49.5 | 0.463 |
| 2009-2010 | 2008-2009 | 52 | 10 (# 14, 23, 27, 30, 35, 41-44, 55) | 72.4 | 0.707 | 93.4 | 0.924 |
| 2010-2011 | 2009-2010 | 47 | 22 (# 3, 5, 11, 13-15, 18-20, 27, 28, 31, 35, 36, 39-44, 47, 55) | 76.5 | 0.752 | 69.5 | 0.663 |
| NA† | 2010-2011 | 44 | NA | 80.2 | 0.788 | NA | NA |

†NA indicates that shift year classification was not run due to the absence of subsequent year ground-truth data.

Table 3. Classification accuracies, kappa statistics, and omitted classes when previous year ground-truth was used on the best set of subsequent year image bands. Shift year accuracy was measured relative to all classified pixels for previous year rather than training/validation sets.

| Ground-truth source cropping year | Image raster properties | | Number missing classes and identification of the omitted classes from the original 57 categories | Normal same year training set best single-run results | | Shift year classification tested with original classified rasters matching in both years | |
|---|---|---|---|---|---|---|---|
| | Cropping year | Bands present | | Accuracy | Kappa | Accuracy | Kappa |
| | | (No.) | | (%) | (Fraction) | (%) | (Fraction) |
| 2004-2005 | 2005-2006 | 42 | 2 (# 41, 42) | 57.9 | 0.560 | 72.3 | 0.700 |
| 2005-2006 | 2006-2007 | 68 | 10 (# 22, 23, 27, 29, 36, 38, 42, 46, 47, 56) | 66.4 | 0.640 | 59.8 | 0.570 |
| 2006-2007 | 2007-2008 | 58 | 0 | 69.1 | 0.675 | 88.1 | 0.867 |
| 2007-2008 | 2008-2009 | 52 | 0 | 72.4 | 0.707 | 46.3 | 0.431 |
| 2008-2009 | 2009-2010 | 47 | 5 (# 23, 27, 35, 44, 47) | 76.5 | 0.752 | 82.8 | 0.806 |
| 2009-2010 | 2010-2011 | 44 | 3 (# 27, 28, 36) | 80.2 | 0.788 | 80.5 | 0.780 |

# PROGRESS ON STEM RUST RESISTANCE GENETICS IN PERENNIAL RYEGRASS

*W. Pfender*

## Introduction

As we reported in the 7th International Herbage Seed Conference Proceedings, we determined several years ago that the perennial ryegrass (*Lolium perenne*) cultivar 'Kingston' (PGG Wrightson Seeds, New Zealand) typically has a lower level of stem rust than other varieties we have tested under our OR production conditions and with our local populations of the pathogen (*Puccinia graminis* subsp. *graminicola*). To gain some insight into genetics of stem rust resistance, we created a mapping population by crossing two plants (resistant and susceptible) that we had selected from 'Kingston' after repeated stem rust testing under controlled conditions.

## Mapping methods

Genetic maps were constructed for a population of 193 F1 progeny from this cross. We have published two genetic maps, one in 2011 and a revised version in 2013. The 2011 map (Pfender et al., 2011) was constructed with RAD (restriction-site associated DNA) (Baird et al., 2008) markers, plus tall fescue SSR (simple-sequence repeat) markers previously developed (Saha et al., 2006) by researchers at the Samuel Roberts Noble Foundation (Ardmore, OK, USA). Additional SSR markers, also run at the Noble Foundation, were originally developed for *Lolium* by other research groups (Gill et al., 2006). The 2013 map (Pfender and Slabaugh, 2013) supplements our 2011 map by having markers in common with several other *Lolium* species maps, including anchor markers from a consensus map published by other researchers (Studer et al., 2010). Our 2013 map therefore allows better comparison of our population and its stem rust phenotypes with various other *Lolium* populations that have been mapped by researchers elsewhere in the world.

Maps were assembled for each parent using JoinMap 4 software and CP (cross-pollinated) population type codes (Kyazma, Wageningen, Netherlands). We used the test for independence LOD (logarithm of the odds) score, which is not affected by segregation distortion, to group markers into seven linkage groups for each map.

## Phenotyping methods

Disease phenotypes were determined in inoculation assays conducted in a greenhouse with bulk inoculum (field-collected, genetically mixed) for analysis of the 2011 map (Pfender et al., 2011). We used single-pustule isolates (genetically uniform) of the rust pathogen for the 2013 map (Pfender and Slabaugh, 2013). We had previously demonstrated pathotype specificity in stem rust of perennial ryegrass by purifying and increasing two different, single-pustule isolates of the pathogen (Pfender, 2009). Isolate 101 is avirulent on one of the mapping population parents, and resistance is inherited as a single dominant gene that is heterozygous in the resistant parent. Isolate 106 is virulent to some degree on both parents.

Phenotypes were scored as number of pustules per plant. There were three replicate (cloned) plants per F1 individual in each experiment, and each experiment was conducted at two different times. QTL (quantitative trait loci) analysis was conducted in MapQTL5 for the male and female parent maps. Kruskal-Wallace analysis and automatic cofactor selection were used to choose cofactors for use in MQM (multiple-QTL mapping) analysis.

## Results

Three major QTL (i.e. locations on the *Lolium* chromosomes) for stem rust resistance were detected in these experiments (Fig. 1). One QTL, located on LG6 (linkage group 6) was associated with resistance to both stem rust pathotypes, and the other two were each associated with only one of the pathotypes (on LG1 for pathotype 106 and on LG7 for pathotype 101) (Pfender and Slabaugh 2013).

The QTL on LG6, designated qLpPg3, was detected on the male and female maps with both pathotypes. QTL qLpPg3 explains 7 to 10% of the phenotypic variance in the response to pathotype 101, and 9 to 11% in response to pathotype 106. This QTL is located between 60 and 68 cM on the female map, and between 59 and 63 cM on the male map (Fig. 1). In both maps the peak of qLpPg3 is located between

markers G01-002 and LP20. These markers have been placed on *Lolium* maps constructed by other research groups as well, but had not previously been associated with stem rust resistance.

Resistance response to pathotype 101 is associated also with a QTL on LG7, designated qLpPg1. QTL qLpPg1 is located in a 7-cM interval between markers G02-048 and NFFS275 (Fig. 1), markers which appear on other Lolium maps. It has a large phenotypic effect, explaining 50 to 58% of the phenotypic variance in response to pathotype 101. The response associated with the qLpPg1/pathotype 101 interaction is essentially all-or-none, as 92% of plants carrying the resistance-associated allele at the marker closest to the QTL are resistant, whereas only 5% without the "g" allele at the marker are resistant. Thus, this locus behaves genetically like a single dominant gene.

Resistance response to pathotype 106 is associated with a QTL (designated qLpPg2) on LG1. This QTL explained 17 to 30% of the phenotypic variance in these experiments. It is located between markers G01-031 and LpRa060 on the female and male maps (Fig. 1). QTL qLpPg2 on LG1 (unlike the QTL on LG7) is associated with a more quantitative response rather than acting as a single dominant gene.

QTL qLpPg3 and qLpPg1 together explained 60 to 65% of the phenotypic variance in response to pathotype 101, whereas qLpPg2 was not detected in response to this pathotype. qLpPg3 and qLpPg2 together explained 30 to 39% of the phenotypic variance in response to pathotype 106; qLpPg1 was not detected in response to pathotype 106. When the mapping population was inoculated with a mixed collection of stem rust spores from the field, all three QTL were activated (Pfender et al., 2011). It appears that this multiple-QTL response to mixed inoculum is due to independent activation of different QTL by specific pathotypes, as well as their activation of a common QTL.

Research is in progress, using crosses of plants from this mapping population with other plants, to further test and select genetic markers that co-segregate with the stem rust resistance QTL. Such markers could be useful in a marker assisted selection strategy for genetic improvement of perennial ryegrass. We expect to release germplasm with stem rust resistance, and information on markers linked with that resistance, as the products of this research.

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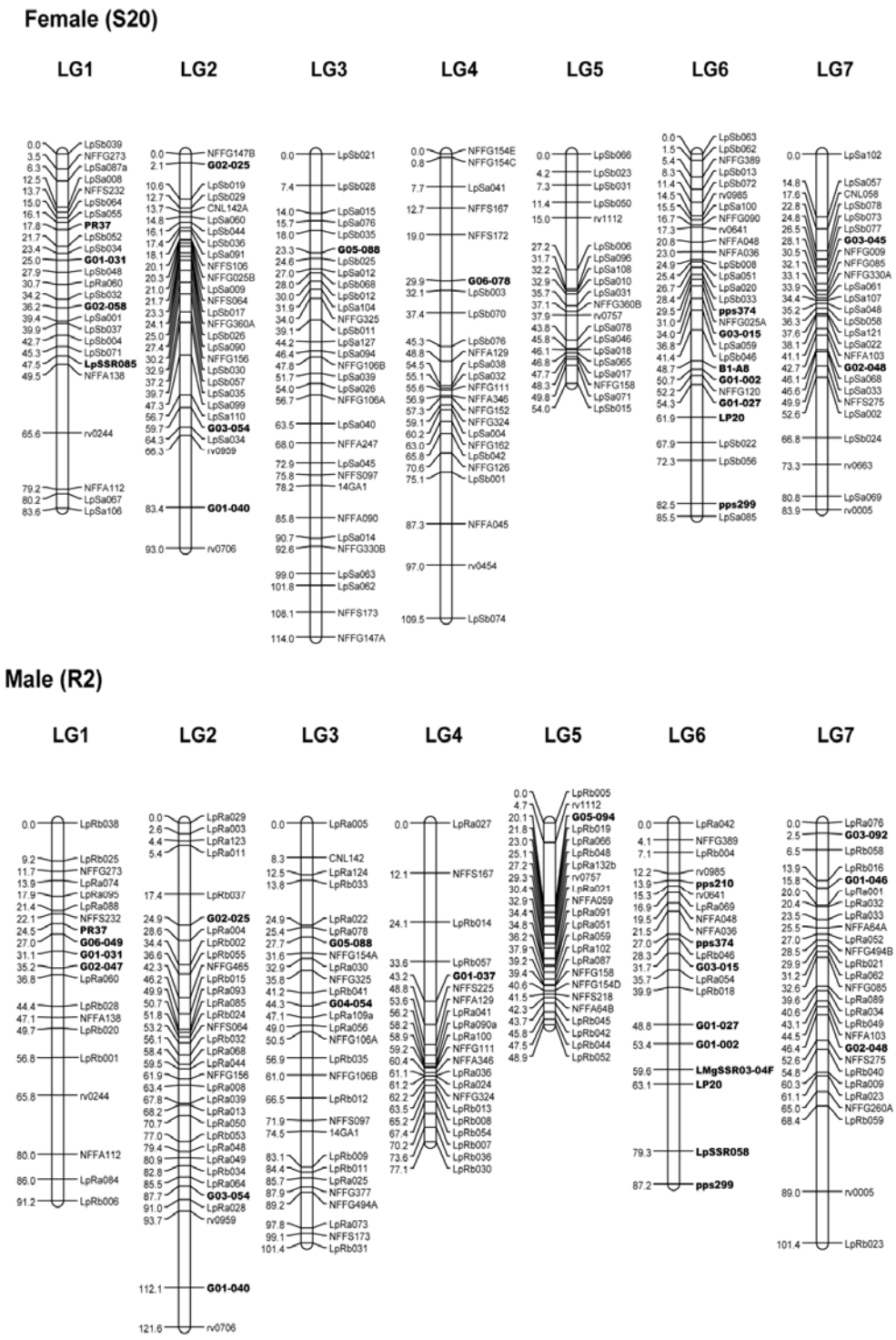


**Fig. 1.** Linkage maps of parents (S20 rust-susceptible female, R2 rust-resistant male) of *Lolium perenne* F1 population used to detect QTL activated by inoculation with pathotypes of the stem rust pathogen, *Puccinia graminis* subsp. *graminicola*. QTL (2-LOD interval) are indicated by shaded sections of chromosomes. Two QTL, qLpPg1 (LG7) and qLpPg3 (LG6), were detected when plants were inoculated with pathotype 101. The QTL qLpPg2 (LG1) and qLpPg3 (LG6) were detected when plants were inoculated with pathotype 106. The star, within qLpPg1 on male LG7, indicates map location of binary phenotype (resistant vs. susceptible) for plants inoculated with pathotype 101. Markers in bold font, selected from those used on other *Lolium* maps, were added to the previously-published map (Pfender et al., 2011) to create this map (Pfender and Slabaugh, 2013).

# POTENTIAL FOR MANAGEMENT OF THE CLOVER CROWN BORER PEST IN RED CLOVER SEED PRODUCTION USING BIOLOGICAL CONTROL

*S. Rao, A.R. Corkery, and D. Bruck*

The clover crown borer (also known as the clover root borer), *Hylastinus obscurus*, is a major pest of red clover seed production in the Willamette Valley (Rockwood 1926, Rao et al. 2012). This bark beetle pest, native to Europe, was inadvertently introduced into the US over 100 years ago. Damage to red clover is caused by adult and larval feeding internally within roots. This disrupts nutrient and moisture transport within the plant, and as a result, infested plants turn brown, wilt and die (Rockwood 1926). The presence of five or more larvae per root can result in 43% reduction in above-ground foliage (Koehler et al. 1961). In addition, mining caused by the pest often becomes a site for infection for pathogens that also contribute to a decline in clover stands. Due to all of these factors, clover crown borer infestation leads to a reduction in plant population, forage yield, and seed yield in the subsequent year. Thus, even though red clover is a perennial plant, the crop can only be grown economically for two years (Rockwood 1926, Steiner and Alderman 2003).

Management tactics for the clover crown borer are critical in the Willamette Valley where red clover is raised for seed on approximately 20,000 acres, and economic losses can be extensive. However, the clover crown borer is a challenge to control due to its subterranean life cycle. In the past, it was managed with organochlorine insecticides such as aldrin, BHC, chlordane, dieldrin, heptachlor and lindane (Gyrisco and Marshall 1950, Gyrisco et al. 1954, Koehler et al. 1961). These insecticides were, however, subsequently banned due to negative impacts on the environment resulting from their persistence in the environment. No new insecticides were labeled for the pest (http://www.ipmcenters.org/pmsp/pdf/WestAlfalfa CloverSeed.pdf) due to the challenge of getting insecticide materials to reach clover crown borer larvae and adults feeding within the roots. In a field trial conducted in 2011, four insecticides labeled for red clover seed production were evaluated but none caused significant mortality compared with the controls (Rao et al. 2012).

For other subterranean pests, biological control with nematodes that are pathogenic to insects, which are known as entomopathogenic nematodes, has been effective (Shapiro-Ilan et al. 2012). Entomopathogenic nematodes in the genera *Steinernema* and *Heterorhabditis* are potent biocontrol agents that kill a wide variety of economically important insect pests, and are applied at a commercial scale in numerous cropping systems (Grewal et al. 2005). The two genera differ in the manner in which they seek hosts. *Steinernema* spp. are sedentary and use ambush tactics while *Heterohabditis* spp. actively seek out their hosts. Currently, there is no information on the impacts of these species on the clover crown borer. Hence the objective of this study was to determine the virulence of *Steinernema* and *Heterorhabditis* spp. nematodes when exposed to clover crown borer adults.

## Material and Methods

Over 300 clover crown borer adults were obtained from two commercial red clover seed production fields in the Willamette Valley. Infested roots were placed in Berlese funnels at Oregon State University for collection of adults. The adults were kept cool in the refrigerator for 3-5 days until they were used in the experiments.

Two species each of commercial *Steinernema* and *Heterorhabditis* nematodes were evaluated in a laboratory bioassay. These included *H. marelata*, *H. bacteriophora*, *S. carpocapsae*, and *S. kraussei*. Nematodes were added to filter paper along with distilled water in petri dishes and exposed to ten clover crown borer beetles per dish. Each nematode species was evaluated at the following two concentrations, 25 infective juveniles per $cm^2$ and 75 infective juveniles per $cm^2$, with four replications for each treatment. Petri dishes containing clover crown borer adults but no nematodes served as the controls.

Clover crown borer beetles in each petri dish were monitored every other day for three weeks. The

numbers of dead adults in each petri dish were recorded to determine which nematode species and dose, if any, caused greater mortality compared with the controls.

**Data Analysis**
Data on mean mortality of clover crown borers per petri dish were analyzed using analysis of variance.

**Results**
Entomopathogenic nematodes belonging to both genera evaluated, *Steinernema* and *Heterorhabditis* were observed to cause mortality of adult clover crown borers in the laboratory bioassay. However, mean mortality of clover crown borer adults varied across the nematode species and dose tested (Figure 1; $P < 0.01$). Over 15% mean mortality was recorded with the higher dose (75 infective juveniles per $cm^2$) for all nematode species evaluated except *H. bacteriophora*. No mortality was observed in the controls, while mean mortality in dishes exposed to the lower dose (25 infective juveniles per $cm^2$) of all species was minimal, ranging from 0 to less than 5%.

**Discussion**
This is the first study that has evaluated the potential for biological control of the clover crown borer with entomopathogenic nematodes. The laboratory bioassay documented that adult clover corn borers can be killed when exposed to *H. marelata*, *H. bacteriophora*, *S. carpocapsae*, and *S. kraussei* in petri dishes. However, the dose is critical; for all species tested except *H. bacteriophora*, the higher dose (75 infective juveniles per $cm^2$) caused considerably greater mortality compared with the controls.

Based on the promising results of this study, further research is needed to determine the impact of *Steinernema* and *Heteorhabditis* spp. in commercial red clover seed fields. Nematodes have been shown to effectively locate and infect another Willamette valley pest, the strawberry crown borer, *Synanthedon bibionipennis*, larvae of which are located in the strawberry crown (Bruck et al. 2008). However, as the clover root borer develops within red clover roots, there may be limited impact when the nematodes are applied to the soil but this needs to be evaluated. A more effective strategy could be autoinoculation, a tactic in which pest insects are used to vector the biological control pathogen to conspecifics, other members of the same species, after they have acquired the pathogen (Vega et al. 1995). For this tactic, the beetles need to be lured initially to traps containing the entomopathogenic nematode. Typically, food baits are used as the lure, but host plant volatiles or pheromones may be effective for the clover root borer since bark beetles are known to respond effectively to olfactory cues from hosts and conspecifics.

For other pest species, much higher doses than the ones included in the current study have been used. High doses were not evaluated in the current study due to the low cash value of red clover seed crops and high cost of entomopathogenic nematodes. However, with the autoinoculation approach, entomopathogens will need to be employed in relatively small quantities and thus costs will be greatly reduced. Given the lack of alternative management tactics, and the positive results documented in this study, this approach warrants further investigation.

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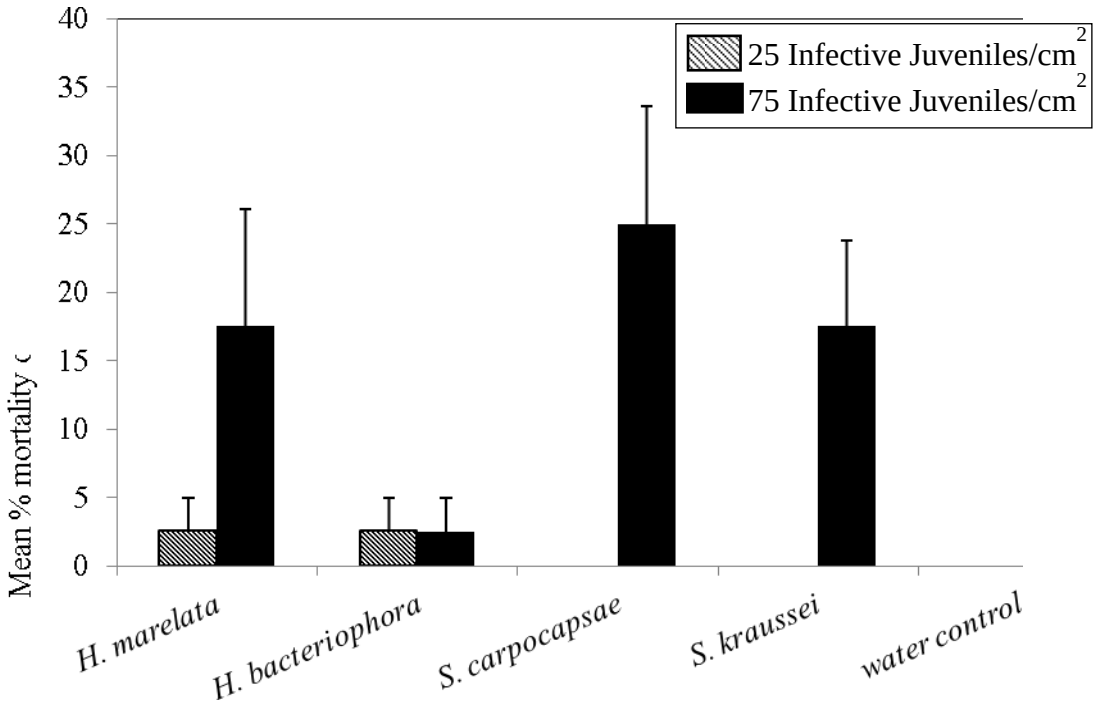


Figure. 1. Impact of entomopathogenic nematodes on adult clover crown borers in a laboratory bioassay ($P < 0.01$).

# ALKALI GRASS REMOVAL PROGRAM FOR CENTRAL OREGON

*G. Sbatella and S. Twelker*

**Abstract**

Growers face the challenge of removing established stands and controlling volunteer seedlings when rotating out of an established alkali grass seed production field due to seed left onsite due to natural seed shatter or seed loss during harvest. A study is being conducted near Madras, Oregon, to evaluate pre- and post-emergence herbicide options for control of alkali grass at different growth stages. Preliminary results from these studies suggest that there are viable chemical control options for alkali grass seedling control with pre-emergence herbicides such as dimethenamid and primisulfuron. However, if seed germination is delayed, control may decline over time as the risk of herbicide degradation increases. Initial observations suggest that mature alkali grass plants can be controlled with post-emergence herbicides such as clethodim and glyphosate.

**Introduction**

Alkali grass (*Puccinellia distans*) is a native perennial bunchgrass that grows in a wide range of soils, but it is particularly adapted to alkali soils. Alkali grass is used to help stabilize soils and reduce the risk of soil erosion in disturbed areas. Therefore, it is frequently used in reclamation projects or roadside stabilization. Alkali grass is one of the many grass species grown in Central Oregon for seed, and controlling matures plants and seedlings is a challenge when rotating out of the crop. The objective of this study was to evaluate pre- and post-emergence herbicide options for control of volunteer seedling and mature alkali grass plants.

**Materials and Methods**

Two studies were conducted in a field under irrigation at the Central Oregon Agricultural Research Station in Madras, Oregon, during 2012. Studies were designed as a randomized complete block with three replications. Plot sizes were all 10 ft wide by 25 ft long. Herbicides were applied with a backpack sprayer calibrated to deliver 20 gallons of spray solution per acre at 40 psi pressure using XR 8002 Teejet® nozzles. Application date, environmental conditions, and alkali grass growth stage are provided in Table 1. Treatments for alkali grass control with the pre-emergence herbicides included dimethenamid (Outlook®), pendimethalin (Prowl H20®), metribuzin (Sencor DF 75®), S-metholachlor (Dual Magnum®), and primisulfuron (Beacon®). Application rates of these pre-emergence herbicides are provided in Table 2. Treatments for alkali grass control with the post-emergence herbicides included clethodim (Select Max®), terbacil (Sinbar®), diuron (Diuron 4L®) and glyphosate (Roundup PowerMax®). Application rates of these post-emergence herbicides are provided in Table 3. Herbicide efficacy was estimated 30 and 60 days after treatment (DAT) for the pre-emergence treatments and 30 DAT for the post-emergence treatments through visual evaluations.

**Results and Discussion**

The level of alkali grass control achieved with pre-emergence treatments changed with time. Outlook® applied at 16 fluid ounces/acre provided very good control was very good and remained highly effective 60 DAT (Table 2). This was not the case for Prowl H20®, r which resulted initially in 92% control observed 30 DAT but then declined to 50% by 60 DAT. Alkali grass control levels with Sencor 75DF® and Dual Magnum® also declined by 60 DAT, however, the initial control resulting from these treatments was not commercially acceptable. Control with one application of Beacon® improved with time and was 94 % at 60 DAT. Splitting the full rate of Beacon® into two applications did not improve alkali grass control.

Evaluations of the post-emergence herbicides 30DAT indicated that control of mature alkali grass plants with Roundup PowerMax® at 32 fluid oz/acre was 97 % and 83 %t with Select Max® applied at 32 fluid oz/ac. Sinbar® and Diuron 4L® were not effective in controlling alkali grass at the tested rates.

The results from these studies suggest that there are viable options for alkali grass seedling control, but control may decline with time if seed germination is

delayed. Initial observations suggest that mature plants can also be controlled with post-emergence herbicides.

**Acknowledgments**
The authors thank Jim Carroll from CHS for his collaboration on the project.

**Table 1**. Applications dates, environmental conditions, and alkali grass growth stage at time of herbicide applications.

| | | | |
|---|---|---|---|
| Application Date | 9/22/2012 | Application Date | 10/4/2012 |
| Time of Day | 12:00 PM | Time of Day | 10:00 AM |
| Air Temperature | 68 | Air Temperature | 47 |
| Relative Humidity | 34 | Relative Humidity | 50 |
| Wind Speed | 3 | Wind Speed | 3 |
| Wind Direction | NNE | Wind Direction | WNW |
| Crop Stage | Pre emergence | Crop Stage | Mature plants |

**Table 2**. Alkali grass percent control with pre emergence herbicides, 30 and 60 days after treatment (DAT).

| | Treatment[1][2] | Rate | 30 DAT | 60 DAT |
|---|---|---|---|---|
| 1 | Outlook® | 16 fl oz/a | 98 a | 95 a |
| 2 | Prowl H2O® | 4 qt/a | 92 a | 50 b |
| 3 | Sencor 75DF® | 0.5 lb/a | 73 b | 47 b |
| 4 | Dual Magnum® | 1.3 pt/a | 60 b | 48 b |
| 5 | Beacon® | 0.76 oz/a | 88 a | 94 a |
| 6 | Beacon®<br>Beacon® | 0.38 oz/a<br>0.38 oz/a | 88 a | 82 a |
| | Untreated Check | | 0 c | 0 c |
| 7 | LSD | | 18 | 16 |

[1]Some treatments included in the study were used with experimental purposes and are NOT currently labeled for public use. Before using an herbicide make sure is properly labeled for the intended use.

[2]Means among columns followed by the same letter are not different at P=0.05.

**Table 3**. Mature alkali grass plant control with post-emergence herbicides 30 days after treatment (DAT).

| | Treatment[123] | Rate | 30 DAT |
|---|---|---|---|
| 1 | Select Max® | 32 fl oz/a | 83 b |
| | AMS | 4 lb/a | |
| 2 | Sinbar® | 0.5 lb/a | 0 c |
| | COC | 0.5% v/v | |
| 3 | Diuron 4L® | 1 qt/a | |
| | NIS | 0.25 % v/v | 0 c |
| 4 | Roundup PowerMax® | 32 fl oz/a | 97 a |
| | AMS | 4 lb/a | |
| 7 | Untreated Check | | 0 c |
| | LSD | | 9 |

[1]Some treatments included in the study were used with experimental purposes and are NOT currently labeled for public use. Before using an herbicide make sure is properly labeled for the intended use.

[2]Abbreviations: AMS, ammonium sulfate, COC, crop oil concentrate, NIS, Non ionic surfactant.

[3]Means among columns followed by the same letter are not different at P=0.05.

# MEDUSAHEAD (*TAENIATHERUM CAPUT-MEDUSAE*) CONTROL WITH PRE-EMERGENCE HERBICIDES LABELED INKENTUCKY BLUEGRASS APPLIED AT 3 FALL APPLICATION TIMINGS

*G. Sbatella and S. Twelker*

**Abstract**

Reports indicate that medusahead is present in Kentucky bluegrass (KBG) seed production fields in central Oregon. Medusahead plants establish primarily during the fall, but the seedling emergence pattern is affected by rainfall patterns. The efficacy of pre-emergence herbicides applied in the fall for medusahead control relies on rainfall for appropriate incorporation because irrigation water is not available. For this reason, is important to time the herbicide application with the fall precipitation to ensure the control of seedling medusahead. A field study was conducted comparing Outlook® (21 fl oz/acre) and Prowl $H_20$® (3.2 qt/acre) applied at three different timings during the fall for Medusahead control. Herbicide performance was affected by the amount of rainfall after the application, particularly of Prowl $H_20$®, a less water soluble herbicide. Medusahead control with Prowl $H_20$® was poor and it only reached 19 percent when applied in October. In comparison, control with Outlook® was significantly better, particularly with the November and December applications where control was above 80 %. Results indicate that Outlook® can be an option for Medusahead control in KBG when irrigation water to incorporate herbicides is no longer available.

**Introduction**

Due to morphological and physiological similarities, it is very difficult to control annual grasses within a field of perennial grass grown for seed. The persistence of annual grass weed infestations result in perpetual loss of seed yield. Medusahead is an ubiquitous invader of rangelands and pastures in OR. Recent reports indicate the annual grass weed species is now present in Kentucky bluegrass (KBG) seed production fields in central Oregon. Medusahead infestations in pastures and rangelands are characterized by rapid and aggressive spread, therefore, a rapid and effective response is required to address infestations in KBG fields. The presence of medusahead is of economic concern among producers because of the potential to reduce KBG seed yield and affects seed quality. In rangeland and pasture medusahead infestations can produce large amounts of dry biomass which serves as fine fuel, thus, creating hazardous fire conditions. Finding an effective chemical control for medusahead that is already labeled for use in KBG is a high priority because obtaining a label for a new herbicide in grasses grown for seed requires time.

**Materials and Methods**

A field study to evaluate fall applications of pre-emergence herbicides for Medusahead control was initiated in October of 2011 in Jefferson County, Oregon. The study was conducted on non-agricultural land to ensure a high density Medusahead infestation. A lawn mower was used to mow and remove the medusahead thatch with minimal soil disturbance before spraying to improve soil contact by herbicides. The entire area was later sprayed with glyphosate to ensure that the Medusahead plants inside the plots would only be those that germinated after the initiation of the study. The study design was a randomized complete block with four replications. Plot size was 10 ft wide by 30 ft long. The treatments consisted of applying pendimethalin (Prowl $H_20$®) and dimethenamid (Outlook®) at 3.2 qt/a and 21 fl oz/a respectively. Herbicides were applied at three different application timings, the first in mid-October followed by November and December applications with about 30 days intervals. To determine the time of the year when the majority of the Medusahead germination occurred, three sets of untreated checks were included, one for each herbicide application timing. At each application timing, the corresponding untreated check was sprayed with glyphosate to eliminate the medusahead that had previously germinated. Herbicides were applied with a backpack sprayer calibrated to deliver 20 gallons of spray solution per acre at 40 psi pressure using XR 8002 Teejet® nozzles. Application dates and environmental conditions are provided in Table 1. Treatments were evaluated 120 days after the last application (DAT) during the spring of 2012.

## Results and Discussion

The number of Medusahead seed heads in the untreated checks averaged 46 head/ft$^2$, and no significant differences were observed in the densities among the untreated checks, suggesting that most Medusahead plants germinated during spring. Medusahead control with Prowl $H_2O$® was not commercially acceptable regardless of the application timing with control levels ranging from 8 to 19 % (Table 2). Control with Outlook® was significantly higher, particularly when applied in November or December with 83 and 84 % control achieved, respectively. These levels of control can be considered good levels of control for four months after the applications, when one takes into consideration that the herbicides tested require moisture after application to ensure soil incorporation and activation. The amount of rainfall for proper herbicide incorporation was a critical factor as indicated by the precipitation recorded after the applications (Table 3). Outlook® is a more water soluble herbicide (1174 mg/l) and the amount of precipitation after the November and December applications was probably enough to incorporate the herbicide in the soil. In contrast, Prowl $H_2O$® is a less soluble herbicide (0.275 mg/l) that is deactivated by sunlight if not incorporated after the application. These preliminary results suggest that Outlook® can be an option for Medusahead control for fall applications when irrigation water is no longer available. Prowl H20® should not be discarded as an alternative for controlling Medusahead. The efficacy of Prowl H20® if applied when irrigation water is still available to ensure incorporation should be further explored.

## Acknowledgments

The authors thank Jay McCabe and Bill Durette for their collaboration on this project.

**Table 1**. Application dates and environmental conditions for herbicide application timings.

| | A | B | C |
|---|---|---|---|
| Application Date | 10/15 | 11/20 | 12/14 |
| Time of Day | 1 PM | 11 AM | 1 PM |
| Air temperature (F) | 51 | 42 | 38 |
| Relative Humidity (%) | 59 | 72 | 54 |
| Wind Speed (MPH) | 6 | 3 | 5 |
| Wind Direction | N | W | ENE |

**Table 2**. Medusahead percent control compared to the untreated check 120 days after the last application.

| | Treatment[1] | Rate | Unit | Code[2] | % Control[3] | |
|---|---|---|---|---|---|---|
| 1 | Prowl H2O® | 3.2 | qt/acre | A | 19 | c |
| 2 | Prowl H2O® | 3.2 | qt/acre | B | 9 | c |
| 3 | Prowl H2O® | 3.2 | qt/acre | C | 8 | c |
| 4 | Outlook® | 21 | fl oz/acre | A | 46 | b |
| 5 | Outlook® | 21 | fl oz/acre | B | 83 | a |
| 6 | Outlook® | 21 | fl oz/acre | C | 84 | a |
| 7 | Untreated Check | | | | 0 | c |
| | LSD (P=.05) | | | | 16 | |

[1]Some treatments included in the study were used for experimental purposes and are NOT currently labeled for public use. Before using an herbicide, make sure it is properly labeled for the intended use.
[2]Application codes: A= 10/15/2011; B=11/20/2011; C=12/14/2012
[3]Means among columns followed by the same letter are not different at P=0.05.

**Table 3**. Amount of rainfall (inches) recorded over the duration of the study.

| Period 2011-2012 | Inches |
|---|---|
| 10/15 – 11/15 | 0.08 |
| 11/15 – 12/15 | 0.14 |
| 12/15 – 1/15 | 0.77 |
| 1/15 – 5/1 | 4.41 |

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**Business Address**

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

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

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