# 1996
# SEED PRODUCTION RESEARCH
## AT OREGON STATE UNIVERSITY
## USDA-ARS COOPERATING
### Edited by William C. Young III

Page



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## CROP RESIDUE MANAGEMENT AND ESTABLISHMENT SYSTEMS FOR ANNUAL RYEGRASS SEED PRODUCTION

*W.C. Young III, T.G. Chastain, M.E. Mellbye, T.B. Silberstein and C.J. Garbacik*

**Introduction**
Historically, a low-cost annual ryegrass (*Lolium multiflorum*) seed production system based on open field burning of post-harvest residue followed by no-till drilling to establish the subsequent crop has been very effective. With recent restrictions on open field burning, non-thermal crop establishment systems are needed that also provide an economical system for growing annual ryegrass seed. Starting in the Fall 1994, a three year study focusing on non-thermal crop residue and establishment systems was begun. This report summarizes research data collected during the second crop year (1995-96). Data from 1995 and details on the background, methods, and field histories at the locations these trials are being conducted at are in last year's report (Ext/CrS 106, 3/96).

The experiment is designed to investigate low cost crop residue management and seeding practices for annual ryegrass seed production, and to determine the effects of straw removal and seeding practices on establishment, growth, development, and yield of subsequent annual ryegrass seed crops.

**Procedure**
Two on-farm sites near Halsey, OR were selected for field-scale experiments using grower-owned, commercial size farm equipment. One site, owned by John and David Smith, is a tiled, Woodburn silt loam soil that is moderately well drained. Gulf annual ryegrass has been grown on it continuously for at least the past twenty years. The other site is owned by Jack Pimm, and is a Dayton silt loam soil that is poorly drained.

The experimental design is a randomized split-block, where each site has three main treatments: (i) plow and conventional drill, (ii) no-till drill, and (iii) volunteer. Each main plot treatment is split, with half having the straw baled and removed and half having the straw flailed and left on the soil surface. In total, six treatments were arranged in three replications at each site.

Plot size is 25 x 400 ft at Smith's and 22 x 600 ft at Pimm's, which allow plots to be harvested with the growers' swathers and combines. A weigh wagon was used to determine the bulk seed weight harvested from each plot. Clean seed yield is calculated from percent cleanout values obtained from sub-samples cleaned for each plot.

Straw was baled and removed from half the plots at both sites. The straw on the unbaled plots was flailed twice. The baled plots were flailed once to keep stubble height consistent in all treatments. Baling was done on August 12; flail chopping was completed September 1. Following these straw management practices, the conventionally tilled treatments were plowed on September 6 and subsequently worked into a seedbed at both sites.

Both on-farm sites were planted on ten inch row-spacing at 15 lb/a annual ryegrass with band-applied dry fertilizer (16-20-0) at 120 lb/a (broadcast equivalent) using a no-till drill. The drill was also used to apply banded fertilizer (no seed) on the volunteer plots to keep the fertilizer treatments consistent. Pimms was planted on October 16 and Smiths was planted on October 18.

Roundup herbicide (1.5 pt/a) was applied October 19, 1995 to conventionally tilled and no-till plots at both sites for the control of volunteer seedlings that had germinated on the soil surface. This technique, known as a "sprout spray," can be effective in controlling stand density when there is a "sprout" of volunteer seedlings before the crop emerges. Timely fall rains resulted in a good volunteer sprout emergence in 1995. Treatment with Nortron herbicide was broadcast at 3 pt/a (4 lb a.i./gal) in mid-November to all plots. The growers' normal fertilizer management (135-140 lb N/a in early April) was also broadcast applied to all plots.

In January 1996, plants were removed from a 4 x 20 inch area and counted to determine the actual stand density established. In addition, plant biomass was dried and weighed. The no-till stand was re-drilled on February 1, 1996 at the Smith site as the original stand on this treatment was lost (probably due to an extreme slug infestation during early emergence in the fall). The stands were evaluated again in June (near peak anthesis) by sampling a 10 x 12 inch area from which fertile and vegetative tiller numbers were determined, as well as subsampled to determine spikelet and floret number per inflorescence. Plots were swathed July 1 and July 6 (Smith's and Pimm's, respectively) except the February-drilled plots at the Smith site, which were swathed a week later (July 8) due to delayed maturity from replanting. Combine harvest was completed on July 16 and August 15 at Smith's and Pimm's, respectively.

**Results**

Establishment. The stand density in January was greatest in the volunteer established plots and was least in the drilled plots (Tables 1 and 2). Stand density in the no-till plots was intermediate in relation to volunteer and conventionally tilled plow plots at Pimm's. (Samples in the no-till plot were not taken at Smith's due to loss of stand.) Plants in the drilled plots developed more tillers than plants in the other establishment methods. At the Smith site, plants in the drilled treatment had a larger number of tillers than at Pimm's (3.1 tillers per plant vs 1.6) and were also greater in dry weight per seedling (Tables 1 and 2). At Smith's, dry weight per seedling was inversely related to stand density and dry weight per unit area; thus, at lower densities individual seedlings were larger in size. In contrast to this, dry weight per seedling was greater in the volunteer plots at the Pimm site. This can be attributed to the volunteer seedlings starting growth much earlier than the drilled plots. Drilled plots were planted later and were affected by the cooler, wet weather in poorly drained soil during a very wet 1995-96 winter season. The drilled plots at Smith's were able to establish and grow more rapidly in the better drained soil. Density and size of seedings were very similar in volunteer established stands at both locations. Straw removal (baling) had a slight, positive effect on above the ground dry weight at Pimm's.

Harvest. Seed yield decreased at Pimm's as the level of management was reduced (Table 5). The volunteer established plots yielded 78% of the drilled plots, and no-till plots yielded 86% of the drilled plots. Although volunteer plots had more fertile tillers per unit area, the yield per fertile tiller was reduced. This indicates the density of fertile tillers was more than optimum for this crop. Indication of overcrowding is shown in Table 3 where the volunteer and no-till sowing methods had more total tillers ($P \leq 0.10$) than the drilled plots. A slight reduction in fertile tiller number in the no-till stand resulted in a better yield. Also, the volunteer stand was in a stage of self-thinning as indicated by comparing the density at maturity with earlier densities (see Table 1). In addition, higher cleanout in the volunteer stand caused by more chaff and plant material may be from more seed sites not filling or effectively maturing to harvest.

At Smith's, drilled and no-till plots yielded the same, while the volunteer established crop yielded about 81% of the drilled plots (Table 6). Yield components were significantly affected in the volunteer established stand at Smith's (Table 7). A reduced number of spikelets on each spike as well as a shorter spike length was observed; both are good indications of decreased yield potential. This difference in yield potential as well as an overall stand reduction from the winter population (compare Tables 2 and 4) is the likely cause for a decreased yield in the volunteer stand. The no-till stand yielded about the same as the drill stand although it was planted four months later on February 1. Even though the no-till stand had fewer spikelets, and shorter spike lengths (Table 7), the newly planted stand grew vigorously and was able to produce enough fertile tillers to give a good seed yield.

Table 7. Yield components of Gulf annual ryegrass established under different cropping systems at Smith Farm, 1996.

| Cropping system | Component of yield: Spikelets per spike | Florets per spikelet | Spike length |
|---|---|---|---|
| | -------(no.)--------- | | (cm) |
| Sowing method | | | |
| Drill | 29.1 a | 12.4 | 32.3 a |
| No-till | 20.3 b | 12.9 | 25.4 b |
| Volunteer | 26.6 a | 13.4 | 28.1 b |
| Residue removal | | | |
| Bale | 24.8 | 13.3 | 28.9 |
| No removal | 25.9 | 12.5 | 28.3 |

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values (P=0.05)

Both locations had a comparable ratio of fertile tillers in the stand at maturity; the stands had an average of 61% fertile tillers at Pimm's and 59% at Smith's (Tables 3 and 4). Volunteer establishment reduced yield at both locations by about 20% (Tables 5 and 6), although seed yields were generally higher at Pimm's. In contrast, dry matter yield was decreased by no straw removal at Pimm's yet was increased at Smith's (both P≤0.10). The Pimm site had higher above ground dry weight than Smith's (Tables 3 and 4) and a lower harvest index (Tables 5 and 6). Fertile tiller number at Smith's was higher in the full straw load as compared to the baled plots but was not enough to affect yield.

Seed yields above the industry average were obtained across treatments at both sites. It is likely that differences in soil drainage characteristics and varieties at these two sites could explain the different results observed. These field treatments will be maintained for one additional crop years; thus, our second-year results should not be used to establish conclusive recommendations.

*Acknowledgments: This research was supported in part through funds from the Grass Seed Cropping Systems for a Sustainable Agriculture Special Grant program administered by USDA-Cooperative States Research Education and Extension Service. We are also appreciative of the assistance of John and David Smith, and Jack and Eric Pimm in providing equipment and labor to accomplish numerous farming operations.*

Table 1. Effects of establishment cropping systems on stand density, tillering, and dry weight in TAM 90 annual ryegrass at Pimm Farm, January 1996.

| Cropping system | Seedlings per unit area | Tillers per seedling | Above-ground dry weight per seedling | Above-ground dry weight per unit area |
|---|---|---|---|---|
| | (no./sq. ft.) | --------(no.)-------- | (mg/seedling) | (g/sq. ft.) |
| Sowing method | | | | |
| Drill | 57 b | 1.6 a | 28 b | 87 (b) |
| No-till | 239 a | 1.1 b | 9 b | 101 (a) |
| Volunteer | 402 a | 1.3 ab | 94 a | 104 (a) |
| Residue removal | | | | |
| Bale | 192 (b) | 1.3 | 54 | 106 (a) |
| No removal | 273 (a) | 1.3 | 33 | 88 (b) |

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values P=0.05 (P=0.10).

Table 2. Effects of establishment cropping systems on stand density, tillering, and dry weight in Gulf annual ryegrass at Smith Farm, January 1996.

| Cropping system | Seedlings per unit area | Tillers per seedling | Above-ground dry weight per seedling | Above-ground dry weight per unit area |
|---|---|---|---|---|
| | (no./sq. ft.) | --------(no.)-------- | (mg/seedling) | (g/sq. ft.) |
| Sowing method | | | | |
| Drill | 45 b* | 3.1 a | 195 (a)* | 8 b* |
| No-till[1] | -- | -- | -- | -- |
| Volunteer | 363 a | 1.2 b | 75 (b) | 23 a |
| Residue removal | | | | |
| Bale | 223 | 2.3 | 119 | 15 |
| No removal | 184 | 2.0 | 151 | 16 |

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values P=0.05 (P=0.10).

[1]No-till treatment not sampled; stand was lost and replanted in February, 1996.

Table 3. Effect of establishment cropping systems on spring tiller density and dry matter production in TAM 90 annual ryegrass at Pimm Farm, June 1996.

| Cropping system | Tiller density Total | Vegetative | --------Fertile-------- | | Above-ground dry weight |
|---|---|---|---|---|---|
| | ---------------- (no./sq. ft.) | ---------------- | | (%) | (ton/a) |
| <u>Sowing method</u> | | | | | |
| Drill | 161 (b) | 72 | 90 b | 55 | 4.2 (b) |
| No-till | 216 (a) | 93 | 123 a | 57 | 4.9 (a) |
| Volunteer | 209 (a) | 71 | 137 a | 70 | 5.0 (a) |
| <u>Residue removal</u> | | | | | |
| Bale | 184 | 61 | 124 | 67 | 5.1 (a) |
| No removal | 206 | 97 | 110 | 55 | 4.2 (b) |

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values P=0.05 (P=0.10)

Table 4. Effect of establishment cropping systems on spring tiller density and dry matter production in Gulf annual ryegrass at Smith Farm, June 1996.

| Cropping system | Tiller density Total | Vegetative | --------Fertile------- | | Above-ground dry weight |
|---|---|---|---|---|---|
| | ---------------- (no./sq. ft.) | ---------------- | | (%) | (ton/a) |
| <u>Sowing method</u> | | | | | |
| Drill | 86 b | 36 b | 50 | 58 | 4.0 |
| No-till | 137 a | 60 a | 77 | 54 | 3.7 |
| Volunteer | 104 b | 37 b | 67 | 65 | 4.7 |
| <u>Residue removal</u> | | | | | |
| Bale | 99 | 42 | 56 (b) | 56 | 3.7 (b) |
| No removal | 119 | 46 | 73 (a) | 62 | 4.5 (a) |

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values P=0.05 (P=0.10)

Table 5. Harvest characteristics of TAM 90 annual ryegrass established under different cropping systems at Pimm Farm, 1996.

| Cropping system | Harvest index | Cleanout | Seed yield | Seed yield |
|---|---|---|---|---|
| | ------------(%)--------- | | (lb/a) | (% of Drill) |
| Sowing method | | | | |
| Drill | 26 a | 2.9 (b) | 2878 a* | 100 |
| No-till | 20 b | 3.9 (b) | 2474 b | 86 |
| Volunteer | 19 b | 5.9 (a) | 2248 c | 78 |
| Residue removal | | | | |
| Bale | 20 b | 3.9 b | 2544 | -- |
| No removal | 23 a | 4.6 a | 2523 | -- |

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values P=0.05 (P=0.10)

Table 6. Harvest characteristics of Gulf annual ryegrass established under different cropping systems at Smith Farm, 1996.

| Cropping system | Harvest index | Cleanout | Seed yield | Seed yield |
|---|---|---|---|---|
| | ---------(%)-------- | | (lb/a) | (% of Drill) |
| Sowing method | | | | |
| Drill | 25 | 3.9 | 2586 a | 100 |
| No-till | 28 | 3.9 | 2534 a | 98 |
| Volunteer | 19 | 4.4 | 2083 b | 81 |
| Residue removal | | | | |
| Bale | 27 | 4.1 | 2444 | -- |
| No removal | 21 | 4.1 | 2358 | -- |

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values (P=0.05)

# STAND DENSITY EFFECTS ON ANNUAL RYEGRASS SEED CROPS

*W.C. Young III, T.G. Chastain, M.E. Mellbye, T.B. Silberstein and C.J. Garbacik*

**Introduction**

Recent legislative restrictions on open field burning have changed the methods of establishing annual ryegrass (*Lolium multiflorum*) stands. Increased costs associated with conventional tillage have increased interest in volunteer crop establishment. Because the amount of seed shattered can easily be 10% of the harvested crop, 200 lb/a of seed on the ground from a 2000 lb/a yield develops into a very dense stand when compared to normal seeding rates of 15 to 20 lb/a.

The effect of dense stands has typically been a reduction in seed yield. Optimum stand density for maximum seed yield in annual ryegrass has not been determined. Thus, a trial was established in 1994 to study the impact of a wide range of seeding rates in both row-planted and broadcast-sown systems to compare typically sown stands with simulated volunteer stands at different seed densities. This is the second year this trial has been conducted. Data from 1995 and additional background information is contained in last year's report (Ext/CrS 106, 3/96).

**Procedure**

A 2.5 acre field located at the Hyslop Crop Science Research Farm was seeded in September 1995. The field was planted to field peas summer in 1994. These green manure crops were plowed down in June 1995 and the site was summer fallowed prior to planting the annual ryegrass.

Nine treatments were selected to provide a wide range of possible stand densities. Treatments included four seeding rates that were drilled in twelve inch rows at 3, 6, 12, and 24 lb/a. Five treatments were broadcast seeded at 24, 48, 96, 192 and 384 lb/a. Each plots was 15 x 200 feet and replicated three times in a randomized complete block design.

Gulf annual ryegrass was seeded at the OSU Hyslop Research Farm on September 22, 1995, using a conventional double disk drill calibrated to the seeding rates mentioned previously for the drilled treatments. The broadcast seeding was completed on the same date using a Gandy Orbit-air seeder. The Gandy Orbit-air seeder meters seed into tubes and blows it out to where the ends of the tubes are connected to a boom. A pre-plant fertilizer application of 200 lb/a 16-20-0-14(S) was incorporated during seedbed preparation. Herbicide management included an application of Nortron applied on October 1, 1995, at a rate of 3 pt/a (4 lb a.i./gal). A spring fertilizer application of 105 lb/a N (as urea) was applied on April 4, 1996.

During the first week of December, plants were removed from a 4 x 12 inch area and counted to determine the actual stand density established. In addition, biomass was determined on oven-dry weight of plant samples. The stand was evaluated again on June 5 (near peak anthesis) by sampling a 12 x 12 inch area from which fertile and vegetative tiller numbers were determined, as well as subsamples to determine spikelet and floret number per inflorescence. Yield assessment was determined from a 14 ft swath cut through the center of each 200 ft plot. Plots were swathed on July 1 and combine harvested on July 15, 1996. A weigh wagon was used to determine the bulk seed weight harvested from each plot. Clean seed yield was calculated from percent cleanout values obtained from the bulk seed.

**Results**

As expected, stand density paralleled the range of seeding rates within this study (Table 1). Dry weight per seedling was inversely related to stand density, thus, at lower densities individual seedlings were larger in size. Nevertheless, total above ground dry weight of the seedling population increased as the stand became more dense. However, by the time the stand was nearing maturity there was no difference in the total above-ground biomass (Table 2).

Plant density had no effect on the number of fertile or vegetative tillers at maturity (Table 2). This is in stark contrast to the data from 1995. Heavy rains and flooded conditions during January and February 1996 caused a high level of seedling mortality in the broadcast sown stands. It looked like large parts of the higher density stands would be lost. However, the stand regrew, but with a reduced plant population (compare Table 1 with Table 2). Thus, the stand returned to a spring tiller population equivalent to the 12 to 24 lb/a drilled rate from the previous year, which was the best yielding treatment. Seed yield was higher this year than in 1995. A high percent (≅75%) of the tillers that survived the flooding produced seed heads (Table 2). Components of seed yield did not differ significantly (Table 3).

Table 1. Effect of planting density on stand establishment and dry weight in Gulf annual ryegrass, January 1996.

| Seeding rate | Seedlings per unit area | Above-ground dry weight per seedling | Above-ground dry weight per unit area |
|---|---|---|---|
| (lb/a) | (no./sq. ft.) | (mg/seedling) | (g/sq. ft.) |
| Drill, 3 | 17 e* | 119.8 a | 1.9 e |
| Drill, 6 | 48 de | 83.5 bc | 3.8 de |
| Drill, 12 | 67 de | 96.2 ab | 6.4 cd |
| Drill, 24 | 177 cd | 58.2 cd | 10.2 b |
| Broadcast, 24 | 130 de | 61.5 cd | 7.1 bcd |
| Broadcast, 48 | 297 c | 33.7 de | 9.7 bc |
| Broadcast, 96 | 706 c | 21.4 e | 14.9 a |
| Broadcast, 192 | 1294 b | 14.7 e | 18.4 a |
| Broadcast, 384 | 1683 a | 11.1 e | 18.5 a |

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values (P=0.05)

In contrast with the previous year, where higher tiller density had a deleterious effect on seed yield, environmental conditions (flooding) forced stands with greatly varied tiller populations to reach a similar stand density and productivity (Table 4). The optimum density appears to be within a seeding rate range of 3 to 24 lb/a. This is within the normal seeding rate of 15 to 20 lb/a for annual ryegrass although volunteer cropping systems can exceed this optimum by 10 times or more. Even when unburned fields are plowed all of the shattered seed from the previous crop is mixed into the soil during seed bed preparation, thus, many commercial annual ryegrass stands are too dense to achieve maximum seed yield.

Table 2. Effect of planting density on spring tiller production in Gulf annual ryegrass, June 1996.

| Seeding rate | Tillers Total | Vegetative | Fertile | % Fertile | Above-ground dry weight |
|---|---|---|---|---|---|
| (lb/a) | (no./sq. ft.) | | | (%) | (ton/a) |
| Drill, 3 | 105 | 21 | 84 | 82 | 5.4 |
| Drill, 6 | 102 | 23 | 79 | 77 | 4.6 |
| Drill, 12 | 102 | 25 | 78 | 76 | 4.6 |
| Drill, 24 | 126 | 31 | 95 | 76 | 5.5 |
| Broadcast, 24 | 100 | 29 | 71 | 73 | 3.8 |
| Broadcast, 48 | 115 | 31 | 83 | 73 | 4.5 |
| Broadcast, 96 | 96 | 24 | 72 | 75 | 3.7 |
| Broadcast, 192 | 156 | 45 | 111 | 71 | 5.7 |
| Broadcast, 384 | 129 | 41 | 89 | 69 | 4.7 |

Table 3. Effect of planting density on seed yield components of Gulf annual ryegrass, June 1996.

| Seeding rate | Spikelets per spike | Florets per spikelet Bottom | Middle | Top | Mean | Spike length |
|---|---|---|---|---|---|---|
| (lb/a) | (no.) | | | | | (cm) |
| Drill, 3 | 29 | 13 | 13 | 10 | 12 | 31.8 |
| Drill, 6 | 28 | 14 | 14 | 11 | 13 | 30.9 |
| Drill, 12 | 27 | 13 | 16 | 9 | 13 | 29.5 |
| Drill, 24 | 27 | 15 | 14 | 10 | 13 | 29.3 |
| Broadcast, 24 | 27 | 13 | 13 | 10 | 12 | 28.1 |
| Broadcast, 48 | 26 | 12 | 12 | 9 | 11 | 27.9 |
| Broadcast, 96 | 25 | 13 | 13 | 10 | 12 | 28.3 |
| Broadcast, 192 | 26 | 13 | 13 | 10 | 12 | 29.5 |
| Broadcast, 384 | 25 | 13 | 13 | 10 | 12 | 27.7 |

Table 4. Harvest characteristics of Gulf annual ryegrass established at different densities, 1996.

| Seeding rate | Harvest index | Cleanout | Seed yield |
|---|---|---|---|
| (lb/a) | (%) | | (lb/a) |
| Drill, 3 | 19 | 5.7 | 2549 |
| Drill, 6 | 21 | 5.7 | 2410 |
| Drill, 12 | 20 | 6.4 | 2325 |
| Drill, 24 | 17 | 6.9 | 2308 |
| Broadcast, 24 | 24 | 6.0 | 2340 |
| Broadcast, 48 | 20 | 5.9 | 2221 |
| Broadcast, 96 | 25 | 6.3 | 2338 |
| Broadcast, 192 | 18 | 5.7 | 2311 |
| Broadcast, 384 | 21 | 6.0 | 2420 |

*Acknowledgments: This research was supported in part through funds from the Grass Seed Cropping Systems for a Sustainable Agriculture Special Grant program administered by USDA-Cooperative States Research Education and Extension Service. A special thanks to the Hectors for helping harvest the plots.*

# ESTABLISHMENT OF ROWS IN VOLUNTEER ANNUAL RYEGRASS SEED CROPS USING A SHIELDED SPRAYER

*W.C. Young III, T.G. Chastain, M.E. Mellbye, T.B. Silberstein and C.J. Garbacik*

**Introduction**

With reductions in the acreage allowed for open field burning, annual ryegrass growers are changing the methods used for establishing annual ryegrass (*Lolium multiflorum*) stands. In the past, open field burning followed by no-till establishment methods were used for sequential cropping of annual ryegrass over several years. This provided a cost conserving method of establishment in this low profit margin seed crop. One of the non-burning methods of establishing a subsequent crop is to allow the shattered seed from the previous crop to germinate resulting in a "volunteer" stand.

Since shattered seed losses can easily be 10%, a volunteer seeding of 200 lb/a (10% of 2000 lb/a yield) can result in very dense stands compared to 15-20 lb/a normally planted in rows. This ultimately results in reduced yields caused by too much inter-plant competition for limited resources. One of the ways that has been suggested and tried on a limited basis is to use herbicides on a staggered spacing to make "rows" by spraying out inter-row regions leaving the non-sprayed strips as "rows" in the field. In order to find how much of the stand needs to be sprayed out, we began a trial at the OSU Hyslop Research Farm in the fall of 1995. A volunteer stand from the previous year's planting density study was used.

**Procedure**

A 2.5 acre field located at the OSU Hyslop Research Farm was seeded in September 1994 for a stand density study. Following plot harvest in 1995, half of the plots had straw baled and removed and on the other half straw was flail chopped (2-3 passes) and left on the field. The stubble left from the baling operation was also flailed. A volunteer crop was allowed to germinate in these main plots. Four subplot treatments were applied to both the baled and the full straw load strips in each replication. The four treatment were an untreated check, and three spray widths of 3, 6, and 9 inches wide in an effort to leave a solid stand, and rows 9, 6, and 3 inches wide, respectively. Rows were sprayed on 12 inch center spacing. Each plot was 15 x 200 feet organized in a split-plot design with residue (full straw load and baled) as main plots and the spray widths as subplots. All treatments were replicated three times. Rows were sprayed on December 19, 1995 with a shielded row sprayer using Roundup at 2.0 pt/a (with 0.25% surfactant) applied at 55 gal/a. The sprayer was adjusted to spray the appropriate widths for each treatment. Other weed control management included an application of Nortron applied on October 9, 1995, at a rate of 3 pt/a (4 lb a.i./gal). A fall application of 200 lb/a of 16-20-0-14(S) was broadcast applied on October 11. Spring fertilizer applications were 105 lb/a N (as urea) on April 4, and 30 lb/a N (as urea) on May 4, 1996.

The stand was evaluated on June 5 (near peak anthesis) by sampling a 12 x 12 inch area from which fertile and vegetative tiller numbers and total dry matter production were determined, as well as subsamples to determine spikelet and floret number per inflorescence. Yield assessment was determined from a 14 ft swath cut through the center of each 200 ft plot. Plots were swathed July 1 and combine harvested July 15, 1996. Both operations were conducted using grower equipment. A weigh wagon was used to determine the bulk seed weight harvested from each plot. Clean seed yield was calculated from percent cleanout values in sub-samples obtained during harvest.

**Results**

Residue management: Straw removal had no effect on the density of spring tillers (Table 1) or on seed yield (Table 3). The only factors affected by residue management were spike length and 1000 seed weight, which were reduced under the full straw load regime (Table 2 and 3, respectively).

Row spraying: The solid stand treatment produced more tillers per unit area, but resulted in no increase in total dry matter production as individual tillers were thinner in size (Table 1). Solid stands also had significantly more fertile tillers per unit area (Table 1), however, these tillers had a shorter spike length and fewer potential seed sites as indicated by a reduced number of spikelets per spike (Table 2). Seed yield was increased by removing strips in the solid stand using herbicides to make rows (Table 3). Seed yield improved as the unsprayed rows became narrower. The highest yield was obtained when a 3 inch row remained (75% of the solid stand removed), which resulted in a 68% improvement over the solid stand. The seed yield in 3 inch row plots was significantly better than the 6 inch and 9 inch wide rows (Table 3).

First-year results indicate that volunteer stands may negatively impact anticipated seed yield. Optimum tiller populations for high seed yield are less than what results in solid stand volunteer establishment. Band-spraying herbicides to create rows in solid stands appears to be an effective and economical way to reduce the tiller populations and increase seed yield potential.

*Acknowledgments: This research was supported in part through funds from the Grass Seed Cropping Systems for a Sustainable Agriculture Special Grant program administered by USDA-Cooperative States Research Education and Extension Service. A special thanks to the Hectors for helping harvest the plots.*

Table 1. Effect of residue management and row spaying on spring tiller production in Gulf annual ryegrass, June 1996.

| Treatment | Tillers Total | Tillers Vegetative | Tillers Fertile | % Fertile | Above-ground dry weight |
|---|---|---|---|---|---|
| Residue | ---------------- (no./sq. ft.) | | ---------------- | (%) | (ton/a) |
| Flail full straw load | 337 | 45 | 292 | 86 | 3.7 |
| Bale + flail stubble | 316 | 44 | 273 | 84 | 4.4 |
| Row spray (% stand remaining) | | | | | |
| 3 inch rows (25%) | 302 b* | 45 | 257 b* | 84 b* | 4.4 |
| 6 inch rows (50%) | 210 b | 39 | 171 b | 81 b | 4.1 |
| 9 inch rows (75%) | 282 b | 49 | 234 b | 83 b | 3.9 |
| Solid stand (100%) | 514 a | 46 | 468 a | 91 a | 3.8 |

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values P=0.05

Table 2. Effect of residue management and row spraying on seed yield components of Gulf annual ryegrass, June 1996.

| Treatment | Spikelets per spike | Florets per spikelet Bottom | Florets per spikelet Middle | Florets per spikelet Top | Florets per spikelet Mean | Spike length |
|---|---|---|---|---|---|---|
| Residue | ---------------------- | ---------- (no.) | ---------------------- | ---------------------- | ---------------------- | (cm) |
| Flail full straw load | 21 | 13 | 13 | 10 | 12 | 23.8 b* |
| Bale + flail stubble | 20 | 14 | 14 | 11 | 13 | 24.5 a |
| Row spray (% stand remaining) | | | | | | |
| 3 inch rows (25%) | 20(c)* | 13 | 13 | 11 | 12 | 24.1(ab)* |
| 6 inch rows (50%) | 21(bc) | 14 | 14 | 11 | 13 | 24.0(ab) |
| 9 inch rows (75%) | 22(ab) | 13 | 13 | 10 | 12 | 26.2(a) |
| Solid stand (100%) | 19(c) | 13 | 13 | 10 | 12 | 22.3(b) |

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values P=0.05, (P=0.10)

Table 3. Harvest characteristics of Gulf annual ryegrass established at residue and row spray treatments, 1996.

| Treatment | Harvest index | Cleanout | Seed yield | 1000 seed weight |
|---|---|---|---|---|
| Residue | ---------------(%)----------- | | (lb/a) | (g) |
| Flail full straw load | 18 | 7.0 | 1575 | 2.99(b)* |
| Bale + flail stubble | 15 | 7.1 | 1519 | 3.09(a) |
| Row spray (% stand remaining) | | | | |
| 3 inch rows (25%) | 18 | 6.6 | 1904 a* | 2.97 |
| 6 inch rows (50%) | 18 | 6.6 | 1658 b | 3.07 |
| 9 inch rows (75%) | 16 | 7.8 | 1494 b | 3.11 |
| Solid stand (100%) | 13 | 7.1 | 1132 c | 3.01 |

*Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values P=0.05, (P=0.10)

## NUTRIENT UPTAKE BY TALL FESCUE UNDER FULL STRAW LOAD MANAGEMENT

*M.E. Mellbye, G.A. Gingrich, N.W. Christensen, J.M. Hart, and M. Qureshi*

Chopping the full straw load is one method of residue management used in tall fescue seed production. In 1996, approximately 15% of the acreage had the straw chopped as compared to 10% of the acres which were open field burned. One of the benefits of returning crop residue is nutrient recycling. Higher levels of soil K, for example, have been measured under full straw chopping compared to vacuum-sweep treatments (Young et al., 1993). Although nutrient uptake by cool-season grass seed crops has been characterized for burning and for baling management systems, the impact from leaving all the straw chopped in the field has not been documented (Hart et. al., 1988. Horneck et al., 1992, Horneck et al., 1993). The objective of our study was to evaluate N, P, K, S, Ca, Mg, Mn, Fe, Zn, Cu, and B uptake by tall fescue under full straw load versus bale and vacuum-sweep management. This was accomplished by taking whole plant samples through the 1993 season from residue management field trials already established on farms in the Willamette Valley.

Four existing tall fescue trials in Linn and Marion counties were selected for the study. Two of the trial locations were established in 1992 following harvest of the first year's seed crop. These were designated as "first-year" sites and compared one year of full straw versus vacuum-sweep management. At two trials established in 1990, designated as "third-year" sites, the two residue management systems had been maintained for three years.

Field trials were located on well drained and poorly drained soils. First-year fields consisted of: 'Rebel II' on a Dayton silty clay loam (poorly drained), and 'Crewcut' on a Willamette silt loam (well drained). The third-year fields were 'Cochise' on a Woodburn silt loam (moderately well drained), and 'Arid' on a Dayton silty clay loam (poorly drained). Spring N fertilizer was applied between early February and mid-April by individual farmers. All sites received split applications totaling 140 to 145 lb N/acre. Plant and soil samples were taken from each plot six times starting March 24 and ending at swathing time on July 1, 1993. Three replications were sampled. Plant samples were dried to determine biomass accumulation and nutrient content. These data were used to calculate nutrient uptake.

Results for N uptake, plant growth, and seed yields were discussed in the 1993 Seed Report (Mellbye et al., 1993). In that article, we reported that N uptake and plant growth (biomass accumulation) were slightly reduced on first-year sites by chopping the full straw load, compared to complete removal by the bale and vac-sweep system. In contrast, plant growth and N uptake were greater on third-year sites where straw had been chopped for three consecutive years. On both first and third-year sites, differences between residue management treatments were more pronounced on the well drained fields - a reflection of more responsive plant growth on those soil types. Seed yield, biomass production, and N data are included in the tables that accompany this report. Data for N and the other nutrients are averaged across well drained and poorly drained fields to provide a more generalized picture of the effect of chopping the full straw load on nutrient concentration and uptake.

The concentration of nutrients in the plants was influenced by residue management, especially after three years of chopping a full straw load (Tables 1 and 2). Concentrations tended to be lower on first-year sites and greater on third-year sites where the straw was chopped rather than removed. The increase in plant concentration after three years of full straw chopping was small for most nutrients, with the exception of K. The concentration of K at physiological maturity (swathing time) on the third-year sites was over two times greater where straw had been chopped. While the concentration of nutrients was influenced by residue management, there was no evidence these differences were related to seed yield (Table 3). Plants appeared healthy across locations; there were no visual symptoms of nutrient deficiency or toxicity associated with residue management treatments. With the exception of K on third-year sites, the age of the plants (sampling date) had more affect on nutrient concentrations through the season than residue management.

Nutrient uptake at the end of the growing season, a function of concentration in the plant and biomass accumulation at swathing, was affected by residue management in much the same manner that concentration was. For some nutrients, there was a slight reduction in uptake on first-year sites, but an increase on third-year sites (Table 3). The increase in uptake with full straw management varied considerably among nutrients. Potassium (K) showed the most dramatic increase in uptake after three years of chopping straw (Figure 1 and 2). Sulfur (S) followed the same pattern. Phosphorus (P), Ca, Mg, and the trace minerals showed a similar pattern, but in general the increase in uptake of these nutrients was small compared to that of K. As with N, differences were more pronounced on well-drained soils.

Results of this study indicate that extra fertilizer is not needed after the initial year of chopping straw on tall fescue seed fields. Even though some immobilization of N and other nutrients may occur, the effect is small. After three years of chopping straw, increases in N, P, and S uptake were measured suggesting that these nutrients were being mineralized as residue decomposed. The increased uptake was small, however, and probably not enough to reduce the need for commercial fertilizer during the first three years of chopping straw. Potassium is a different story. The significant increase in plant K concentration and 2 - 4 fold increase in K uptake by the crop, after just three years of full straw chopping, confirm this nutrient is readily recycled. Maintenance applications of potash fertilizer could be eliminated on soils that test over 100 ppm K, the level considered adequate for grass seed production (OSU Fertilizer Guide FG 36). Continued application of K fertilizer under a full straw chopping system may simply result in luxury consumption.

The pattern of nutrient uptake supports the commercial practice that adequate fertilizer should be applied in February and March, prior to the rapid uptake of N and S that occurs in April. This could be especially important on well-drained soils, following the first year of full straw management, where reductions in uptake of these nutrients due to residue management is most likely to occur.

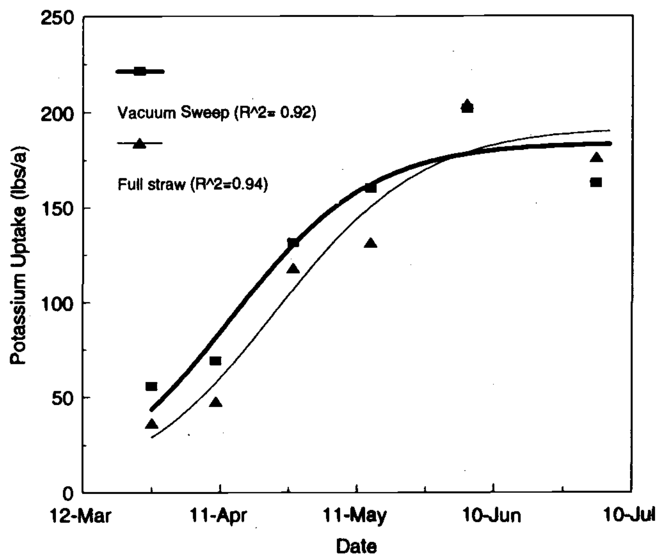


Figure 1. K uptake as influenced by residue management on a first-year, well drained site (Willamette silt loam soil, 1993). Soil test K values equaled 160 ppm on vac-sweep and 202 ppm on full straw treatments.

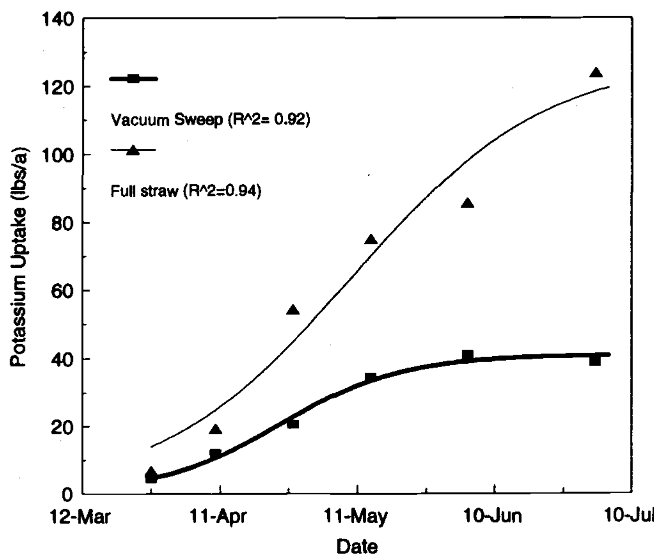


Figure 2. K uptake as influenced by residue management on a third-year, well drained site (Woodburn silt loam soil, 1993). Soil test K values equaled 100 ppm on vac-sweep and 236 ppm on full straw treatments.

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*Acknowledgment: This research was supported in part by a grant from the Oregon Seed Council.*

Table 1. Nutrient concentration in tall fescue as influenced by residue management on first year sites, averaged across well-drained and poorly drained sites, on three sampling dates, 1993.

| Nutrient | Early stem elongation 3/26/93 | | Boot-early heading 5/7/93 | | Physiological maturity (swathing) 7/1/93 | |
|---|---|---|---|---|---|---|
| | Vac-sweep | Full straw | Vac-sweep | Full straw | Vac-sweep | Full straw |
| N (%) | 3.63 | 3.56 | 2.00 | 1.93 | 1.18 | 1.09 |
| P (%) | 0.39 | 0.40 | 0.23 | 0.22 | 0.14 | 0.13 |
| K (%) | 2.08 | 2.17 | 1.50 | 1.48 | 0.89 | 1.03 |
| S (%) | 0.40 | 0.38 | 0.27 | 0.23 | 0.22 | 0.20 |
| Ca (%) | 0.36 | 0.36 | 0.27 | 0.23 | 0.27 | 0.18 |
| Mg (%) | 0.15 | 0.15 | 0.12 | 0.10 | 0.09 | 0.08 |
| Mn (ppm) | 119.0 | 119.0 | 84.0 | 78.0 | 59.0 | 54.0 |
| Fe (ppm) | 544.0 | 243.0 | 158.0 | 149.0 | 84.0 | 70.0 |
| Zn (ppm) | 21.0 | 20.0 | 13.0 | 11.0 | 7.2 | 6.5 |
| Cu (ppm) | 2.8 | 2.5 | 1.7 | 1.3 | 0.8 | 1.0 |
| B (ppm) | 3.0 | 2.8 | 1.0 | 1.0 | 2.0 | 1.5 |

Table 2. Nutrient concentration in tall fescue as influenced by residue management on third year sites, averaged across well-drained and poorly drained sites, on three sampling dates, 1993.

| | Early stem elongation 3/26/93 | | Boot-early heading 5/7/93 | | Physiological maturity (swathing) 7/1/93 | |
|---|---|---|---|---|---|---|
| Nutrient | Vac-sweep | Full straw | Vac-sweep | Full straw | Vac-sweep | Full straw |
| N (%) | 4.25 | 4.21 | 2.46 | 2.19 | 1.12 | 1.14 |
| P (%) | 0.28 | 0.24 | 0.21 | 0.21 | 0.14 | 0.18 |
| K (%) | 1.54 | 1.56 | 1.11 | 1.58 | 0.65 | 1.51 |
| S (%) | 0.32 | 0.28 | 0.24 | 0.25 | 0.23 | 0.33 |
| Ca (%) | 0.29 | 0.21 | 0.21 | 0.24 | 0.23 | 0.27 |
| Mg (%) | 0.16 | 0.12 | 0.14 | 0.13 | 0.13 | 0.16 |
| Mn (ppm) | 143.0 | 120.0 | 96.0 | 92.0 | 76.0 | 94.0 |
| Fe (ppm) | 833.0 | 238.0 | 210.0 | 172.0 | 79.0 | 102.0 |
| Zn (ppm) | 21.0 | 16.0 | 12.0 | 13.0 | 5.2 | 8.8 |
| Cu (ppm) | 2.0 | 1.8 | 1.7 | 2.3 | 0.8 | 2.0 |
| B (ppm) | 3.0 | 2.3 | 1.7 | 1.7 | 2.8 | 3.7 |

Table 3. Nutrient uptake by tall fescue as influenced by residue management, averaged across well-drained and poorly drained sites at swathing time, 1993

| | First Year | | Third Year | |
|---|---|---|---|---|
| Nutrient | Vac-sweep | Full straw | Vac-sweep | Full straw |
| | ------------- (lb/a) ------------- | | ------------ (lb/a) ------------- | |
| Biomass Production | 11,360 | 11,130 | 8,020 | 8,550 |
| Seed yield | 1,560 | 1,760 | 1,340 | 1,430 |
| N | 136 | 122 | 88 | 97 |
| P | 17 | 14 | 11 | 15 |
| K | 131 | 147 | 64 | 157 |
| S | 25 | 23 | 18 | 28 |
| Ca | 25 | 20 | 19 | 23 |
| Mg | 11 | 9 | 10 | 13 |
| Mn | 0.65 | 0.59 | 0.62 | 0.80 |
| Fe | 0.90 | 0.74 | 0.65 | 0.88 |
| Zn | 0.09 | 0.08 | 0.04 | 0.08 |
| Cu | 0.01 | 0.01 | 0.01 | 0.02 |
| B | 0.02 | 0.02 | 0.02 | 0.03 |

Note: To determine $P_2O_5$ and $K_2O$ uptake, multiply P by 2.29 and K by 1.2.

# FULL STRAW MANAGEMENT: EFFECT OF SPECIES, STAND AGE, TECHNIQUE, AND LOCATION ON GRASS SEED CROP PERFORMANCE

*T.G. Chastain, W.C. Young III, C.J. Garbacik, T.B. Silberstein and M.E. Mellbye*

Grass seed growers have shown considerable interest in post-harvest management of crop residues without removal by baling. This form of residue management is commonly known as full straw management. Full straw management is a reasonable alternative tool that allows producers to forego baling when straw might not meet quality standards. Moreover, some growers object to the loss of several important plant nutrients that is possible when grass seed crop straws are removed by baling. Unfortunately, results have not always been positive with full straw management as some growers have found that yields were sometimes not stable over time. Since it was apparent that a number of questions regarding full straw management needed to be resolved, we investigated several factors that may influence the performance of grass seed crops with this system.

On-farm trials on full straw management were conducted over a six-year period in several seed crop species. All trials were initiated immediately after the first-year seed harvest at each site. In our initial research trials (maintained from 1992 until 1995), we observed the impact of full straw residue management (chopping residue three times with a conventional flail mower) on performance of the 2nd, 3rd, and 4th seed crops of tall fescue, perennial ryegrass, orchardgrass, Chewings fine fescue, and Kentucky bluegrass. One of the tall fescue sites was continued for a 5th seed harvest in 1996. Follow-up trials were initiated in 1994 and will conclude after the 1997 harvest to learn how partial removal of a full straw load and flail type influenced crop performance of perennial ryegrass and tall fescue. Management by a conventional-type flail blade (full straw load was chopped three times) was compared with management by a straight-blade flail (full straw load was chopped two times). Partial straw removal was accomplished by using a needle-nose rake following straw chopping by one of the flail types.

The quantity of straw remaining on the field after harvest differed among the species evaluated in our trials. Full straw loads often exceeded 6000 lbs. per acre in perennial ryegrass, tall fescue, and orchardgrass. In Chewings fescue and Kentucky bluegrass, the full straw load usually ranged from 4000 to 5000 lbs. per acre. Partial removal by needle-nose rake accounted for 35 to 40% of the total straw load, regardless of flail type.

Full straw loads averaged 24% and 10% more soil water in summer than complete removal of straw at the 3-inch and 9-inch soil depths, respectively. No increases in soil water content were observed under full straw loads during fall or spring. The straw acted as a mulch and soil water was conserved during the dry summer months.

Decomposition of the straw layer over time caused marked improvement of several important soil characteristics. Soil pH was increased by full straw management in 29% of soil samples taken from the root zone each fall. Organic matter was similarly improved in 21% of soil samples, suggesting the possible benefit of returning straw on soil tilth. Nutrient levels increased by full straw management included: potassium, magnesium, and phosphorus were increased in 57%, 21%, and 14% of soil samples, respectively.

Full straw management often increased the height of tillers and reduced tiller numbers at the end of fall regrowth. These negative impacts on crop regrowth in fall sometimes caused reductions in fertile tiller number in the following spring. Partial straw removal and flail type did not affect spring tiller production in 'Affinity' perennial ryegrass, but spring tiller production was reduced by the conventional flail with straw removal in 'Cutter' perennial ryegrass. No effect of flail type or partial straw removal on spring tiller production was observed in tall fescue.

Three types of crop yield responses to full straw management were exhibited among the species tested in our trials. Orchardgrass seed yields were never affected by full straw management during the study period (Figure 1). A second response type was characteristic of tall fescue (Figure 2) and perennial ryegrass (Figure 3). Seed yields in tall fescue and perennial ryegrass were cultivar, location, and stand age dependent. The final response type was observed in Chewings fescue (Figure 4) and Kentucky bluegrass (not shown). Chewings fescue and Kentucky bluegrass will not tolerate full straw load management as seed yields were consistently low.

Seed yields were not reduced by full straw management anytime over the stand life of 'Anthem' tall fescue, and of 'Manhattan IIE,' 'Pennant,' 'Yorktown III,' and 'Affinity' perennial ryegrass. Yield losses were recorded caused by full straw loads in older stands of 'Crewcut,' 'Rebel Jr.,' and 'Rebel II' tall fescue, and 'Linn' and 'Oasis' perennial ryegrass. Low yields resulting from no straw removal were found during the 4th seed harvest in tall fescue (Figure 2) and during the 3rd and 4th seed harvests in perennial ryegrass (Figure 3). Seed yields were low under a full straw load over the entire stand life in 'Pennfine' perennial ryegrass.

Full straw management had a different effect on tall fescue seed yield depending on location of the production field (Figure 5). Yields were reduced by full straw loads in the northern Willamette Valley earlier in the stand life (3rd and 4th seed harvests) than in the southern Willamette Valley

(4th and 5th seed harvests). Perennial ryegrass seed yield was more likely to be reduced by full straw management in the southern portion of the Willamette Valley rather than in the north.

Full straw load management or partial removal of the full straw load did not affect seed harvest in second-year stands of 'Titan' and 'Barlexas' tall fescue (Table 1). Seed yield was also not influenced by flail type. Flail type and straw removal methods did not affect seed yields in a second-year stand of 'Cutter' perennial ryegrass nor were yields affected in second- or third-year stands of 'Affinity' perennial ryegrass (Table 2). Full straw management techniques (flail types and partial vs. no straw removal) have not had any impact on seed crop performance in tall fescue and perennial ryegrass. Since the crop stands are still relatively young, it is also possible that partial removal may alleviate lower yields often evident as stands age.

Table 1. Effect of partial straw load removal and flail type on seed yield second-year stands of tall fescue. Seed yield is expressed as a percentage of the clean vacuum-sweep treatment.

| Flail type | Straw removal | Titan | Barlexas |
|---|---|---|---|
| | | --- (% of clean management) --- | |
| Straight-blade | None | 96 | 103 |
| | Partial | 97 | 109 |
| Conventional | None | 95 | 99 |
| | Partial | 94 | 104 |

Table 2. Effect of partial straw load removal and flail type on seed yield in second- and third-year stands of Affinity perennial ryegrass and in a second-year stand of Cutter perennial ryegrass. Seed yield is expressed as a percentage of the clean vacuum-sweep treatment.

| | | Affinity | | |
|---|---|---|---|---|
| Flail type | Straw removal | 2nd | 3rd | Cutter |
| | | --- (% of clean management) --- | | |
| Straight-blade | None | 99 | 102 | 100 |
| | Partial | 105 | 100 | 100 |
| Conventional | None | 102 | 101 | 102 |
| | Partial | 103 | 108 | 102 |

Seed germination was not influenced by full straw management, but seed purity was sometimes lessened by lack of straw removal. This was usually due to an increase in inert matter and was sometimes accompanied by increased percent cleanout. Seed purity and seed cleaning problems caused by full straw management tended to increase as the stand aged.

Our studies have answered some of the questions posed by growers wishing to use full straw management in grass seed fields. Significant differences in crop performance were observed among species of grass seed crops and among seed crop cultivars. While it is troubling that cultivar differences exist, cataloguing individual responses for all of the perennial ryegrass or tall fescue cultivars grown in Oregon would be exceedingly difficult. Growers must base their decision to manage a full straw load after careful consideration of several important factors. These factors include the choice of seed crop species grown, intended length of stand life, the site-specific financial requirements of the farming operation, and others.

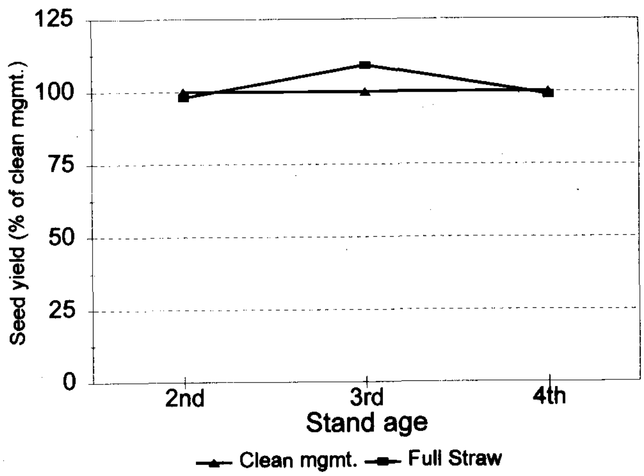


Figure 1. Influence of full straw management and stand age on seed yield in orchardgrass.

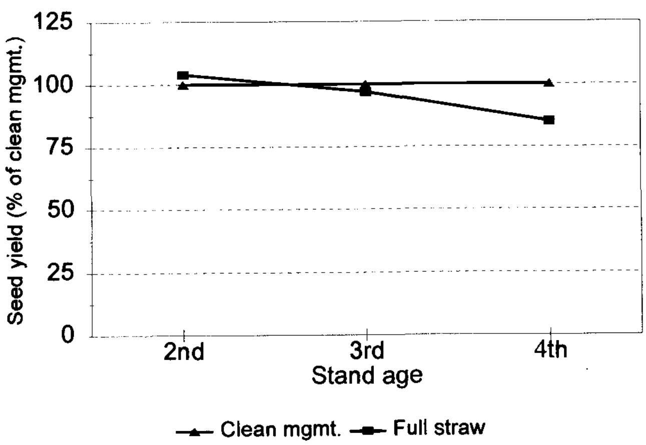


Figure 2. Effect of full straw management and stand age on seed yield in tall fescue.

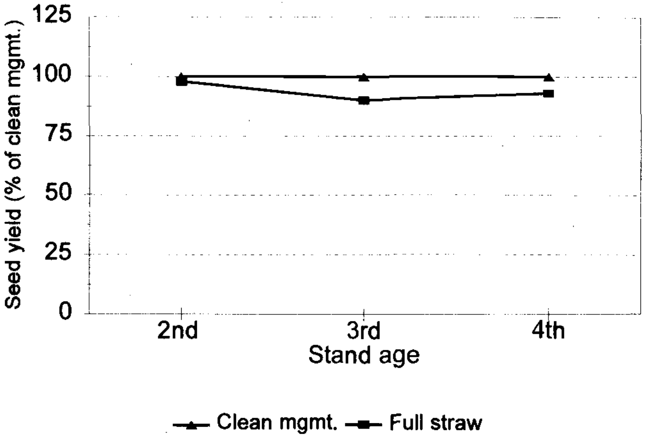


Figure 3. Effect of full straw management and stand age on seed yield in perennial ryegrass.

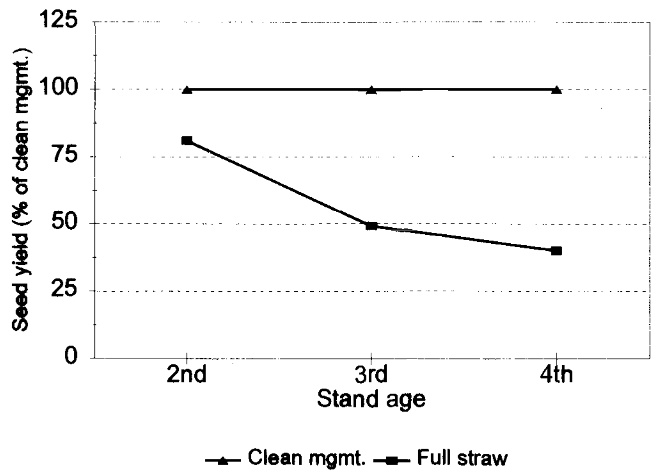


Figure 4. Influence of full straw management and stand age on seed yield in Chewings fescue.

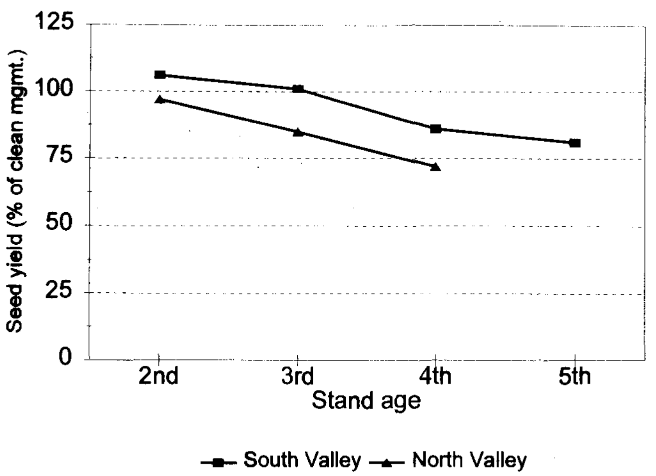


Figure 5. Effect of location and stand age on seed yield of Rebel Jr. tall fescue managed with a full straw load.

# STUBBLE MANAGEMENT FOR CREEPING RED FESCUE AND KENTUCKY BLUEGRASS SEED CROPS

*T.G. Chastain, W.C. Young III, G.L. Kiemnec, C.J. Garbacik, T.B. Silberstein, G.A. Gingrich, and G.H. Cook*

Our work to date has shown that degree of stubble removal in rhizome forming species may affect crop performance. Rhizome forming grass seed crops are perhaps the most difficult to manage without the use of fire. Our previous studies have shown that Kentucky bluegrass can only be grown without open-field burning when straw removal is thorough and stubble height is reduced. No straw and stubble practices have substituted for burning in creeping red fescue. On-farm studies were conducted over a three-year period in these two species of rhizome forming grasses to learn how stubble management influences seed crop performance and seed yields.

Trials were conducted near Silverton in two cultivars of creeping red fescue: Shademaster (1994-95) and Hector (1995-97). A similar trial was conducted near Imbler in Baron Kentucky bluegrass (1994-97). Treatments at all sites included: (i) bale + straight-blade flail (short stubble) + needle-nose rake, (ii) bale + straight-blade flail (long stubble), (iii) bale + conventional flail + needle-nose rake (short stubble), (iv) bale + conventional flail + needle-nose rake (long stubble), (v) bale + vacuum-sweep, and (vi) burn. All trials were initiated after the first seed harvest.

Our previous work suggested that fall tiller height at the end of the regrowth period is a good forecast tool for seed yield in the coming season relative to burning (Table 1). This relationship also seems to hold true in the present work. For example, when fall tiller height in the 2nd-year stand of Kentucky bluegrass was increased by low cutting height of the conventional flail, a corresponding decrease in seed yield was observed in that summer's harvest. The 3rd-year stands of Kentucky bluegrass produced seed yields that were in proportion to fall tiller height. Both cultivars of creeping red fescue followed this general pattern.

Reduction in stubble height generally caused a reduction in fall tiller height in both creeping red fescue and Kentucky bluegrass when the stubble was chopped by the straight-blade flail (Table 1). However, only in the 3rd-year stand of Kentucky bluegrass were tiller heights reduced when the stubble was cut by the conventional flail at the low height. Fall tiller height did not differ significantly among treatments in a 2nd-year stand of Hector creeping red fescue although trends in height might be related to degree of stubble removal.

Flail type and stubble removal did not affect spring tiller production in Hector creeping red fescue, but fertile tiller production was reduced by all nonthermal treatments in Shademaster. No significant differences in fertile tiller number were observed in Baron Kentucky bluegrass in 2nd-year stands, but not in 3rd-year stands. Fertile tiller production was greatest when both flail types were operated at a low stubble cutting height and when the crop was vacuum-swept after harvest.

Shademaster creeping red fescue seed yields were reduced by all nonthermal management practices in a 2nd-year stand (Table 2). Only the straight blade flail operated at low stubble height produced seed yields that were equivalent to burning in a 2nd-year stand of Hector creeping red fescue (Table 2). Overall, low stubble cutting heights were superior to high cuts for both flail types. Flail type was important in creeping red fescue as the straight-blade flail produced somewhat higher yields than the conventional flail.

Seed yields in 2nd-year stands of Kentucky bluegrass were influenced more by stubble height than by flail type (Table 2). Short stubble height tended to increase seed yields with the straight-blade flail, however, seed yields were reduced when low stubble height was achieved by using the conventional flail. All nonthermal treatments produced yields equal to or greater than burning in 3rd-year stands of Kentucky bluegrass (Table 2). Best yields in the 3rd-year stand were observed with both flail types operated at a low stubble cutting height and vacuum-sweep.

Low stubble height may be an important aspect of post-harvest management in rhizome forming grass seed crops. Our results show that highest seed yields with nonthermal management of Kentucky bluegrass and creeping red fescue will generally be obtained by reducing stubble height to less than 1.5 inches. Kentucky bluegrass seed yields with nonthermal management are equivalent to burning when stubble and straw removal is thorough, but may not be as economical as open-field burning. As in our previous trials, nonthermal management is not a reliable method for seed production of creeping red fescue.

Table 1. Influence of flail type, cutting height, and stand age on fall tiller height in creeping red fescue and Kentucky bluegrass in 1995 and 1996.

| Flail type | Stubble height | Creeping red fescue | | Kentucky bluegrass | |
|---|---|---|---|---|---|
| | | Shademaster (2nd) | Hector (2rd) | Baron (2nd) | Baron (3rd) |
| | | (cm) | | | |
| Straight-blade | High | 7.2 b† | 11.5 | 8.5 bc | 7.2 ab |
| | Low | 6.3 a | 10.8 | 7.1 a | 5.8 a |
| Conventional | High | 7.7 b | 11.2 | 8.9 bc | 10.0 c |
| | Low | 7.7 b | 11.1 | 9.3 c | 6.5 a |
| Vacuum | | 7.0 ab | 11.4 | 8.4 bc | 5.6 a |
| Burn | | 6.8 ab | 10.8 | 8.0 ab | 9.0 bc |

†Means in columns followed by the same letter are not significantly different by Fisher's protected LSD values P=0.05.

Table 2. Influence of flail type, stubble height, and stand age on seed yield in creeping red fescue and Kentucky bluegrass in 1995 and 1996. Seed yield is expressed as a percentage of the burn treatment.

| Flail type | Stubble height | Creeping red fescue: Shademaster (2nd) | Creeping red fescue: Hector (2rd) | Kentucky bluegrass: Baron (2nd) | Kentucky bluegrass: Baron (3rd) |
|---|---|---|---|---|---|
| | | (% burn) | | | |
| Straight-blade | High | 72 | 88 | 95 | 101 |
| | Low | 82 | 96 | 98 | 109 |
| Conventional | High | 63 | 87 | 100 | 96 |
| | Low | 71 | 92 | 92 | 107 |
| Vacuum | | 75 | 92 | 100 | 108 |
| Burn | | 100 | 100 | 100 | 100 |

# PHYSIOLOGICAL RESPONSES OF CREEPING RED FESCUE TO STUBBLE MANAGEMENT AND PLANT GROWTH REGULATORS

*P.D. Meints, T.G. Chastain, W.C. Young III, G.M. Banowetz and C.J. Garbacik*

**Introduction**

Residue management practices for producing creeping red fescue seed crops without open-field burning have not been identified. The development of practical and economical post-harvest residue management techniques for creeping red fescue is dependent on better understanding of the physiological nature of crop regrowth and flowering. The low yield response to nonthermal management in creeping red fescue may be directly related to how the stubble is managed after harvest. This article reports our findings and illustrates the physiological reasons for this yield loss.

**Procedure**

Field trials were conducted for the past three seasons in commercial seed production fields of 'Shademaster' and 'Hector' creeping red fescue near Sublimity, Oregon, and in research plots of 'Shademaster' and 'Seabreeze' creeping red fescue at Hyslop Farm. Shademaster and Hector are known to produce high numbers of rhizomes, whereas Seabreeze produces relatively few rhizomes. Stubble removal treatments were applied after straw was removed on plots 1 $m^2$. Open burn plots were established for each cultivar to be used as a comparison check. A gasoline-powered brush cutter was used to achieve complete stubble removal (0.0 cm stubble height). Stubble was also partially removed to 2.5 cm and 5.0 cm using a sickle-bar mower. Plant growth regulators were applied at $10^{-5}$ M and $10^{-6}$ M rates. Plant growth regulators (PGRs) are compounds that are functional analogs to hormones naturally occurring in the plant. PGRs evaluated include ethylene (Ethephon), abscisic acid (ABA), cytokinin (BA), auxin (IAA), and gibberellic acid ($GA_3$). Tiller development and population response to the stubble treatments and PGR treatments were measured on samples taken during the fall regrowth period.

Non-structural carbohydrates and other reserves were measured during the fall regrowth period to evaluate the effect of treatments on regrowth potential. This was done by placing light restricting tubes over the crop row and by measuring dry weight of the etiolated growth. Root and rhizome connections were severed before placing the tubes over the plants. Light quality (red:far-red ratio) in the regrowth canopy was measured weekly to detect changes due to stubble and new vegetative material. Measurements were taken at mid-day beginning after stubble height treatments and continued through the fall regrowth period.

**Progress**

Complete stubble removal (0.0 cm) significantly reduced tiller height. Open-burned plants tended to have shorter tillers in all cultivars than when stubble was present (Table 1). Fertile tiller production was greatest with complete stubble removal and when burned in Shademaster and Hector (high rhizome number). In Seabreeze (low rhizome number), however, fertile tiller number was greatest when the crop was burned. Fertile tiller number was reduced by all nonthermal treatments in Seabreeze. Height of fall regrowth was increased when more than 2.5 cm of stubble remained after harvest. Tiller maturity, growth stage, or vegetative biomass were not consistently influenced by stubble treatment. Stubble remaining on the field caused emerging tillers to be more etiolated than when stubble was completely removed. Stubble removal significantly reduced rhizome production allowing greater partitioning to vegetative tillers in fall and to fertile tiller development in the following spring. Rhizomes and fall tillers arise from the same crown buds during regrowth. Rhizome production was lowest when stubble was completely removed (0.0 cm) or burned.

Fall regrowth did not respond consistently to applications of plant growth regulators in any fall tiller measurements. Rhizome production was not affected by any PGR treatment (data not shown). Post-harvest application of Ethephon (ethylene source) caused reduction in fertile tiller production in older stands of Shademaster (1995) and Hector (1996), but effects were inconsistent in younger stands (Table 2). The natural production of ethylene by decaying stubble during crown bud differentiation, regrowth, and development may have a negative impact on maturation and floral induction in creeping red fescue particularly in older stands where vegetative matter is greater.

Table 2. Impact of plant growth regulators (PGR) on flowering in creeping red fescue cultivars.

| PGR treatment | Shademaster (1995) | Shademaster (1996) | Hector (1996) | Seabreeze (1996) |
|---|---|---|---|---|
| | (% Fertile tillers) | | | |
| Ethephon | 22 a* | 16 | 34 a | 20 a |
| ABA | 28 ab | 15 | 46 b | 20 a |
| BA | 23 ab | 13 | 45 b | 20 a |
| IAA | 26 ab | 16 | 43 ab | 23 ab |
| $GA_3$ | 29 ab | 15 | 44 ab | 22 a |
| No-burn (check) | 27 ab | 13 | 44 ab | 18 a |
| Burn (check) | 33 b | 16 | 53 b | 28 b |

*Means followed by the same letter are not different by Fisher's protected LSD values.

Light quality (red:far-red ratio) was measured during the first ten weeks after stubble treatments (Fig. 1). In 1996, (shaded symbols) light quality was not different for any of the treatments over the sampling period. This suggested that light quality is not affected by the presence or absence of stubble and had little impact on post-harvest tillering and development. Although presence of stubble was not significant, vegetative tillers absorbed a greater quantity of red light and transmitted or reflected more far-red light as the plant canopy neared closure. The inverted spike in red: far-red ratio at week eight may be due to large changes in canopy structure and color following an application of diuron herbicide during week six. In 1997, (open symbols) light quality again did not vary over any of the treatments. Regrowth during fall 1997 was relatively slow, hence the absorption and transmission of light were not affected by the developing plant canopy.

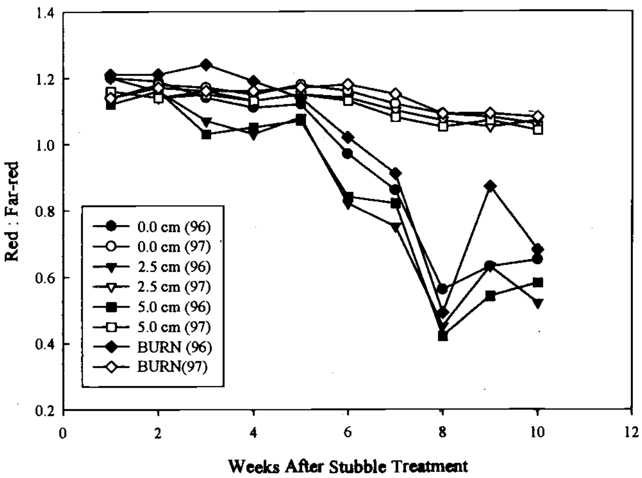


Figure 1. Changes in the red/far-red ratio for differing stubble heights in Shademaster creeping red fescue over two years.

Nonstructural carbohydrate reserves were reduced when stubble was removed without fire (0.0 cm and 2.5 cm) and when burned, but not when stubble was removed to 5.0 cm (Figure 2).

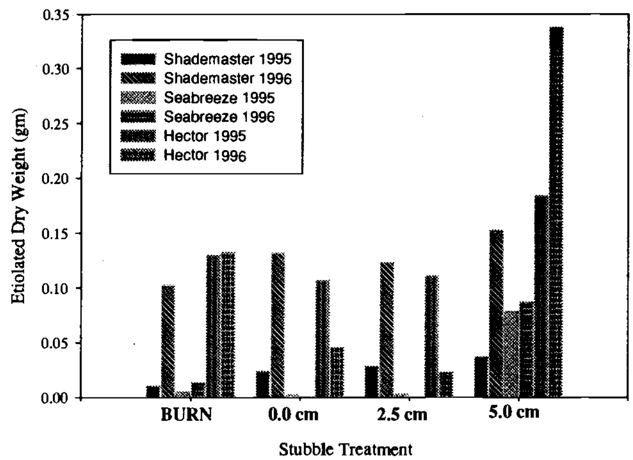


Figure 2. Carbohydrate reserves as measured by etiolated regrowth in three cultivars of creeping red fescue over two years.

Carbohydrates may be remobilized from rhizomes for use in regrowth of existing tillers and production of new tillers. The Shademaster stand was in its first year in 1996 and had limited rhizome development In 1997, the rhizome mass of Shademaster stands was greater and contributed more energy to the regrowth and production of new tillers. The

Hector stand was older and showed greater reserves as indicated by etiolated regrowth in 1996 and 1997. Seabreeze exhibited reduced carbohydrate reserves in both 1996 and 1997 except when the height of remaining stubble was greater than 2.5 cm. Carbohydrates may be remobilized from stem tissues prior to defoliation and contribute to regrowth potential in all creeping red fescue cultivars. For cultivars that form few rhizomes, stubble remaining on the field may be a significant source of carbohydrates during early tiller development. All cultivars tested had greater carbohydrate reserves available for regrowth when stubble was maintained at a height greater than 2.5 cm.

Our work demonstrates that field burning in creeping red fescue maintains seed yields by reducing stubble height, thereby allowing better crop regrowth and flowering and reducing rhizome production. While rhizome production is a desirable characteristic of the end-use quality of creeping red fescue as turf, too many rhizomes in a seed production stand can clearly have an adverse impact on flowering of the crop. How stubble removal promotes flowering and improves seed yield in creeping red fescue is not exactly known. Light quality (red:far-red ratio) was not changed by the presence or absence of stubble and does not appear to have a significant impact on tillering and development. Nevertheless, it may be possible that ethylene production by stubble can alter tiller production and development, and enhance development of rhizomes.

Table 1. Fall vegetative development and flowering responses of creeping red fescue cultivars to stubble management.

| | | Cultivar | | | |
|---|---|---|---|---|---|
| | Stubble | Shademaster | | Hector | Seabreeze |
| Trait | treatment | (1995) | (1996) | ------------- (1996) | ------------- |
| | Burn | 7.0 b* | 14.7 b | 11.2 b | 9.7 b |
| Tiller | 0.0 cm | 5.3 a | 12.7 a | 9.9 a | 8.5 a |
| height | 2.5 cm | 7.3 b | 15.3 b | 11.7 b | 11.4 c |
| (cm) | 5.0 cm | 8.0 b | 14.8 b | 11.7 b | 11.4 c |
| | Burn | 103.1 a | 24.2 a | 72.6 ab | 1.2 a |
| Rhizome | 0.0 cm | 103.1 a | 19.1 a | 59.8 a | 1.2 a |
| weight | 2.5 cm | 151.5 b | 67.5 b | 85.3 b | 30.5 b |
| ($gm^{-2}$) | 5.0 cm | 143.9 b | 56.0 b | 86.6 b | 19.1 b |
| | Burn | 32 b | 16 b | 53 b | 28 b |
| Fertile | 0.0 cm | 29 b | 17 b | 52 b | 19 a |
| tillers | 2.5 cm | 22 a | 15 a | 39 a | 21 a |
| (%) | 5.0 cm | 22 a | 13 a | 38 a | 21 a |

*Means followed by the same letter are not different by Fisher's protected LSD values.

# SOIL BIOLOGICAL, CHEMICAL, AND PHYSICAL DYNAMICS DURING TRANSITION TO NONTHERMAL RESIDUE MANAGEMENT GRASS SEED SYSTEMS

*R.P. Dick and R.A. Christ*

**Abstract**
As field burning is phased out for grass seed production, alternative nonthermal practices (e.g. straw removal or return to soils; diverse crop rotations) are being developed, but impacts of these systems on crop productivity is not well understood. At three sites in Western Oregon, the effects of these systems on soil dynamics and quality are being investigated in tandem with other agronomic factors. The most significant accomplishments were: (1) high straw inputs have increased organic matter at the 2 of the 3 sites in the first 4 years; (2) preliminary evidence that certain physical properties are improving in soils with the high straw treatment; and (3) some soil enzyme activities are the quite sensitive to short term soil management effects. In particular, β-glucosidase appears to be a precursor for organic matter accumulation because positive effects by high straw on soil biology paralleled a trend of increases in

organic carbon at two of the three sites. These methods offer potential for growers to have early predictors of long-term impacts of cropping on soil quality. Further work is in progress to relate the soil data to agronomic performance of grass seed.

**Justification**

Increased use of alternative nonthermal practices such as post harvest straw residue removal or incorporation to the soil, and crop rotations (e.g. legumes and cereals) are being developed. There is little information available on the practicality and impacts of nonthermal systems on productivity, pests and soil properties. Consequently, in 1992, the multidisciplinary 'Non-Thermal Cropping Systems Project' was initiated at three diverse sites in the Willamette Valley. Studying the effect of these new systems on soil dynamics is critical for cross comparison with parallel studies on entomology, plant pathology, and crop production. Furthermore, this provided an excellent opportunity to evaluate soil quality indexes for their potential to be sensitive discriminators of soil management effects which are needed to aid farmers as early indicators of changes in soil management.

**Procedures**

The nonthermal grass seed production study was initiated in the prime grass growing region of the Willamette Valley. The crops, soils, and sites are: 1) perennial ryegrass/Amity series (a somewhat poorly drained fine-silty, mixed clay loam,) at the Coon Farm, Linn County; 2) a turf-type tall fescue/ Woodburn series (moderately well-drained, fine-silty, mixed, loam) at Oregon State University, Hyslop Research Station, Benton County; and 3) a fine fescue/ Nekia series (well drained weathered, clayey, mixed, red hill soil) at the Jaquet Farm, Marion County. The treatments with a randomized complete block design (4 replications) at all sites are: 1) crop rotation - continuous grass seed production or grass seed rotated with a legume; and 2) residue management - *in situ* chopped straw residue (high straw return) or straw removal. Soil samples were taken to a depth of 48 inches from these plots in September of 1992 and 1994 and characterized for total C and N and extractable nutrients. In September of 1992, 1994, and 1995, the 0-4 inch and 4-12 inch depths were characterized for certain physical, chemical and biological properties. In 1995, new physical measurements included infiltration and penetrometer readings (hand-held in-field penetrometer) and a new C-fraction, particulate organic matter. The sites were fully characterized for "static" soil properties such as texture (i.e. clay, sand and silt content) and landscape position in 1992.

**Results**

<u>Chemical Properties</u> A trend that organic matter (total C) increased was noted in the 4 inch depth, from 1992 to 1995 under continuous grass seed and high straw loading at Hyslop and Jaquet Farm (Figure 1). Although total C levels decreased in 1996, the high straw/continuous grass had higher total C values than low straw treatment in the 0-4 inch depth at these same two sites. Conversely, at the Coon site that has a heavy clay soil, organic matter levels decreased among all treatments (although there was less of a decrease with high straw loading) from 1992 to 1994 in the 0-4 inch depth with slight increase in total C (organic matter) in 1995. These results show the importance of soil type and probably past field history in relation to soil response to nonthermal grass seed management options. However, longer term monitoring of these sites is needed to verify these trends.

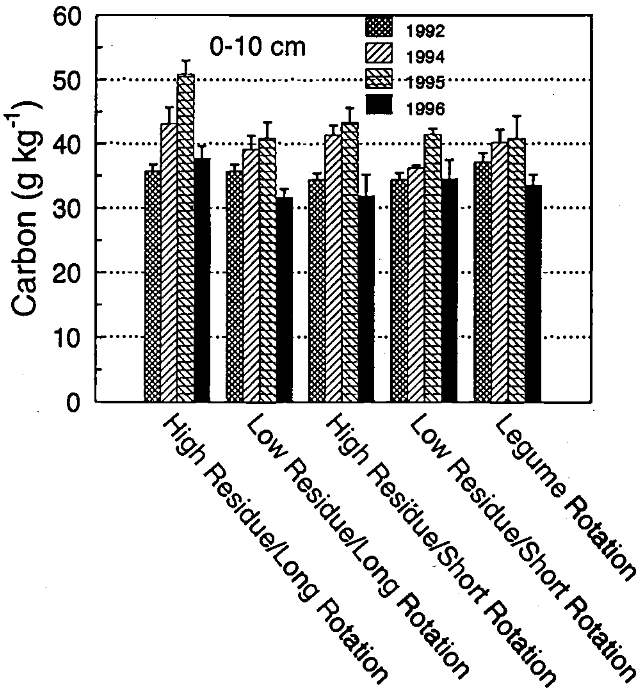


Figure 1. Total C of soils at Jacquet Farm.

The 1995 soil samples were analyzed for the light organic matter fraction (undecomposed plant and microbial debris) or more commonly called particulate organic matter (POM) by density fractionation. This was done to investigate whether POM is playing a role in the increase of total C when straw is returned to soil. From the samples taken in the fall of 1995, we found no significant treatment effect on POM. Thus it seems that the increase in organic matter noted at Hyslop and Jaquet Farm is associated with products of plant residue decomposition. However, it may be that this fraction is transient on a seasonal basis. Consequently, for the coming year we propose to do more detailed studies of various C compounds including POM during the spring and early summer season.

At the Coon and Jaquet Farm sites, again as last year, there were no significant treatment effects on soil pH. However, in contrast to last year at the Hyslop site, there was a significant treatment effect on pH where the soil under continuous grass seed with straw return had significantly higher pH (5.58 to <5.30 for the other treatments). Organic amendments could increase pH by releasing hydroxyls during decomposition and by complexing acid-forming ions such as free Al in very acid soils. This might have practical implications because returning straw to soil might reduce the expensive liming requirements for grass seed production.

Physical Properties Presumably increasing soil organic matter inputs should decrease bulk density and improve aggregate size and stability but last year we reported that neither of these properties were significantly affected by straw return or crop rotation. Because of this, we introduced two new integrative measurements of soil physical properties - infiltration and penetrometer resistance (handheld Dickey John cone penetrometer was used which provides an in-field measurement of penetration resistance). From our preliminary testing last year, we refined the infiltration apparatus by increasing the dia. from 6 to 12 inches and made it a constant head water delivery system. This greatly decreased our within-plot spatial variability and streamlined data collection.

We found the Dickey John penetrometer to be quite good at providing reproducible results and at showing differences among soil types and identifying hard pans (the drawback is that the exact reading is dependent on soil moisture so that it is not possible to get absolute values). It was unable to detect differences due to straw loading but it did show differences among different crop rotations/management systems which is shown in Figure 2. The legume/grass treatment increased resistance at all sites in the spring of 1996. Although this instrument needs more testing, we feel this has potential to be used by farmers to get a general impression of the compaction level of their soils.

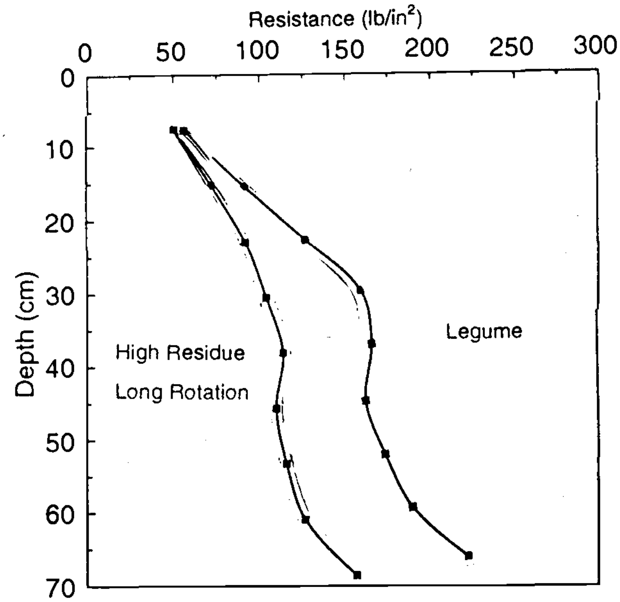


Figure 2. Pentetromenter readings at Hyslop in 1996.

Infiltration rates were sensitive to treatment effects at the Jaquet and Hyslop sites (P<0.05). Within a short or long grass seed rotation, high straw consistently showed a trend of increased water infiltration (indicating better water-holding capacity, aggregation, etc.,) at these sites.

More years of testing physical properties are needed because of the inconclusive results found so far. In the next year, we propose to use a different method for bulk density (in-field density gauge) which will improve accuracy and increase the number samples that can be taken. Furthermore, it seems important to look at aggregation during the growing season (which is being proposed for next year) because there are a few reports that there can be seasonal development and degradation of aggregates.

Biological Properties Microbial biomass C (MBC) has shown rather high year-to-year variation but continues to discriminate between treatment effects. In 1994 the legume rotation at the Coon site (Amity soil, high clay content) (which had just completed 2 yr of clover) had significantly (P<0.10) higher microbial biomass C than either high or low straw in the 0 to 4 inch depth with the low straw having the lowest MBC. Since then, at all sites the MBC tended to be the lowest in the legume/grass seed rotation. In 1995 there were trends of the higher straw input increasing microbial biomass C, but it was less evident than previous years which may be due the extremely dry period prior to sampling. At the Coon and Jaquet farms continuous grass with high straw has consistently had the highest MBC in the 0-4 inch depth. At the Hyslop site there has been consistent trend of increased MBC with high straw loading.

Enzyme analysis of the samples taken in 1994 showed that amidase, protease, and FDA hydrolysis were relatively insensitive to treatment effects. β-glucosidase, dipeptidase and, to a lesser extent arylsulfatase and acid phosphatase activities were sensitive in discriminating between treatment effects. β-glucosidase (Figure 3), had the best correlation with C inputs from straw and seems to be a precursor for organic matter increases noted this year. This provided encouraging evidence that this enzyme might be a good integrative biological index of soil quality.

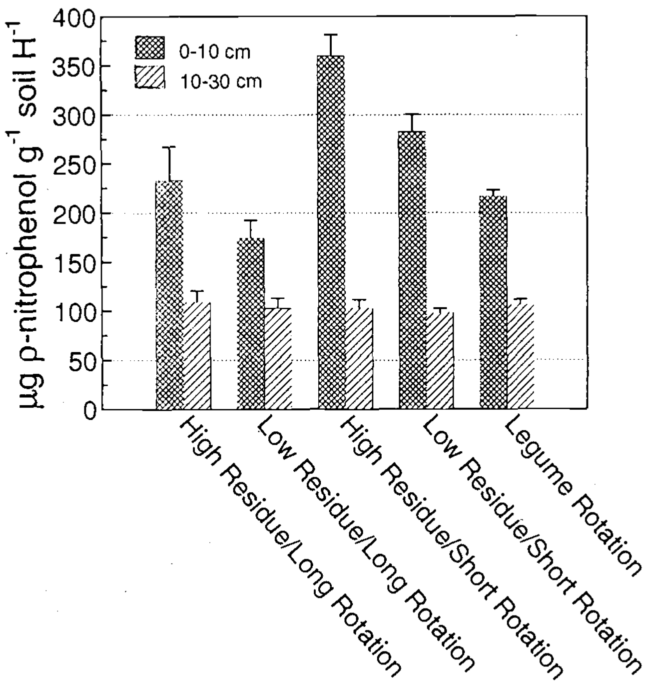


Figure 3. Soil enzyme activity at Hyslop in 1995.

Relationship of Soil Properties to Agronomic Data We have integrated grass seed and biomass yields from 1993 to 1995 with soils. Preliminary correlations showed a significant correlation of grass seed yield and biomass with penetrometer readings (r=-0.71*** and -0.65***, respectively). Clover biomass and seed yields were significantly correlated with biological parameters.

# SLUG POPULATIONS IN GRASSES GROWN FOR SEED

*G.C. Fisher, J.T. DeFrancesco and R.N. Horton*

## I. Effects of Annual Ryegrass Cropping System

Annual ryegrass has been produced for years in the Willamette Valley with post harvest open field burns and/or plowing used as standard practices in establishing the next season's annual ryegrass seed bed. As this basic pattern has shifted to cropping systems that incorporate alternate grasses, legumes or new crops with increased frequency within a field, post harvest residue management in these same fields is also evolving from a system reliant solely on open field burns and/or plowing to non-thermal means of straw management such as bailing, flailing or vacuum sweeping. Concurrently, conservation tillage and no-till systems of field management are being adopted with increasing speed.

A change of farming practices is often accompanied by a corresponding change in insect, mite and slug pests–their population structure and role as pests.

The Crop and Soil Science department has a number of on-farm sites demonstrating effects of cropping system and residue management on production of seed, crop growth, stand characters and weed management over successive seasons. We have used one such site, Smith Farms, Shedd OR, to study the effects and interactions of cropping system (tillage, seeding and volunteer crop management) and residue management on slug populations. Gray garden slug and marsh slug are the two species encountered in annual ryegrass production of western Oregon. Tremendous differences in slug numbers and damage to the crop are noticed from field to field by producers of the commercial crop. Below we describe the practices and their effects on slug numbers during the 1996-1997 season.

The treatments included: (1) plowing and conventional seeding, (2) spraying off sprouts and then no-till drilling, and (3) volunteer crop establishment (without sprout spray or seeding). In addition, imposed on each cropping system treatment was a post harvest residue management system of either full straw (flailed and left in the field) or straw baled and removed, and stubble flailed. Each plot is 25 ft. x 50 ft., and replicated three times in a randomized block experimental design.

Slug populations were determined using open bait stations consisting of three metaldehyde bait pellets per station, with three bait stations within each treatment in each replicate. Number of slugs visiting each bait station was recorded 24 hours after each baiting episode, approximately weekly, between mid-October 1996 and mid-February 1997. Due to unfavorable slug conditions (freezing temperatures, wind, flooding) number of slugs could not be determined for some weeks during the fall and winter.

Results and Discussion

How the annual ryegrass stand was established in the fall (cropping system) had a greater effect on slug population than did how post harvest residue was managed (Table 1). Plowed plots, with or without straw residue, had the fewest number of slugs. Plots established with volunteer seedlings had the greatest number of slugs. A simple explanation for these observed differences may be due to presence and availability of food source for the slugs. September and October is a critical time of renewed slug activity. Plots with volunteer seedlings generally have the most growth, and therefore food, at this time of year. Feed availability and quality is critical to an expanding slug population.

Table 1. Effects of annual ryegrass cropping system and post harvest residue management on slug populations, Smith Farms, Shedd, OR, 1996-1997.

| Cropping system | Residue management | Total number of slugs per plot |
|---|---|---|
| Plow + conv. seeding | Full straw | 2.9 ab[2] |
| | Baled and removed | 0.7 a |
| No-till drill + sprout spray | Full straw | 22.4 ab |
| | Baled and removed | 27.1 bc |
| Volunteer crop | Full straw | 50.5 cd |
| | Baled and removed | 56.2 d |

[2] Means followed by same letter do not differ significantly by Fisher's protected LSD (P=0.05)

In this experimental design, slugs are also more likely to migrate towards the plots with lush growth, which provides ample food and cover, and allows for successful feeding and reproduction. The individual plot size in this experiment must be considered when interpreting these results and extrapolating to field-size situations.

There were no statistically significant interactions between cropping system and post harvest residue management system. Table 2 presents mean number of total slugs for cropping system and residue management system. Statistically significant differences in slug populations occurred within the three cropping systems (Table 2).

Table 2. Effects of annual ryegrass cropping system and post harvest residue management on slug populations, Smith Farms, Shedd, OR, 1996-1997.

| | Number of slugs per plot[1] |
|---|---|
| Sowing method | |
| Drill | 1.8 a[2] |
| No-till | 24.8 b |
| Volunteer | 53.4 c |
| Residue removal | |
| Bale | 28.0 |
| No removal | 25.3 |

[1] Total number per plot from nine evaluation dates
[2] Means followed by the same letter do not differ significantly based on Fisher's protected LSD (P=0.05)

During this study, no differences in number of slugs occurred between plots where the straw was baled and removed and plots that had full straw left in the field. Lack of significant differences may suggest that there are more critical factors than post harvest straw management affecting slug populations, such as weather and soil conditions. Also, the narrow plots in this experiment allow for rapid migration by slugs from one plot to the next, creating quite a large opportunity for error in interpreted results.

**II. Effects of Post Harvest Residue Management**

Trials were established in tall fescue (Koos Bros., Lebanon, OR) and perennial ryegrass (Stellmacher, Albany, OR) to determine the effects of post harvest crop residue management practices on slug populations. Treatments at both sites included plots that were either baled and vacuumed or were flailed and the straw left in the field. Each plot was approximately 25 ft. x 400 ft. and replicated three times in a randomized block experimental design. Slug populations were determined as per method described in Section I of this report.

Results and Discussion

In both fields, there was no statistically significant differences in slug populations due to residue management technique. The trend was for slightly fewer slugs in the plots where post harvest straw had been baled and vacuumed (Tables 3 and 4). Again, differences may by due to the fact that the plots are narrow and slugs migrated between plots. Interestingly, previous observations indicated that a greater number of slugs are found with increased post harvest straw load. This difference in results from one year to the next may be a function of weather, particularly amount and time of precipitation, and its influence on slug activity and availability of food and cover.

### III. Effects of Grass Species on Slug Population

Different grass species grown in the Willamette Valley appear to experience different degrees of slug problems. The differences can be due to the micro-climate or soil type on which the different grasses are grown, or they may be due to differences in the grasses themselves.

Four different grass species, two cultivars each, growing side by side under the same micro-climate and soil type at OSU's Hyslop Research Farm were monitored for slug populations. Each plot is 115 x 150 feet.

Slug populations were determined using the methods described in Section I of this report; however, evaluations for this trial began in mid-September 1996 and continued until mid-February, 1997.

<u>Results and Discussion</u>

As plots are unreplicated, statistical analysis of the effects of grass species on slug population could not be performed. However, there appears to be differences in slug population between grass species (Table 5).

Table 5. Effects of grass species on slug population, Hyslop Farm, 1996-1997

| Grass species and cultivar | Total number of slugs [1] |
|---|---|
| Chewings fescue | |
| SR 5100 | 137 |
| Jamestown II | 49 |
| Creeping red fescue | |
| Shademaster | 95 |
| Seabreeze | 97 |
| Perennial ryegrass | |
| Affinity | 144 |
| Buccaneer | 105 |
| Tall fescue | |
| Fawn | 150 |
| Rebel II | 192 |

[1] Total number of slugs per plot from fourteen evaluation dates

The Chewings fescue cultivar Jamestown II had from two to four times fewer slugs than any of the other cultivars. This could be an indication that Jamestown II provides less desirable food and/or habitat for slugs; however, the low slug counts in this plot may be more attributable to environmental conditions. The Jamestown II plot is located in the wettest part of the field and experiences saturated conditions more often than the other plots. Slugs do not tolerate saturated soil conditions very well and would be more likely to not establish or migrate out of the plot under such circumstances.

**Summary and Conclusions**

The trials described in Sections I and II were conducted on plots previously established by the grower and the department of Crop and Soil Science. In retrospect, this design served the agronomic aspects under study very well. Unfortunately, the narrowness of these plots very likely allowed easy access of slugs to adjacent plots. Slugs can travel over 20 feet in the course of being above ground while searching for food. Interpretation of experimental results must be done with migration as an overriding factor in these trials.

Results of studies reported here, as well as ongoing and previous trials, can be used to explain some of the key factors in annual ryegrass production that influence slug populations. Plowing, quite simply put, destroys slugs and is an extremely effective method to manage slugs. Shallower tillage also can contribute to slug mortality, by crushing individual slugs and destroying soil structure critical to subsurface survival and movement. However, there is a critical depth to which the soil must be disturbed to effect any control. Very shallow tillage, as used for weed control purposes, can create problems because slug populations are not impacted at this shallow depth. Additionally, the soil has been disturbed and the structure thus created often allows gray garden slugs to feed undetected under the soil surface, destroying swelling seeds and very young seedlings prior to appreciable emergence.

On the other extreme, no-till establishment favors optimum slug populations by allowing soil structural integrity to remain undisturbed. Volunteer seedlings used to establish a new crop in the fall provide an early, abundant and excellent food source for slug populations establishing in the fall. However, if these are removed by herbicide to accommodate a direct seeded crop, all subsequent feeding activity is shifted to the few plants that emerge in the row.

Table 3. Effects of post harvest residue management on slug populations in tall fescue, Koos Bros., Lebanon, OR, 1996-1997.

| Treatment | Number of slugs per plot observed between October 24 and February 12 | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 10/24 | 10/31 | 11/7 | 11/14 | 11/21 | 12/13 | 1/10 | 1/24 | 1/29 | 2/12 | Total |
| Bale + Vac | 6.5 | 7.8 | 15.0 | 12.7 | 9.7 | 17.5 | 18.2 | 1.7 | 5.2 | 2.4 | 96 |
| Full straw | 9.7 | 5.2 | 22.3 | 13.8 | 5.7 | 16.2 | 19.7 | 1.9 | 9.4 | 4.1 | 108 |

Table 4. Effects of post harvest residue on slug population, perennial ryegrass, Stellmacher, Albany OR, 1996-1997.

| Treatment | Number of slugs per plot observed between October 24 and February 12 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10/24 | 10/31 | 11/14 | 11/21 | 12/13 | 1/10 | 1/24 | 1/29 | 2/12 | Total |
| Bale + Vac | 17.0 | 9.2 | 11.8 | 5.3 | 10.8 | 33.3 | 7.9 | 12.5 | 14.5 | 122 |
| Full straw | 15.7 | 10.0 | 10.8 | 5.3 | 17.0 | 28.9 | 5.7 | 18.1 | 14.3 | 126 |

# GENETIC DIVERSITY OF ANNUAL BLUEGRASS IN WESTERN OREGON GRASS SEED CROPS

*G.W. Mueller-Warrant, L.W. Mengistu, and R.E. Barker*

Annual bluegrass (*Poa annua* L.) is a common weed wherever cool-season turf grasses are grown. Its presence as a contaminant in grass seed is arguably the most serious weed problem facing grass seed growers worldwide. Recent reductions in field burning in the Pacific Northwest and cancellations of registrations for older herbicides have created increased reliance on the several remaining registered herbicides for annual bluegrass control in grass seed crops. Not unexpectedly, biotypes of annual bluegrass resistant to two widely used herbicides, diuron and ethofumesate, have now become serious threats to the continued production of *Poa*-free grass seed. Cool-season grass seed production and reports of herbicide resistant annual bluegrass are concentrated in the Willamette Valley of Oregon. We therefore conducted a survey of the genetic diversity of annual bluegrass in this region to learn more about this weed. Our long range goal is to modify old and develop new seed production and weed control practices that will prolong our ability to control this species by delaying the advent and minimizing the extent of resistance to herbicides and cultural weed control practices. The genetic diversity was assayed using random amplified polymorphic DNA (RAPD) markers on individual seedlings collected in a structured survey.

A total of 1578 2-leaf stage annual bluegrass seedlings were collected from 10 grass seed production fields in the Willamette Valley from early fall 1994 through early spring 1995. Two of the 10 fields were further subdivided on the basis of post-harvest residue management treatments (two at Hyslop and six at Bowers) imposed annually since 1992, creating a total 16 sampling sites. Permanent plots were marked in the fields, and young seedlings were collected from the same general area at each site in three collection periods (early fall 1994, early winter 1994/95, and early spring 1995), creating a total of 47 populations (no new seedlings were found in the spring at Glaser's meadowfoam, probably due to use of Prism herbicide). Seedlings were transferred to the greenhouse and grown until fresh leaves were harvested for DNA extraction. DNA was then amplified using polymerase chain reaction (PCR) methods, and separated as bands (DNA profiles or genetic 'fingerprints') on polyacrylamide gels. Gels were scored for the presence or absence of 18 bands, and usable data were obtained for 1357 of the samples, yielding a total of 496 distinct banding patterns or haplotypes. A variety of techniques were used to display and interpret the enormous data set, including dendograms (genetic trees) and molecular analysis of variance (AMOVA). Data were statistically analyzed using a nested design testing for significance of sampling sites versus the whole population, collection dates within sites, and collections versus the whole population. We also subdivided the data into two groups (Bowers and all other sites) to explicitly test the effects of the six residue management treatments at Bowers. Simple descriptive statistics were used to characterize genetic diversity across sites.

Dendograms and other plots of the entire data set, or large subsets of it, were extremely complex and difficult to interpret. Individuals from any particular site were scattered over large portions of the trees or plots. Large numbers of equally valid trees were produced by the programs, and tree nodes were often highly branching. For example, the 49 individuals possessing the single most common banding pattern were found at 10 of the 16 sites and in 19 of the 47 collections. Our general interpretation of the trees was that the annual bluegrass population possessed substantial genetic diversity, only a small fraction of which might be potentially attributed to sites or collection dates within sites. Examination of trees for samples collected from individual fields suggested the presence of small, although apparently significant effects of collection date within sites. For example, a minimum spanning tree of the Hyslop data was examined for the tendency of individuals at the same or adjacent nodes to have come from the same collection date, and this was found to be statistically significant. However, it was also obvious that the tendency of a given type to germinate in the fall, winter, or spring was seldom, if ever, absolute. Some genetic exchange would probably occur between types even if all of the individuals germinating in fall, winter, or spring could be prevented from cross pollinating with individuals germinating in other time periods by effective herbicide treatments, other cultural practices, or natural plant maturation and senescence.

A simple analysis of the frequency of occurrence of more than one individual with the same haplotype at a site revealed some interesting differences among the populations from the 10 fields. At Hyslop, a diuron-susceptible site, 82.1% of the individuals were needed to represent all of the types found there, and the single most common type only accounted for 5.4% of the plants (Table 1). A similar degree of genetic diversity was found at Bowers, a diuron-resistant site, for all six residue management treatments. In contrast, at Manning's full straw load chop field, the proportion of plants needed to represent all of the banding patterns dropped to only 37.9%, while the single most common type accounted for 18.4% of the total population. Annual bluegrass in Glaser's meadowfoam field, like Manning's full straw field, was also less diverse than at Hyslop, and dominated by relatively few haplotypes. Genetic diversity at most of the other sites was intermediate between that at Hyslop and Bowers' and that at Manning's full straw and Glaser's.

AMOVA conducted over all 16 sites revealed the presence of statistically significant differences among sites, among collection dates within sites, and within collections (Table 2). However, approximately 88% of the total variance fell within the individual collections, quantifying our findings from the dendograms that the diversity existing within collections was much greater than that associated with sites or collection dates within sites. The variance among sites was about 50% larger than the variance among collections within sites. When data from the Bowers' field were analyzed separately, the six residue management treatments that had been imposed for three consecutive years prior to our sampling had no effect on the genetic structure of the annual bluegrass population. The within collections and among collection dates within residue treatment components were highly significant. Indeed, the among collections within residue treatments component was much larger at Bowers, where it averaged nearly 9% of the variance, than at the other 10 sites, where it averaged only 2% of the variance. Similar results were obtained between two residue management treatments at Hyslop. Interesting results were obtained when we split the data into the 184 most commonly occurring haplotypes (those found in more than one individual in the whole population) and the 312 least common (unique) types. Variance among sites increased to over 10% for the most common types, while it decreased to under 4% for unique types. Variance among collection dates was unchanged by splitting data into the most common and least common groups. The within collections correlation was 45% lower for the unique types than for the most common types, although still achieving high statistical significance.

Upon reflection, these results make biological sense. The most common haplotypes are, by definition, those doing best as weeds in grass seed production fields. These most common types show strong differences among sites because each field has had a unique history of selection pressure and weed seed importation, creating its own unique mix of successful, dominant types. In contrast, the least common types are those not faring as well under current grass seed production practices. These least common types have weaker effects of site and represent the background population diversity in Willamette Valley annual bluegrass, the gene pool from which the more successful types have arisen. The stability of the among collection dates within sites component suggests that weed control selection pressure has not isolated the fall, winter, and spring germinating cohorts.

It is almost certain that the most abundant biotypes germinating in commercial seed production fields are those that have tolerated the herbicide and residue management practices previously imposed by growers. However, we did not measure the specific herbicide resistance or susceptibility of individual plants collected in this study, and it is likely that some susceptible plants remain in the soil seed bank in all cases. We are now looking for genetic markers to distinguish between herbicide susceptible and resistant individuals. If we succeed in finding markers that do classify annual bluegrass plants as resistant or susceptible to diuron and other herbicides with a high degree of fidelity, this tool would be extremely useful in the study of gene flow between resistant types and the diverse background population. However, even without such a tool, our new knowledge of the genetic diversity of Willamette Valley annual bluegrass should help us formulate more effective strategies for managing this weed.

Several major implications for managing annual bluegrass resistance are apparent. First, the high degree of genetic diversity present in Willamette Valley annual bluegrass, both in fields resistant and susceptible to herbicides such as diuron, guarantees that we will have a hard time regaining control of this weed. Second, because collection date (and therefore germination date) is only a very minor barrier to gene flow, survival traits selected for in any single event will have a good chance of recombining with those selected for at other times. This cross pollination (gene transfer) can occur in subsequent years (and crops) when different biotypes in the soil seed bank germinate, establish, and reproduce, or even within the same growing season if niches exist for later flushes of the weed. Because severe crop injury in the fall or winter can create those very niches, it is important to avoid excessive crop injury (unless you want to worsen your annual bluegrass problems). Third, because there are genetic differences between sites, it is important to minimize the transport of annual bluegrass seed between fields by sanitizing equipment, covering truck loads of seed, confining and destroying weed seeds at the cleaning plant, and planting only *Poa*-free seed stock. To a considerable degree, the herbicide resistant annual bluegrass in each field is unique, and our problems will only worsen if we share biotypes (and genes) between fields.

Table 1. Annual bluegrass haplotype class distributions by site.

| Site where annual bluegrass seedlings were collected | Individuals collected per site | Distinct haplotype per site | Single most common haplotype | Most common N haplotypes (N = √ no. of distinct types) |
|---|---|---|---|---|
| | (number) | ---------- (% of each site's population) ---------- | | |
| Bowers, 6 residue trt. avg. | 75 | 84.9 | 4.4 | 24.0 |
| Hyslop, 2 residue trt. pooled | 56 | 82.1 | 5.4 | 27.8 |
| McLagan Pugh Rd. | 119 | 71.4 | 6.7 | 30.6 |
| McLagan Belle Plain | 120 | 61.7 | 5.8 | 32.3 |
| Glaser per. rye. | 114 | 61.4 | 6.1 | 32.5 |
| Manning, bale/flail/rake | 108 | 57.4 | 12.0 | 37.6 |
| George Pugh, tall fescue | 110 | 60.0 | 10.0 | 38.4 |
| George Pugh, per. rye. | 97 | 55.7 | 9.3 | 44.4 |
| Glaser meadowfoam | 80 | 50.0 | 17.5 | 55.0 |
| Manning, full straw chop | 103 | 37.9 | 18.4 | 58.0 |
| Bowers, pooled data | 450 | 57.3 | 2.7 | 25.0 |
| All sites, pooled data | 1357 | 36.6 | 3.6 | 34.3 |

Table 2. Hierarchical analysis of molecular variance on distance matrices for annual bluegrass haplotypes.

| Variance component | Observed partition | | Probability[1] | Φ-statistics[2] |
|---|---|---|---|---|
| | Variance | % total | | |
| among sites | 0.161 | 7.51 | <0.001 | 0.075 |
| among collections within sites | 0.104 | 4.84 | <0.001 | 0.052 |
| within collections | 1.887 | 87.64 | <0.001 | 0.123 |

[1] Probability of more extreme variance component than observed value by chance alone, based on 1000 random permutations of the data matrix.
[2] Φ-statistics denote the average correlation between individuals within a group relative to that for randomly chosen individuals from the whole population.

## TREATMENT OF DIURON-RESISTANT ANNUAL BLUEGRASS IN A PERENNIAL RYEGRASS SEED CROP

*G.W. Mueller-Warrant*

Annual bluegrass is one of the worst weeds confronting grass seed growers in the Willamette Valley. Its presence in harvested seed complicates seed cleaning and reduces crop value if seed cannot be cleaned to *Poa*-free status. Growers treat established perennial grass stands each fall with various herbicides, including diuron, oxyfluorfen (Goal), metolachlor (Dual), and metribuzin (Sencor/Lexone), in attempts to control volunteer crop seedlings and many other species, including annual bluegrass. While currently registered treatments generally provide good to excellent control of the volunteer crop, they often perform poorly on other weed species, particularly annual bluegrass. It is useful to view annual bluegrass as both a weed control problem and as a symptom of other problems. Annual bluegrass is a problem when its presence reduces crop yield and contaminates the harvested seed. It is also a problem when it gains resistance to herbicides such diuron and ethofumesate (Nortron), chemicals which formerly allowed growers to establish virtually *Poa*-free stands using carbon band planting and maintain them in *Poa*-free condition for many years through a combination of field burning and herbicide treatment. However, development of herbicide resistance is also a symptom of reliance on too few chemicals for too many years and under use of effective crop rotations. High populations of annual bluegrass are also symptoms of other problems, including poor stands, low crop vigor, and excessive herbicide injury, all factors creating ecological niches for annual bluegrass in the soil seed bank to germinate and establish in grass seed fields.

Some growers who have recently adopted full straw chop residue management for perennial ryegrass have reported decreases in annual bluegrass. However, they have been simultaneously adjusting their herbicide treatment program to reduce crop injury, leaving questions of whether, and why, they have a less severe annual bluegrass problem unresolved. We therefore studied the response of herbicide-resistant annual bluegrass in an established perennial ryegrass stand near Tangent, Oregon, to a wide range of weed control treatments, including registered and experimental herbicides, shallow tillage using an offset rotary hoe, and straw disturbance with a straight blade flail and a rotary tedder, using full straw load chop and vacuum sweep residue management. Some of the herbicides were applied through the flail on October 2 in an attempt to get them down to the soil underneath the straw. We applied 24 treatments in full straw load plots and repeated four of these in vacuum sweep conditions. The field was a poorly drained site in its second year of production. Annual bluegrass and volunteer perennial ryegrass ground cover between the crop rows were measured March 13, 1996, and 5 ft. wide by 55 ft. long areas in each plot were harvested July 11, 1996. Data are presented as treatment means in Table 1 and in logical contrast groups in Table 2.

Ground cover in the untreated (no herbicide and no mechanical disturbance) checks was 26% volunteer perennial ryegrass and 16% annual bluegrass in full straw, and 4% volunteer crop and 18% annual bluegrass in vacuum sweep (Table 1). Averaged over four common herbicide treatments, vacuum sweep had 80% less volunteer perennial ryegrass and 44% less annual bluegrass (Table 2). Nearly all treatments provided good control of volunteer perennial ryegrass, with all but four of them exceeding 90% control. None of the 28 treatments (25 herbicides and 3 checks) achieved better than 75% control of annual bluegrass. Indeed, a majority of them <u>increased</u> annual bluegrass ground cover compared to the untreated full straw check. The presence of volunteer perennial ryegrass was suppressive to annual bluegrass, and annual bluegrass ground cover doubled when volunteer crop seedlings were removed by treatments such mechanical disturbance without herbicides (tedding October 16 followed by rotary hoeing November 14). Annual bluegrass density increased even more when herbicide treatments injured the crop and opened up the canopy, reaching 49% ground cover for 0.25 lb/a Goal plus full rate diuron (1.6 lb ai/a) applied through the flail on October 2. However, the lower rate of Goal plus diuron (0.12 + 1.2 lb/a) was a useful treatment when it followed PRE Prowl or Goal plus Dual, reducing annual bluegrass ground cover to one half the value for the PRE treatment alone (11.0 vs. 22.5% cover). Clearly a significant fraction of the annual bluegrass population at this site remained sensitive to Goal plus diuron, and the high density of annual bluegrass in plots treated with high rates of diuron represents the combined effect of survival by the most resistant annual bluegrass plants and the creation of new niches for annual bluegrass by the serious crop damage.

Annual bluegrass control improved with increasing rate of Prowl applied through the flail October 2 and followed by tedding October 16 and rotary hoeing November 14. Annual bluegrass ground cover for 3 lb/a Prowl in this mechanically disturbed treatment was reduced to 25% of the cover at 1.5 lb/a, and to 14% of the cover for mechanical disturbance without any herbicide. The effects of post-emergence mechanical disturbance (tedding on October 16 followed by rotary hoeing on November 14) varied with species and herbicide treatment: volunteer crop control improved with mechanical disturbance both with and without PRE Prowl, whereas annual bluegrass control improved with mechanical disturbance with PRE Prowl, but worsened in the absence of Prowl (ground cover increase significant at the $P$=10% level). Prowl tended to be more effective on volunteer perennial ryegrass when it was incorporated under the straw by flailing during spraying or tedding after spraying than when it was surface broadcast. Method of application had little effect on performance of Prowl on annual bluegrass. The biological control agent XcP (*Xanthomonas campestris*) was ineffective when applied as a broadcast spray, despite making a total of four applications between March 7 and April 29. Standing water prevented use of the roller during the early applications, and continued rainfall and cool weather during the later applications may have interfered with efficacy of infection. (Performance of XcP in a separate study at Hyslop Crop Science Research Farm was also quite discouraging.)

Surface broadcast application of 0.25 lb/a Goal + 1.5 lb/a Dual on Oct. 2 provided control of annual bluegrass and volunteer perennial ryegrass similar to that from 2.0 lb/a Prowl through the flail. However, Goal + Dual caused greater crop injury, reducing perennial ryegrass clean seed yield by an average of 203 lb/a. The Roundup row spray treatment also reduced yield significantly compared to the average of all other herbicide treatments, although it did provide 75% control of annual bluegrass. The presence of areas of standing water when plots were row sprayed may be partly at fault for the crop injury from Roundup. Application of 0.25 lb/a Goal plus 1.6 lb/a diuron on November 9 reduced perennial ryegrass seed yield by 194 lb/a compared to October 2 application. Tank-mixing of Prowl, Goal, and 1.6 lb/a diuron on October 2 caused serious crop injury, and this tank-mix applied through the flail reduced seed yield by 212 lb/a compared to normal (broadcast surface) application of Goal+diuron without Prowl on October 2. The highest yielding individual treatment was 2.0 lb/a Prowl through the flail on October 2 followed by 0.12 lb/a Goal plus 1.2 lb/a diuron on November 16. However, this treatment only reduced annual bluegrass ground cover by 38% relative to the untreated check.

Overall, our treatments resulted in a wide range of annual bluegrass density and perennial ryegrass injury. Selecting the 10 herbicide treatments in full straw load that caused the least crop injury, an inverse relationship between annual bluegrass ground cover and perennial ryegrass seed yield was apparent (Figure 1). Increasing annual bluegrass density in the range between 13 and 42% ground cover reduced crop seed yield by 198 lb/a. Clearly, annual bluegrass was capable of seriously competing with perennial ryegrass for resources. However, since many treatments can directly reduce perennial ryegrass seed yield through crop damage (and may even increase total annual bluegrass ground cover), we need to be cautious in our choice of treatments for attempted control of this weed. The practical limit for annual bluegrass control from treatments tested in this study was approximately 75% control relative to treatments that controlled only the volunteer crop. Registration of Prowl (possibly by fall 1998) will improve control that perennial ryegrass seed growers can obtain of diuron-resistant annual bluegrass. However, growers will still have to limit the aggressiveness of their total weed control program to treatments that cause only minimal crop injury if they wish to achieve the maximum practical annual bluegrass control.

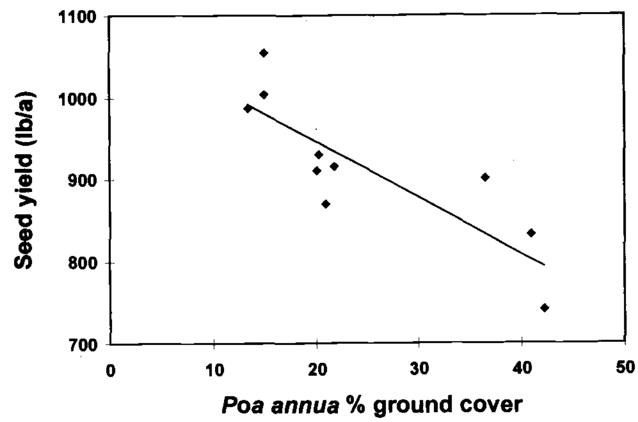


Figure 1. Relationship between perennial ryegrass seed yield and annual bluegrass ground cover of 10 herbicide treatments in full straw load residue management. Yield = 1084 - 6.87 x percent ground cover, $R^2$ = 70.8%, $P$ = 0.002. Treatments #5, 7, 9, 10, 12, 13, 14, 15, 19 and 20 are graphed.

Table 1. Annual bluegrass and volunteer perennial ryegrass ground cover, March 1996, and perennial ryegrass seed yield, July 1996, Tangent, Oregon.

| Treatments and application dates, 1995-96 growing season† | Annual blue-grass | Perennial ryegrass Volunteer seedling | Perennial ryegrass Crop seed yield |
|---|---|---|---|
| ---------------------------(herbicide rates in lb/a)--------------------------- | (% ground cover) | | (lb/a) |
| Untreated check | 16.1 | 25.7 | 878 |
| 1.5 Prowl:flail Oct. 2 / tedder Oct. 16 / rotary hoe Nov. 14 | 18.4 | 0.8 | 908 |
| 2.0 Prowl:flail Oct. 2 / tedder Oct. 16 / rotary hoe Nov. 14 | 8.1 | 0.6 | 894 |
| 3.0 Prowl:flail Oct. 2 / tedder Oct. 16 / rotary hoe Nov. 14 | 4.6 | 0.5 | 832 |
| 2.0 Prowl:flail Oct. 2 | 18.9 | 3.0 | 930 |
| 2.0 Prowl:flail Oct. 2 / tedder Oct. 16 / rotary hoe Nov. 14 (=# 3 + XcP) | 14.3 | 1.2 | 930 |
| 2.0 Prowl:flail Oct. 2 / 0.25 Goal+1.6 diuron Nov. 9 | 18.7 | 2.2 | 910 |
| 2.0 Prowl+0.25 Goal+1.6 diuron:surface Oct. 2 | 19.2 | 0.5 | 850 |
| 2.0 Prowl:flail Oct. 2 / 0.12 Goal+1.2 diuron Nov. 16 | 10.0 | 1.6 | 1055 |
| 2.0 Prowl:flail Oct. 2 / 0.25 Goal+0.8 diuron Nov. 9 / 0.12 Goal+0.8 diuron Dec. 7 | 16.8 | 2.2 | 869 |
| 0.25 Goal+1.6 Diuron:flail Oct. 2 | 48.9 | 0.5 | 876 |
| Flail-only Oct. 2 / 1.44 Prowl:surface+tedder Oct. 16 | 19.6 | 1.4 | 915 |
| Flail-only Oct. 2 / 1.44 Prowl:surface+tedder Oct. 16 / 0.12 Goal+1.2 diuron Nov. 16 | 13.0 | 0.8 | 987 |
| 2.0 Prowl:surface Sept. 26 / 0.12 Goal+1.2 diuron Nov. 16 | 14.2 | 3.9 | 1004 |
| 0.25 Goal+1.5 Dual:surface Oct. 2 | 30.6 | 1.0 | 901 |
| 0.25 Goal+1.5 Dual:surface Oct. 2 / 0.12 Goal+1.2 diuron Nov. 16 | 10.1 | 0.2 | 680 |
| 2.0 Prowl+0.25 Goal+1.6 Diuron:flail Oct. 2 | 18.2 | 0.8 | 782 |
| 0.25 Goal+1.6 Diuron:surface Oct. 2 | 28.2 | 1.7 | 994 |
| Flail-only Oct. 2 / 0.25 Goal+1.6 diuron Nov. 9 | 31.2 | 2.5 | 741 |
| Flail-only Oct. 2 / 0.25 Goal+0.8 diuron Nov. 9 / 0.12 Goal+0.8 diuron Dec. 7 | 39.2 | 4.2 | 832 |
| Flail-only Oct. 2 / tedder Oct. 16 / rotary hoe Nov. 14 | 33.2 | 1.0 | 836 |
| Roundup row spray Dec. 21 | 5.9 | 1.6 | 569 |
| VS untreated check | 18.0 | 4.0 | 734 |
| VS / 1.44 Prowl:surface+tedder Oct. 16 / 0.12 Goal+1.2 diuron Nov. 16 | 5.7 | 0.3 | 852 |
| VS / 2.0 Prowl:surface Sept. 26 / 0.12 Goal+1.2 diuron Nov. 16 | 5.6 | 0.0 | 887 |
| VS / Roundup row spray Dec. 21 | 2.8 | 0.5 | 664 |
| Flail-only Oct. 2 / 1.44 Prowl:surface+tedder Oct. 16 (# 12 + XcP) | 22.4 | 2.2 | 753 |
| Flail-only Oct. 2 / 1.44 Prowl:surface+tedder Oct. 16 / rotary hoe Nov. 14 | 11.7 | 0.9 | 973 |

†VS=Vacuum sweep performed on Sept. 26, 1995. All other treatments were full straw load chop, which was performed on October 2, 1995, after rake tedding to dry out the straw. Herbicides were applied normally to surface of soil or straw except where flail indicates they were applied through a boom mounted under the baffles on a Rear's straight-blade flail. XcP indicates *Xanthomonas campestris* was applied on March 7, March 18, April 5 and April 29, 1996.

Table 2. Treatment contrasts for annual bluegrass and volunteer perennial ryegrass ground cover, March 1996, and perennial ryegrass seed yield, July 1996, Tangent, Oregon.

| Treatment comparisons and contrasts (herbicide rates in lb/a) | Annual bluegrass | Volunteer perennial ryegrass | Perennial ryegrass seed yield |
|---|---|---|---|
| | -------(% ground cover) ------ | | (lb/a) |
| Full straw load chop (4 treatment average) | 11.6 b† | 4.0 b | 860 a |
| Vacuum sweep (4 treatment average) | 6.5 a | 0.8 a | 784 a |
| | | | |
| Prowl or Goal+Dual PRE/0.12 Goal+1.2 Diuron Nov. 16 | 11.0 a | 0.8 a | 907 a |
| Prowl or Goal+Dual PRE/No herbicide Nov. 16 | 22.5 b | 1.7 a | 915 a |
| | | | |
| 2.0 Prowl:surface Sept. 26 / Goal+1.2 Diuron Nov. 16 | 14.2 a | 3.9 b | 1004 a |
| 2.0 Prowl:flail Oct. 2 / Goal+1.2 Diuron Nov. 16 | 10.0 a | 1.6 ab | 1055 a |
| 1.44 Prowl:surface+tedder Oct. 16 / Goal+1.2 Diuron Nov. 16 | 13.0 a | 0.8 a | 987 a |
| | | | |
| No Prowl:flail Oct. 2 / tedder Oct. 16 / rotary hoe Nov. 14 | 33.2 c | 1.0 ab | 836 a |
| 1.5 Prowl:flail Oct. 2 / tedder Oct. 16 / rotary hoe Nov. 14 | 18.4 bc | 0.8 a | 908 a |
| 2.0 Prowl:flail Oct. 2 / tedder Oct. 16 / rotary hoe Nov. 14 | 10.8 b | 0.9 a | 912 a |
| 3.0 Prowl:flail Oct. 2 / tedder Oct. 16 / rotary hoe Nov. 14 | 4.6 a | 0.5 a | 832 a |
| 2.0 Prowl:flail Oct. 2 | 18.9 bc | 3.0 b | 930 a |
| | | | |
| 2.0 Prowl Oct. 2 & no other herbicides | 14.3 a | 1.7 a | 921 a |
| 2.0 Prowl Oct. 2 & various Goal+1.6 Diuron treatments | 18.2 a | 1.3 a | 853 a |
| No Prowl Oct. 2 & no other herbicides | 23.2 ab | 6.3 b | 857 a |
| No Prowl Oct. 2 & various Goal+1.6 Diuron treatments | 36.0 b | 1.9 a | 861 a |
| | | | |
| 2.0 Prowl+0.25 Goal+1.6 Diuron:surface Oct. 2 | 19.2 ab | 0.5 a | 850 ab |
| 2.0 Prowl+0.25 Goal+1.6 Diuron:flail Oct. 2 | 18.2 a | 0.8 a | 782 b |
| 2.0 Prowl Oct. 2 / 0.25 Goal+1.6 Diuron Nov. 9 | 18.7 a | 2.2 a | 910 ab |
| 0.25 Goal+1.6 Diuron:surface Oct. 2 | 28.2 ab | 1.7 a | 994 a |
| 0.25 Goal+1.6 Diuron:flail Oct. 2 | 48.9 b | 0.5 a | 876 ab |
| | | | |
| 0.25 Goal+0.8 Diuron Nov. 9 / 0.12 Goal+0.8 Diuron Dec. 7 | 39.2 b | 4.2 b | 832 ab |
| 0.25 Goal+1.6 Diuron Oct. 2 | 37.2 b | 1.0 a | 935 a |
| 0.25 Goal+1.6 Diuron Nov. 9 | 31.2 ab | 2.5 ab | 741 b |
| No herbicide | 16.1 a | 25.7 c | 878 ab |
| | | | |
| Rotary hoe Nov. 14 - Prowl applied earlier | 11.3 a | 0.9 a | 942 a |
| No cultivation - Prowl applied earlier | 19.9 b | 2.3 b | 882 a |
| Rotary hoe Nov. 14 - No Prowl | 33.2 b | 1.0 ab | 836 a |
| No cultivation - No Prowl | 16.1 ab | 25.7 c | 878 a |
| | | | |
| 0.25 Goal+1.5 Dual:surface Oct. 2 / Goal+1.2 Diuron or no POST | 17.7 a | 0.6 a | 790 b |
| 2.0 Prowl:flail Oct. 2 / Goal+1.2 Diuron or no POST | 13.8 a | 2.2 a | 993 a |
| | | | |
| Roundup row spray | 4.1 a | 1.0 a | 616 b |
| All other herbicide treatments, surface or flail applied | 15.9 b | 1.2 a | 885 a |

†Means followed by the same letter within a group of treatment comparisons do not differ at the *P*=0.05 level for ground cover and at the *P*=0.10 level for seed yield. Ground cover values separated using log transformed data.

# HERBICIDE BANDING IN GRASS SEED CROPS

*D.M. Gamroth, B.D. Brewster and C.A. Mallory-Smith*

Annual bluegrass has been confirmed resistant to many herbicides currently used in grass seed production. Among the herbicides that annual bluegrass is resistant to are: Karmex (diuron), Nortron (ethofumesate), Lexone or Sencor (metribuzin), and Sinbar (terbacil). One way to control annual bluegrass in these problem fields is to use herbicides that have modes of action that have not been used extensively in grass seed production.

Two trials were conducted southeast of Corvallis to evaluate the practicality of banding non-selective herbicides in perennial ryegrass seed production. In both trials, a single-wheel, compressed-air plot sprayer was used to deliver 50 gpa at 22 psi. An unshielded boom was used and a 4-inch-wide band was sprayed between each row. Row spacing was 12 inches at the Tangent site and 14 inches at the Shedd site. The perennial ryegrass crop was 2 to 6 inches tall and the annual bluegrass was emerging to eight tillers at the time of application.

Ignite (glufosinate, 1.67 lb ai/gal) is a herbicide by AgrEvo that is faster than Roundup (glyphosate, 3 lb ae/gal) and slower than Gramoxone Extra (paraquat, 2.5 lb ae/gal) in speed of symptom appearance. Ignite also translocates less than Roundup, therefore not injuring perennial plants as severely. The Command ME (clomazone, 3 lb ai/gal) is a micro-encapsulated formulation of Command herbicide that FMC has marketed for years as an emulsifiable concentrate.

The annual bluegrass control was very good to excellent with Ignite, Roundup, and Gramoxone Extra at the Tangent site (Table 1). Crop injury and weed control were lower at the Shedd site, which may have been affected by the wider crop row spacing (Table 2). The Command ME did not improve control of annual bluegrass at either site compared to using the other herbicides alone. This experiment will be repeated in the 1996-97 crop year.

Table 1. Visual evaluations of seedling perennial ryegrass injury and annual bluegrass control at Tangent.

| Treatment[1] | Rate (fl oz/A) | Perennial ryegrass injury[2] | Annual bluegrass control[2] |
|---|---|---|---|
| Ignite | 57.5 | 3 | 95 |
| Roundup | 32 | 7 | 96 |
| Gramoxone Extra | 32 | 20 | 98 |
| Command ME | 43 | 0 | 23 |
| Ignite + Command ME | 53.5 + 43 | 0 | 90 |
| Roundup + Command ME | 32 + 43 | 17 | 93 |
| Gramoxone Extra + Command ME | 32 + 43 | 17 | 100 |
| Check | -- | 0 | 0 |

[1]Treatments applied December 7, 1995; R-11 non-ionic surfactant added to all treatments @ 1 qt/100 gal.
[2]Evaluated February 22, 1996.

Table 2. Visual evaluations of established perennial ryegrass injury and annual bluegrass control at Shedd.

| Treatment[1] | Rate (fl oz/A) | Perennial ryegrass injury[2] | Annual bluegrass control[2] |
|---|---|---|---|
| Ignite | 38 | 0 | 70 |
| Roundup | 32 | 3 | 78 |
| Gramoxone Extra | 26 | 3 | 57 |
| Command ME | 21 | 8 | 37 |
| Ignite + Command ME | 38 + 21 | 0 | 57 |
| Roundup + Command ME | 32 + 21 | 3 | 77 |
| Gramoxone Extra + Command ME | 26 + 21 | 7 | 70 |
| Check | -- | 0 | 0 |

[1]Treatments applied February 14, 1996; R-11 non-ionic surfactant added to all treatments @ 1 qt/100 gal.
[2]Evaluated April 17, 1996.

# ANNUAL RYEGRASS STRAW FOR PAPER PULP: STRAW HANDLING AND PRE-PROCESSING RESEARCH

*L.R. Schweitzer*

A multi-faceted project was initiated in 1994 to explore and develop the use of grass seed straw as a supplemental fiber for paper pulp production. The Weyerhaeuser Company launched, administered and implemented the project, as well as provided the major resources. The Oregon Department of Agriculture (ODA), using field burning fees, along with Oregon State University and United States Department of Agriculture, using Alternative Agriculture Research and Commercialization (AARC) funds, helped sponsor the project.

Phase I objectives explored a number of variables related to straw production, gathering, handling and storage, and their influence on straw and pulp quality. Phase II objectives focused on pre-processing the straw and developing "straw chip" quality parameters for mill-gate delivery. Phase III activities, still in process, encompass developing and implementing pulping processes in a pilot pulping plant.

A closely integrated overriding objective for the entire project was to determine the economic feasibility of using grass straw as a supplemental fiber source. Economic considerations included straw value on the farm, harvesting a 12-month supply in a 1-month time window, storage of a 1.5-year supply, pre-processing capital/expense, transportation, overall logistics, energy use, pulp mill capital/expense, waste disposal, and potential by-product markets.

This report summarizes results only for Phase I & II objectives relating to straw handling and pre-processing. Cooperators and collaborators in the project included several Willamette Valley grass seed growers; straw handlers and exporters (Gerald Phelan Inc., Steffen Systems, Anderson Hay and Grain Co. Inc.); Oregon State University and Extension personnel (Crop & Soil Sciences, Ag Chemistry, Forestry Dept.); Oregon Department of Agriculture; and several other research and service providers (Seed Tech Plus, M.D. Kauffman Soil Scientist, et. al.).

**Concerns and Questions about Straw and Fiber Quality**

Initial concerns regarding several factors relating to straw and their potential effects on pulping quality included:

- Fines and dirt contaminants
  - influence on pulping process, quality, economics
- Straw moisture content
  - heating, spontaneous combustion
  - discoloration, fiber quality
  - economics of baling (extended baling hours)
- Straw harvest procedures
  - influence on above factors and economics
- Wax and silica content
  - effects on pulping, equipment, chemical recovery
- Soil type and fertility
  - effect on silica content, fiber quality
- Plant population in the field
  - influence on node size, fiber quality
- Ryegrass variety
  - difference in fiber or pulping quality
- Rust infection
  - influence on storage, color, pulping quality

**Straw Production, Harvest and Storage**

<u>General Procedures</u>

In the summer of 1994 annual ryegrass straw was collected from ten different fields involving eight different seed growers, five annual ryegrass varieties, and several straw harvesting variables. Locations ranged north to south from Albany to Cresswell, and east to west from Lebanon to Bellfountain. Crop and management practice histories were obtained for all of the fields. Soil samples collected from six primary fields were analyzed for pH, nutrient, and silica content in order to relate to potential differences in straw or pulping quality.

Normal straw harvest procedures (Control Treatment) were to rake the straw into windrows, bale, stack and transport to storage as soon as possible after seed combining was completed. The 3-tie bales typically weighed 105-110 lb. with a density of 10-11.5 lb./cu. ft., and moisture content from 9-11%. In most cases a full 56-bale block of 3-tie bales was produced by Gerald Phelan Inc. for each treatment variable. These blocks were then stored in Phelan's storage barns for later evaluation and processing. Some were stored for a full two years.

At baling time, before the bales were stacked into blocks, five or six bales from each experimental unit were measured for weight, size (length, width, depth), moisture content (5 probes with a Delmhorst bale moisture tester), and core sampled (two 3/4 x 15 in. cores per bale) for chemical analysis of wax content.

Sample bales from each experimental block were examined by Weyerhaeuser research personnel and tested for fines, dirt, color, silica and fiber quality. OSU Ag Chemistry determined wax content in the core samples collected at baling time and after storage. OSU Forest Products Dept. conducted pulping trials on selected samples. To control costs, not every parameter was measured for each experimental treatment.

Field and Straw Handling Treatments and Objectives

The following list briefly summarizes basic experimental treatments and their proposed objectives. The high-interest treatments of "Rake high" and "High moisture baling" were conducted in three different fields, always in direct comparison to a "Control" in the same field. Most of the other treatments occurred in only one field each.

- Control (standard procedure: combine spreader, rake low, bale at 9-12% MC)
- No rake (bale from combine drop)
  - less fines and dirt, eliminate raking expense
- Rake high (4-5" off ground)
  - less fines and dirt in final product
- Combine chopper, then bale
  - improve bale density and transport economics
  - eliminate chopping step at pre-processing
- Forage chopper, no baling
  - compare handling of chopped vs baled product
  - eliminate chopping step at pre-processing
- Delayed baling
  - exposure effect on straw quality, wax content
- High moisture baling (14-20 %)
  - effect on storage, heating and straw quality
  - extend baling hours
- Low density bale
  - effect on straw quality, pre-processing
- Soil type (Red-Hill and Gumbo clay vs. Typical valley soils)
  - influence on fiber quality, silica content
- High vs. low stand population
  - effect on node size, pre-processing, fiber quality
- Rust infection
  - effect on storage, color, fiber quality

**Field and Harvest Effects on Straw and Fiber Quality**

Field and harvest procedure variables were not as critical as first expected. Variations in straw harvest procedures did not significantly influence straw or fiber quality. Neither soil type, fertility or silica content consistently affected straw fiber quality or silica content. One variable of interest not encountered in 1994 was exposure to rain before baling. However, exposure of one field to a month of normal weathering before baling did not negatively affect straw quality.

**Baling at High Moisture Content**

Four 56-bale blocks of straw were produced by baling earlier in the morning before the dew had completely dried from the windrow. Moisture contents (MC) of the resulting bales averaged 14.2%, 15.9%, 18.0% and 20.2% for the different blocks and fields. Experience at baling time indicated that about 20% MC was the maximum that could be forced through the 3-tie Freeman baler, even with chute tension fully released. Normal baling moisture was usually in the 10-12% MC range.

Electronic data loggers were placed in the blocks at time of bale pick-up in the field. Combination temperature/RH (relative humidity) loggers were placed between bales in the center of the block for two stacks. Temperature loggers with two sensors were placed in four other blocks so that one sensor was located near the edge of the stack and the remote sensor placed near the center of the 56-bale block. Unfortunately, the logger placed in the block baled at normal moisture content of 10-11% was damaged and the data lost.

Figures 1 through 3 show typical temperature and RH patterns of straw baled at three different MC over a one-year storage period. Results can be summarized as follows:

- No heating resulted from baling annual ryegrass straw at moisture up to 20%.
- Humidity within a block stayed fairly constant throughout the 6-month storage period for both blocks that were monitored. However, RH averaged about 13% higher for the straw baled at 18% MC (Figure 2) versus straw baled at 14% MC (Figure 1).
- As expected, bale temperature fluctuation in storage was much greater at the edge of a stack than in the center (Fig. 3).
- Moisture content for all bales, no matter what the original moisture at baling time, equilibrated to around 13% during storage.
- No differences in external appearance were apparent between standard and high moisture bales.

However, some differences were observed in physical characteristics of 'high moisture' bales. Straw baled at higher moisture retained its higher density throughout the two-year storage period even though moisture content eventually equilibrated to the same level as straw baled at the normal 10-12 % MC range. Baling damper straw apparently caused a more permanent crimping of the straw stems and some loss of resiliency and decompression upon releasing string tension. This phenomenon should have little or no effect on straw pre-processing or chip quality. In addition, the absence of any discoloration, mold/mildew development or other evidence of deterioration in straw baled at the higher moisture levels reduces concerns about moisture content at baling time.

Apparently, standard practices for determining suitable moisture for baling straw should provide adequate safeguards for straw storage and final pulping chip quality. This study showed that straw can be baled at moisture levels up to the limits of what a 3-tie baler can physically handle, without causing problems with heating or deterioration in storage. Based on pre-processing experiences, there is probably more potential concern about bales gaining moisture from weather exposure or from the ground during storage than from being baled at higher moisture content.

It should be noted that these studies used 3-tie 100 lb. bales. Although no major differences might be expected with the larger 1-ton bales, it would be wise to confirm these results using the large bales.

**Straw Pre-Processing**

In order to provide a useable clean "chip" product for actual pulping and paper production, the baled straw must be chopped to shorter lengths, and freed of excess node material as well as dirt and fines. A pilot pre-processing plant with a capacity of producing 50 tons of straw "chips" per day was built in the agricultural community at a straw storage facility. This pilot pre-processor has been operating more or less continuously for nearly a year producing straw "chips" for Weyerhaeuser's pilot straw pulping plant operation.

A key component of the pre-processing operation is to reduce the node content in the "chip" product. Grass nodes contain very little useable cellulose fiber for paper making and can cause dark spots or other imperfections in the final paper product.

Extensive research was conducted to remove node material efficiently, and develop a quality testing and assurance program for straw "chips". A special disc milling system was implemented to grind the majority of nodes into finer particles that could be removed by screening or were of less concern for pulping. Many trials were conducted to optimize the mill parameters to achieve maximum node reduction without unduly shredding of the straw "chips" or reducing milling capacity.

Figure 4 illustrates the increase in node content with widening of the disc mill plate gap setting. Whole nodes are the intact nodes that escape destruction and remain in the final "chip" product. Problem nodes include whole nodes plus larger node fragments that could pose potential problems in the pulping process.

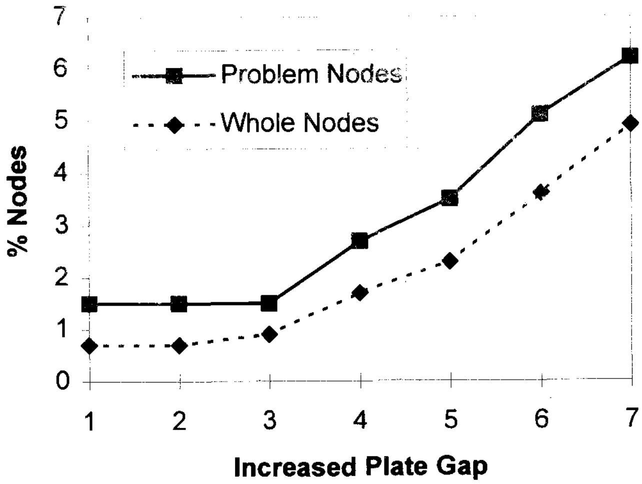


Figure 4. Disc mill plate gap versus node reduction.

After exploration and consideration of several options, a multi-deck oscillating screen was chosen for removing dirt, fines and the pulverized node material in the final step of the pre-processing operation. This screening machine has proven very efficient for the final cleaning of the straw "chips". Exploration of potential uses for the fine reject material is underway.

**Conclusions**

1. Field and harvest procedure variables were not as critical as first expected. Straw harvesting and storage procedures typically used in producing high quality straw for the export market should be adequate for straw destined for paper pulping.
2. Straw moisture content up to 20% at baling time did not create heating, subsequent deterioration or loss of fiber quality in annual ryegrass straw bales, at least for 3-tie bales used in these studies. Moisture gain during bale storage from exposure to rain, condensation or wet floors is probably a greater concern than moisture content at baling.
3. Pre-processing straw to shorten segment length, reduce node content and remove dirt and fines is essential for providing a useable, high quality fiber source for the paper industry. Various procedures and equipment may be available to accomplish these objectives.

*Acknowledgments: This research project was sponsored by the Weyerhaeuser Company. Partial support was provided by ODA and USDA.*

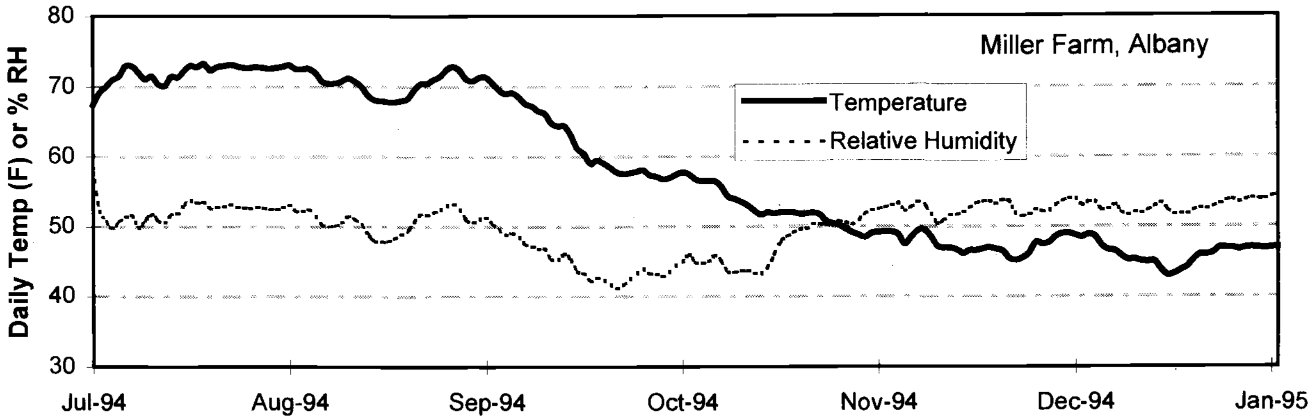


Figure 1. Temperature and relative humidity at center of bale stack; annual ryegrass straw baled at 14.2% MC.

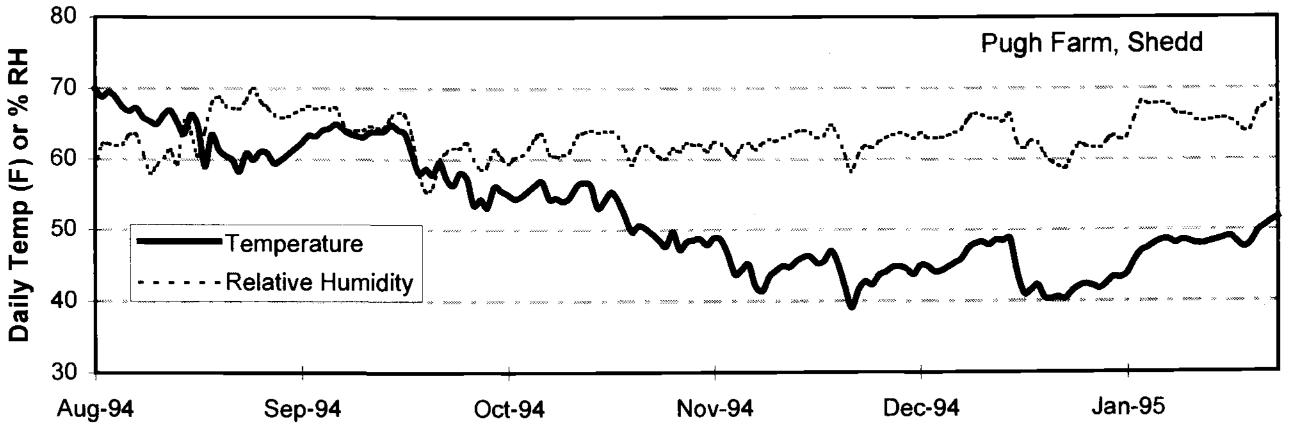


Figure 2. Temperature and relative humidity at center of bale stack; annual ryegrass straw baled at 18.0% MC.

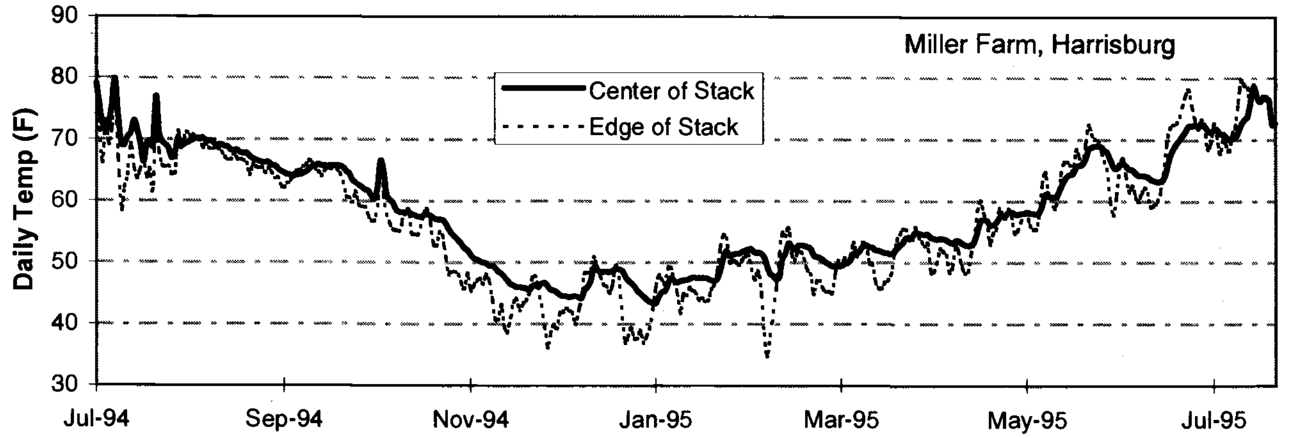


Figure 3. Bale stack temperature (inside and outer edge); annual ryegrass straw baled at 20.2% MC.

# EFFECT OF RECYCLED PAPER RESIDUE SOIL AMENDMENT (RPR) ON RYEGRASS SEED YIELDS

*M.E. Mellbye*

Recycled Paper Residue (RPR), a by-product of the paper making process, has been applied as a soil amendment to grass seed fields in the southern Willamette Valley. The material contains the equivalent of 11 - 14% 100-score lime, and applied free of charge, is an inexpensive liming material. High rates of application, however (up to 50 ton/a), have been reported to reduce seed yields - especially on wetter soil types. This study was conducted to determine the effect of moderately high RPR rates (35 ton/a) on the seed yield of intermediate ryegrass.

The RPR material was applied in September, 1995, to two fields on the David Malpass Farm near Harrisburg, Oregon. The rate of application was 35 ton/a. The fields were planted to two similar varieties of intermediate ryegrass (Froghair and Transtar ) which are similar to annual ryegrass in appearance, growth, and management.

Fields selected for this study included one with a poorly-drained soil type (Dayton silty clay loam), and one with a moderately well-drained soil (Malabon silt loam). In each field, a 100 ft x 400 ft plot was left untreated, while RPR was broadcast on the rest of the ground. The untreated plot was located to facilitate good side-by-side comparisons. The entire field, treated and untreated, was cultivated and seeded in an identical manner. Because of the high C:N ratio of the RPR amendment, supplemental N fertilizer (urea) was applied before planting (40 lb N/a) in mid-September and again after crop emergence (45 lb N/a) in early November by Agri-Tech, Inc. of Oregon to treated portions of each field. In the spring 1996, an additional 33 lb N/a was applied to the Malabon site because it had received RPR with a higher average C:N ratio (114:1) compared to the Dayton site (average C:N ratio of 79:1). In the spring, fertilizer (120 lb N/a) and spray programs were applied uniformly to all plots by the farm cooperator.

Soil samples were taken in the fall, spring, and late summer. Whole plant samples were taken in late June, just prior to swathing, to measure biomass production, nutrient levels in the plant, and nutrient uptake. These were obtained by cutting three 36 inch paired row sections. The whole plant biomass samples were replicated 3 times, with the sampling sites arranged for a paired-T comparison. Soil and plant samples were analyzed at the OSU Central Analytical Laboratory, or at KUO Testing Labs, Inc. Plots were swathed and combined by Malpass Farms. The OSU Crop and Soil Science Department weigh wagon was used to measure bulk seed weight harvested from each plot. Clean seed yields were calculated from percent cleanout of samples taken at harvest from the bulk seed. Five windrows ("replicates"), each 400 ft long, were taken from each treatment.

Clean seed yields of 1760 to 2160 lb/a were obtained from plots in this study (Tables 1 and 2). These are acceptable yield levels for intermediate ryegrass varieties. Application of the RPR product at 35 ton/a reduced seed yield roughly 12% in each field. The yield reduction averaged across the two fields was about 270 lb/a. Soil drainage did not appear to influence the yield response in this trial. Biomass at swathing was also reduced on soil amended with RPR, indicating reduced growth occurred during the spring. The plots treated with the paper by-product did in fact appear to be stunted in the spring, although as swathing time approached, visual differences between treated and untreated areas were not apparent.

Application of the RPR amendment increased soil pH and Ca levels (Table 3). It was an effective liming material. The by-product did not increase soluble salts, Na, or B to levels that would cause a problem for plant growth. Low nitrate-N concentrations following application in the fall showed that the high C:N ratio product tied up available soil N (Table 4). This was compensated for by extra fertilizer N in the fall, and again in spring 1996 for the Malabon site.

Soil tests in the spring (April 9, 1996) showed low nitrate-N levels on both treated and untreated plots (Table 4). This was expected because at this time of year grass plants are actively growing and rapidly taking up nitrates. Ammonium-N levels, however, were higher in the treated plot, indicating that available nitrogen was not going through the nitrification process to nitrate. My observation at the time of sampling was that the ground treated with RPR was wetter than the untreated plot. This would account for the higher ammonium levels. It is common in the spring on grass seed fields to find high ammonium levels in poorly growing areas that are very wet. The fertilizer N is there, but it cannot convert to the more available nitrate form without oxygen. Roots need oxygen too, and while ryegrass plants survive the winter on very wet soils, they do not grow well in the spring on ground that remains saturated. Prolonged saturated conditions through the critical growth period probably contributed to reduced plant growth and reduced seed yield.

High C:N ratio materials like RPR can immobilize N and S in the soil making them unavailable to plants, and this appeared to occur in the fall following incorporation of the by-product. The N and S content in the plants, total N uptake, and C:N ratio of the ryegrass biomass from treated plots at swathing, however, showed they were not deficient in N or S at the end of the growing season (Table 1 and 2). While nutrient immobilization earlier in the season may explain some of the reduced growth and yield reduction, this data suggests it was probably not the only problem. In fact, both N and S levels were higher on treated plots, and total N uptake tended to be higher where RPR was applied, presumably as a result of the supplemental N program applied by Agri-Tech Inc. of Oregon. Phosphorus, potassium, calcium, and magnesium levels in the plants also were not reduced by application of RPR; in fact, concentration and uptake tended to be greater on treated plots (Table 1 and 2).

Soil tests after harvest showed higher nitrate-N levels on the treated plots than on the untreated area (Table 4). Higher levels at this time could be due to mineralization of N from RPR and/or from delayed nitrification of ammonium-N. Both of these process would be enhanced as the soil dried out.

The average seed yield reduction in this trial was 270 lb/a. At $0.20 per lb, this was a loss of $54 per acre. The RPR material applied an equivalent of over 3 tons per acre of 100-score lime. Lime currently costs $50 per acre applied in the southern Willamette Valley. Thus the RPR provided a minimum value of $150 per acre of lime, and soil tests showed this was an effective lime source (i.e., it increased soil pH and Ca rapidly after being disked in). If seed yields are only depressed the first season following application, this is a beneficial trade-off for farmers. Fall growth of the subsequent ryegrass crop, planted in the fall of 1996, looked good. In contrast to boiler fly ash, a non-traditional liming material that is high in adsorptive carbon, RPR did not appear to reduce the effectiveness of soil applied herbicides.

Reduced rates of RPR amendment could be used to minimize or eliminate potential yield reductions. Acceptance by the farm community would be improved if the risk of yield reductions could be largely eliminated, and lower rates of application of RPR could be selected that would still meet a grass seed farmers lime requirements. Seed yields will be obtained from these plots in 1997 to determine if yields are affected beyond the season of application.

*Acknowledgment: Appreciation is extended to Tom Malpass and the staff at David Malpass Farms for helping conduct this trial, particularly the field harvest, and to Tom Silberstein, OSU Crop and Soil Science Department, for helping with the harvest and providing the OSU weigh wagon. This research was supported in part through funds from Agri-Tech Inc. of Oregon.*

Table 4. Soil N levels in the fall, spring, and after harvest in the summer on fields treated with RPR amendment in September, 1995.

| RPR ton/a | Soil N Test | Date 10/30/95 | 4/9/96* 3/15/96 | 8/7/96 |
|---|---|---|---|---|
| Poorly-drained field - Dayton | | | | |
| 0 | NH4-N (ppm) | 6.1 | 9.3 | 8.8 |
| | NO3-N (ppm) | 17.9 | 1.7 | 8.7 |
| | Total N (%)[1] | na | na | 0.2 |
| 35 | NH4-N(ppm) | 25.4 | 27.8 | 11.0 |
| | NO3-N (ppm) | 10.9 | 0.7 | 22.0 |
| | Total N (%) | na | na | 0.2 |
| Well-drained field - Malabon | | | | |
| 0 | NH4-N (ppm) | 9.3 | 8.8 | 8.3 |
| | NO3-N (ppm) | 21.5 | 2.6 | 6.9 |
| | Total N (%) | na | na | 0.2 |
| 35 | NH4-N (ppm) | 9.3 | 7.9 | 11.2 |
| | NO3-N (ppm) | 2.7 | 1.7 | 9.1 |
| | Total N (%) | na | na | 0.2 |

na = not analyzed
* Malabon site sampled 3/15/96;
Dayton site sampled 4/9/96
[1]Total N determined by Kjeldahl extraction.

Table 1. The effect of RPR on seed yield and nutrient content of Froghair intermediate ryegrass, on a poorly drained soil (Dayton silt loam), David Malpass Farm, 1996.

| RPR | Clean seed yield (8/6/96) | Biomass at swathing (Dry wt.) | N Uptake | Nutrient content of whole plant (%) N | S | P | K | Ca | Mg | C:N ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| (ton/a) | (ton/a) | (ton/a) | (lb/a) | ---(%)--- | | | | | | |
| 0 | 2030 | 3.66 | 69 | 0.96 | 0.15 | 0.12 | 0.33 | 0.22 | 0.097 | 46 |
| 35 | 1760 | 2.90 | 81 | 1.39 | 0.19 | 0.16 | 0.44 | 0.45 | 0.120 | 32 |
| *t*-test | NS | NS | NS | * | * | * | NS | * | * | |

NS = Not significant.
*Statistically significant at the 10% probability level ($P<0.10$).

Table 2. The effect of RPR on seed yield and nutrient content of Transtar intermediate ryegrass on a moderately well-drained soil (Malapon silt loam), David Malpass Farm, 1996.

| RPR | Clean seed yield (8/6/96) | Biomass at swathing (Dry wt.) | N Uptake | Nutrient content of whole plant (%) N | S | P | K | Ca | Mg | C:N ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| (ton/a) | (ton/a) | (ton/a) | (lb/a) | ---(%)--- | | | | | | |
| 0 | 2160 | 3.32 | 48 | 0.72 | 0.12 | 0.16 | 0.9 | 0.25 | 0.097 | 61 |
| 35 | 1890 | 3.14 | 64 | 1.00 | 0.18 | 0.17 | 1.3 | 0.38 | 0.130 | 43 |
| *t*-test | * | NS | * | * | * | NS | NS | * | * | |

NS = Not significant.
* Statistically significant at the 10% probability level ($P<0.10$).

Table 3. Soil test values on 10-30-95 from fields treated with RPR amendment in September, 1995.

| RPR (ton/a) | pH | P | K | Ca | Mg | Na | EC* | SMP pH | $SO_4$-S | B |
|---|---|---|---|---|---|---|---|---|---|---|
| | | -----(ppm)---- | | -------- (meq/100g)--------- | | | (mmho/cm) | | -----(ppm)--- | |
| Poorly-drained field - Dayton | | | | | | | | | | |
| 0 | 4.7 | 11 | 125 | 8.7 | 3.4 | 0.2 | 0.60 | 5.5 | 5 | 0.20 |
| 35 | 6.5 | 13 | 113 | 17.0 | 2.7 | 0.3 | 1.10 | 6.5 | 16 | 0.15 |
| Well-drained field - Malabon | | | | | | | | | | |
| 0 | 5.2 | 46 | 299 | 8.9 | 3.5 | na | 0.34 | 5.6 | 4 | 0.14 |
| 35 | 6.1 | 34 | 281 | 13.3 | 3.5 | na | 0.36 | 6.2 | 6 | 0.28 |

na = not analyzed
*EC=Electrical Conductivity, a measure of soluble salts in the soil.

# N RATE AND TIMING RELATIONSHIPS WITH TISSUE N CONCENTRATION AND SEED YIELD IN PERENNIAL RYEGRASS

*S.M. Griffith and T.W. Thomson*

Oregon's Willamette Valley is one of the premier grass seed producing areas in the United States. Nitrogen (N) is a critical element affecting perennial ryegrass seed yield. Western Oregon perennial ryegrass seed producers do not always monitor crop or soil N during the season as a method for making N fertilizer rate and timing decisions. It has been reported that typically 125 to 256 lb/a of N is applied annually to perennial ryegrass seed production fields in western Oregon. Independent of weather conditions, the timing, rate, and type of N material used may vary among producers. Mismanagement of fertilizer N can potentially result in N losses through leaching or soil N processing (e.g., denitrification) that will lower economic return. Improved NUE can reduce current annual N fertilizer inputs by at least 30%.

Although yearly variation in grass seed yields are often attributed to lodging or disease, the effect of N rate and timing on plant growth and seed yield may be a large but unrecognized factor. For example, too much N applied at the wrong time can result in excessive lodging or secondary tillering that result in reduced seed yield.

The objectives of this research were: 1) to determine the interaction of N rate and time of application on plant growth and seed yield; and 2) to determine the relationship between aboveground tissue N concentration with final seed yield as functions of N rate and N timing based on an accumulated growing degree day (GDD) scale.

On-farm (Suver, OR) plots (randomized block with four replications) were established in an existing first-year perennial ryegrass seed field established in the fall of 1995. Prior to the establishment of the plots, the grower applied 15-15-15-6 fertilizer at 40 lb N/a on 7 March, 1996. N treatments consisted of varying rates and timing of fertilizer N in the form of urea-ammonium sulfate (40-0-0-6). Applied rates consisted of 0, 40, 80, and 120 lb/a in addition to the previously applied 40 lb/a. Accumulated growing degree days (GDD) using the $T_{sum}$ method were calculated by summing the daily degree day values obtained by adding the maximum and minimum temperatures for the day, dividing by two, and subtracting the base temperature (0°C). Accumulated GDD was calculated beginning January 1.

In 1996, N fertilizer was applied to each plot at 475 (12 March), 627 (29 March), and 857 GDD (17 April). Aboveground plant biomass samples were taken from plots on 551 (19 March), 701 (15 April), 949 (26 April), 1521 GDD (10 June), and at seed harvest on 2121 GDD (15 July). Crop anthesis occurred between 15 May and 4 June. Plant aboveground biomass was obtained by removing all vegetation above the soil line from a 12 inch length of row in each treatment plot. Prior to harvest, a final fertile tiller count per 12 inch length of row was taken. Seed yield was determined from a 3 x 3 ft area within each plot. Temperature data were obtained from the Oregon Department of Forestry weather site at Dallas, Oregon.

First seed-year seed yield was significantly affected by N rate but not by the timing of applied N (Table 1). Highest seed yield was achieved with 120 lb/a total N applied. This agrees with previous reports. Spike number per unit area was not affected by N rate or N timing. The average spike density at seed harvest was 113 $\pm$ 7 ft$^2$. The rate and total amount of aboveground biomass accumulation by anthesis time was also affected by N rate but not by N timing.

Aboveground plant N concentration (% N per unit dry mass) decreased with time among all N treatments. Across all N treatments, tissue N concentration ranged from 4% at 551 GDD to less than 1% by seed harvest. In most cases, maximum plant N accumulation occurred by anthesis. Total accumulated plant aboveground N ranged from approximately 90 to 190 lb/a, depending upon the level and timing of N applied. At anthesis, higher plant N accumulation occurred among treatments receiving later N applications. Hence, the highest N accumulation was achieved at the highest N rate and latest application time. For example, N applied to plants at 475 GDD at 120 lb/a rate accumulated approximately 125 lb N/a, while plants receiving N at 857 GDD at 120 lb/ac rate accumulated approximately 190 lb N/a. This relationship was related to tissue N concentration and not biomass accumulation. Late-season tissue N concentration was highest for plants receiving later N applications.

Determining tissue N levels can be important in diagnosing the nitrogen needs of a growing crop and may serve as a indicator of the crop's seed yield potential. Thus, aboveground tissue N concentration was related to final seed yield and could be used to determine any correlative relationships. One difficulty in making best correlations is knowing when to sample the tissue and what portion of the plant to sample. We chose to sample at different times of the season and to simplify tissue selection by analyzing the entire aboveground crop for N. Thus, we hoped this would reduce some confounding effects. Overall, it was found that sampling tissue approximately 500 to 900 GDD gave a high correlation to final seed yield (Figure 1). When calculating individual $r^2$ values for specific N treatments, values as high as 0.96 were obtained. Late season (>1521 GDD), tissue N concentration did not correlated well with final seed yield.

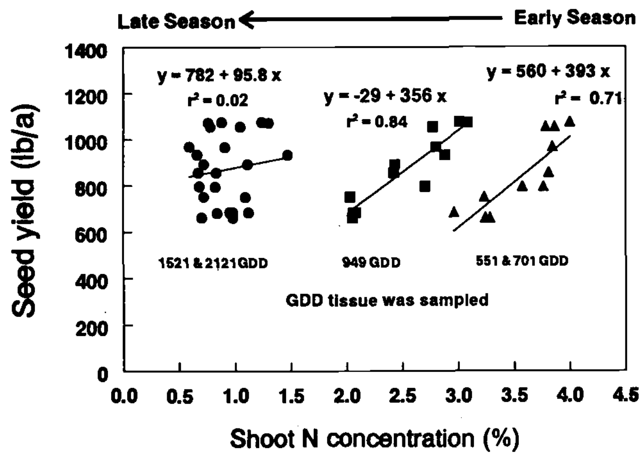


Figure 1. Final perennial ryegrass seed yield as a function of shoot N concentration. The following accumulated growing degree days (GDD), 551, 701, 949, 1521, and 2121 GDD occurred on 19 March, 15 April, 26 April, 10 June, and 15 June 1996, respectively.

These data indicate that spring perennial ryegrass tissue N concentration can be related to final seed yield. Tissue sampled at approximately 900 GDD worked well. In 1996, 949 GDD occurred on April 26. If tissue N analysis on this date determined that crop shoot %N was low, then late season N may be applied using a liquid N fertilizer application. This could be done concurrent with another chemical application (e.g., fungicide). This is being tested during the 1996-1997 season. It must be cautioned that these data represent only one cultivar, one year and one location. Multiple-year and location data for perennial ryegrass and tall fescue are currently being analyzed by Griffith to further test these hypotheses.

Table 1. Values represent mean first year final seed yield (lb/a) of perennial ryegrass as a function of N rate (lb/a) and N timing expressed as accumulated growing degree days (GDD) from January 1 (base temperature of 0°C). All treatments received 40 lb N/a rate on 7 March 1996. Following this date, plots received four N rates at either 475, 627, or 857 GDD. Seed yield was significantly affected by N rate and not N timing. Statistical results are shown only for the combined seed yield data across all N timing treatments. Means followed by the same letter were not significant at $P \leq 0.05$ by the Fisher's protected LSD method.

| Total N applied | Timing of applied N (GDD) 475 | 627 | 857 | Mean seed yield across N timing treatment |
|---|---|---|---|---|
| (lb/a) | ----------(lb/a)---------- | | | |
| 40 +0 | 744 | 769 | 769 | 761 a |
| 40 + 40 | 895 | 844 | 1003 | 914 ab |
| 40 + 80 | 962 | 1087 | 1050 | 1033 bc |
| 40 + 120 | 1185 | 1207 | 1205 | 1199 c |

# WATER STRESS IMPACTS ON DIEBACK OF PERENNIAL RYEGRASS SEED FIELDS

*T.M. Velloza, T.G. Chastain, W.C. Young III and M.E. Mellbye*

## Introduction

Dieback or dieout is the premature decline of perennial ryegrass seed fields. Dieback generally occurs in the third or fourth year of production, but in several instances as early as the second year (Mellbye *et al.*, 1994). This loss in stand is estimated at about $10 million annually in Oregon's Willamette Valley. In recent years the sales of ryegrass seed amounted to $100 million.

Research to date has eliminated the association of the dieback incidence with pathogens, insect pests, nematodes or soil fertility problems (Mellbye and Young, 1994). Nearly all of the perennial ryegrass seed crop is cultivated under rain-fed conditions and most of the vegetation needed to contribute towards the next year's seed crop has to be produced in the summer-fall post-harvest period of regrowth. However, the often dry summer-early-fall period can impose severe moisture stress on this shallow-rooted crop. Hence, continual water stress during this period of regrowth may be a contributing factor to the dieback problem.

The incidence and severity of the dieback symptoms vary between cultivars, but the severity of dieback increases as the stand ages. One possible explanation for this phenomenon is that as the plant ages it is increasing less capable of withstanding water stress. Plant persistence is dependent on the ability of new tillers to replaced the older ones. When the plant is placed under stress, the water and nutrient supply to the young tillers is reduced or halted in an effort to save the plant. Thus, it is the youngest tillers that are most vulnerable in stress situations. The plant's ability to replace older tillers is drastically reduced under drought or other stress conditions. It seems plausible that any factor affecting growth of tillers in the fall may also reduce flowering and seed yield. The impact of water deficit at critical times in the regrowth of the crop cannot be underestimated.

The objectives of this study were to: (1) Investigate how post-harvest leaf and tiller development in perennial ryegrass seed crop is impacted by the timing, severity and length of water stress; and (2) Identify potential relationship to flowering and seed yield.

## Materials and Methods

Field Studies

This experiment was conducted as a randomized complete block design with four replications and five treatments for 2 years at the Hyslop Research Farm. Trials were initiated in the summer of 1995 after harvesting fields that were sown the previous fall. Two cultivars, 'Affinity' and 'Buccaneer,' were used in the study. The entire experiment was replicated in the summer of 1996.

Rainfall was simulated by using a drip emitter system specifically designed for small plot irrigation. The device was 6 ft by 25 ft (same size as each plot) and the irrigation tubes and drip-emitters on each line of tubing were 1 ft on center. Water delivery was via a Pak tank.

The irrigation system was used to simulate rainfall events (1.0 in precipitation) in mid-August (summer), in mid-September (early-fall), and the combination of rainfall events during both periods. The treatments were compared with no rainfall and ambient rainfall conditions. Rain-out covers were used to exclude natural rainfall from all but the ambient treatments. To deliver the equivalent of 1.0 in of precipitation we used an output of 1.25 gal./min for 75 min. This amount increased the soil water potential from about -4 bars to approximately -1 bar.

Weekly monitoring of canopy temperature and volumetric soil moisture content was achieved by using infrared thermometry (Hatfield, 1990) and time-domain reflectometry (Wraith and Baker, 1991), respectively. Wave guides were buried at 6 in and 12 in depths in the root zone. Sequential samples were taken at three weeks after each treatment to follow plant development through the fall period. Plant growth and developmental characteristics including the number of aerial and basal tillers, tiller dry weight, the number of leaves per tiller, tiller basal diameter and tiller height were measured from a random selection of ten tillers. Treatments effects were tested by analysis of variance and means separated by Fisher's Protected LSD values.

Fertile and spring vegetative tiller numbers were measured prior to peak anthesis. Plots were harvested in July 1996 with a small plot swather and dried in windrows to approximately 12% moisture content. Windrows were combined with small plot machinery. The harvested area in one plot consisted of 125 $ft^2$. Seeds were cleaned with a laboratory size clipper M-2B air-screen cleaner.

The percent stand cover was taken in October 1996 to assess plant establishment by noting the presence or absence of a plant at one foot intervals for 25 feet. Three rows were measured in each plot. Mid-morning collecting of plant samples was done to ascertain soluble sugars in plants. Samples were refrigerated, cleaned, oven-dried, ground then again refrigerated until ready for use. Extraction was vial ethanol, and the phenol-sulfuric acid colorimetric method was used to develop solution color. Absorbance was measured in a double beamed UV-VIS scanning spectrophotometer.

The effect of summer and fall drought stress on flowering and seed yield will again be evaluated during the coming spring and summer.

Controlled Environmental Studies

The responses of four perennial ryegrass cultivars (Affinity, Buccaneer, 'Delray' and 'Linn') to water stress are being tested in the greenhouse. These cultivars represent the range of dieback symptoms from unaffected to high incidence and severity. The objectives are to ascertain differences between cultivars in their responses to water stress and to learn whether water stress in a causal factor in the development of dieback in perennial ryegrass seed fields.

Plants were grown in size D-40 conetainers (656 ml) and subjected to water stress at 3 months of age. There were four stress levels: (1) No stress-plants watered on alternate days ($W_0$); (2) No water for 7 days ($W_7$); (3) No water for 14 days ($W_{14}$); and (4) No water for 21 days ($W_{21}$). There were three timings of stress: (a) Plants cut, watered to saturation, then stressed; (b) Plants watered to saturation, stressed, then cut; and (c) Plants watered to saturation, stressed for 1 wk, cut, then stressed. The experiment was a split-split plot with level of stress as whole plot, timing as a sub-plot and cultivars as a sub-sub plot. There were three conetainers of each cultivar per treatment combination. Sample weights, canopy temperature, plant water potential, leaf transpiration rate and stomatal diffusive resistance were obtained weekly.

**Results and Discussion**

The two cultivars responded differently to water stress. However, no rainfall generally produced less regrowth than other rainfall treatments (Table 1). There were no differences in tiller number at the first sampling date (7 August 1995 and 18 August 1996). These dates immediately preceded the summer rainfall treatment.

For Affinity (in both years) there were differences between treatments after the summer irrigation. No rainfall produced less tillers than irrigated treatments. This reduction was about 30% in 1995 and 50% in 1996. This indicated that Affinity responded very rapidly to this early rainfall. This trend continued after the fall irrigation although the difference was not statistically significant. In 1995, Buccaneer did not respond as quickly as Affinity. However, at the end of the fall treatment no rain produced about 30-35% less tillers than the summer and summer-fall treatments. There were no differences between no rain and fall treatments. This suggested that a summer rainfall may be more critical than rain in the early fall. Results for the 1996 (Buccaneer) irrigation treatments were similar to that observed for Affinity.

Ambient conditions produced the highest number of total tillers in both cultivars during the first year of this study. Combined summer and fall rainfall events provided precipitation roughly equivalent to normal level during the regrowth period, but tiller production in this treatment was not different than that observed in the ambient treatment, which received nearly twice normal precipitation. The cumulative natural rainfall at the completion of the summer and early-fall periods in 1995 were 1.1 in and 6.3 in, respectively. For the same periods in 1996 the quantities were 0.1 in and 2.6 in.

It is noteworthy that where treatments received an equal amount of rainfall there was less tiller production in 1996 than in 1995 (Table 1). This supports the contention that as plants become older they are increasingly more susceptible to stress conditions. Therefore, the ability to replace the older tillers as they die is markedly reduced. Continual summer and early-fall water stress may be a major contributing factor to the onset of dieback. The reduction in tiller production from 1995 to 1996 may be an early indicator of dieback in our experimental stands.

Climatic data over the past 20 years indicate that the average rainfall during the summer and early-fall period is about 3.0 in. However, about 4.0 in of rainfall may be necessary for optimum tiller production (Figure 1). Therefore, the crop may be under moderate to severe moisture stress during the early regrowth period in most years. This stress may have had detrimental effects on the plants' ability to recover and produce the tillers necessary for stand persistence.

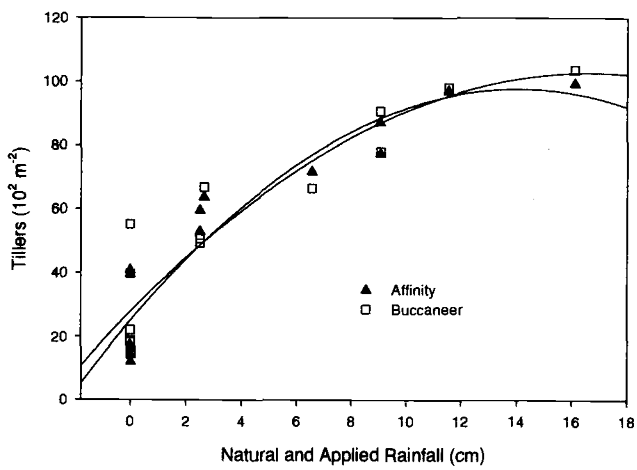


Figure 1. Water stress impact on total tiller number in perennial ryegrass seed fields, 1995.

There was poor correlation between soil moisture content at 6.0 in depth and canopy temperature. However, for up to five days after irrigating, no rain treatment exhibited a higher canopy temperature than recently irrigated plots. Since the crop just commenced its regrowth, the canopy was open and tillers were small which may account for the poor correlation between canopy temperature and soil moisture content.

There were no differences in fertile tiller number in 1996 (Table 2). Also, yields were similar except for the summer treatment in Affinity. Yields may have been reduced in the summer treatment because of rapid growth initiated by the early irrigation. However, as subsequent water was not forthcoming plant growth and development may have been reduced. Buccaneer responded less slowly to early irrigation; therefore, tillers formed late in fall may have contributed to yields. Since perennial ryegrass has little or no juvenility it can be vernalized in the seed (Silsbury, 1965). Thus, the dependence on early-formed tillers in the fall to produce high numbers of inflorescences in the following spring is not very great.

The plant cover was clearly affected by the water stress treatments (Table 3). For both cultivars, the no rain and the summer/fall treatments produced the lowest and the highest amount of plant cover respectively, while the other treatments represented the middle of the range. The no rain, ambient and the summer/fall treatments resulted in equivalent amounts of plant cover in both cultivars. However, the summer and the fall treatments produced slightly less stand in Buccaneer than in Affinity. This agrees with the observations made earlier that the two cultivars responded differently to water stress.

Table 3. Effect of water stress on percent cover was evaluated in perennial ryegrass seed crops on October 11, 1996.

| | Affinity | Buccaneer |
|---|---|---|
| | (% cover) | |
| Ambient | 84.7 b† | 85.0 ab |
| No rain | 68.4 c | 60.0 d |
| Summer | 83.0 b | 77.3 bc |
| Fall | 87.6 ab | 73.4 c |
| Summer + fall | 91.7 a | 88.7 a |

†Means in columns followed by the same letter are not significantly different according to Fisher's Protected LSD values ($P = 0.05$).

In all cases percent stand cover was reduced probably because of the insufficiency of water. Since death and loss of stand is the last response of the crop to water stress then it is important that the stress be less severe. No water in the late summer-early fall period of regrowth resulted in approximately 32-40% loss of stand. In fields greater than 2 years old serious consideration must be given to supplemental irrigation if a dry regrowth period is forecasted. Farmers could be well advised that even a small quantity of water in summer can greatly benefit stand persistence.

Preliminary analysis of water soluble sugars were intriguing. There were no differences between treatments for both cultivars in 1995. However, we did observe that the summer treatment for Affinity had a somewhat lower concentration than the others. When it is noted that this same treatment had a lower yield than the others (Table 2) it is interesting. The ability of a crop to adapt to stress and still continue to function at optimum is critical for its continued development, growth and production. This may be a case where the plants in the other treatment were able to osmotically adjust to the conditions and when later rains came they continued to function optimally. However, as explained before early summer treatments may have initiated rapid growth, but subsequent withholding of water produced adverse effects.

The 1996 trend revealed that the concentration of sugars tended to be greater than in 1995. This may be caused by a concentration effect since there were less tillers in 1996 than in 1995. More sugars would be accumulated when less tillers are present. Since this period of regrowth is not a very active one for the plant, sugars may be accumulated until ready for later use.

**Summary**

Though the two cultivars responded differently to water stress optimum tiller production can be attained in fall regrowth with approximately 4.0 in of water. No irrigation caused a reduction in tiller production by approximately 30% in 1995 and about 50% in 1996. For similar treatments, tiller production decreased as the stand aged, and canopy temperature was not a reliable indicator of water stress during the post-harvest regrowth stage of perennial ryegrass.

In the early production cycle of the crop fertile tiller production and seed yield may be affected by water stress but this is dependent on the time of stress and the cultivar. Insufficiency of water reduced percent stand cover by varying degrees in both cultivars with approximately 32-40% loss with no irrigation. Laboratory analysis revealed that the soluble sugars concentration was generally higher in the 1996 regrowth than in 1995.

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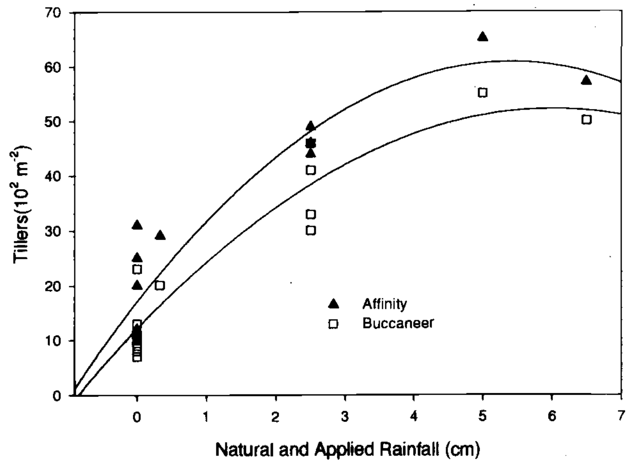


Figure 2. Water stress impact on total tiller in perennial ryegrass seed fields, 1996.

Table 1. Water stress impacts on fall tiller number at various times during regrowth in perennial ryegrass seed crops.

| Rainfall treatment | Affinity 7 Aug | Affinity 8 Sept | Affinity 13 Oct | Buccaneer 7 Aug | Buccaneer 8 Sept | Buccaneer 13 Oct |
|---|---|---|---|---|---|---|
| | (no./sq ft) | | | | | |
| 1995 | | | | | | |
| Ambient | 132 † | 592 a | 924 | 174 | 622 | 964 |
| No rain | 162 | 380 b | 666 | 204 | 370 | 618 |
| Summer | 150 | 492 ab | 810 | 144 | 470 | 844 |
| Fall | 158 | 368 b | 718 | 134 | 512 | 726 |
| Summer + fall | 112 | 554 a | 902 | 170 | 598 | 914 |
| | 18 Aug | 11 Sept | 11 Oct | 18 Aug | 11 Sept | 11 Oct |
| 1996 | | | | | | |
| Ambient | 102 | 270 | 530 | 74 | 186 | 465 |
| No rain | 112 | 186 | 288 | 102 | 121 | 214 |
| Summer | 93 | 409 | 428 | 84 | 279 | 381 |
| Fall | 102 | 232 | 455 | 93 | 121 | 428 |
| Summer + fall | 102 | 455 | 604 | 65 | 307 | 511 |

†Means in columns followed by the same letter are not significantly different according to Fisher=s Protected LSD values ($P = 0.05$).

Table 2. Water stress impacts on fertile tiller number and seed yield in perennial ryegrass seed crops, 1996.

| Rainfall treatment | Affinity | | Buccaneer | |
|---|---|---|---|---|
| | Fertile tillers | Seed Yield | Fertile tillers | Seed yield |
| | (no./sq ft) | (lb/a) | (no./sq ft) | (lb/a) |
| Ambient | 223 † | 1194 | 232 | 1088 |
| No rain | 204 | 1160 | 214 | 1039 |
| Summer rain | 214 | 924 | 195 | 1032 |
| Fall rain | 223 | 1221 | 195 | 1085 |
| Summer + fall | 232 | 1156 | 204 | 1103 |

†Means in columns followed by the same letter are not significantly different according to Fisher's Protected LSD values ($P = 0.05$).

## DISEASE CONTROL IN FINE FESCUE SEED FIELDS IN THE WILLAMETTE VALLEY

*G.A. Gingrich*

Over the past six to seven years there has been an increase in the incidence of leaf diseases infecting fine fescue seed fields grown on the east side of the Willamette valley. These diseases include powdery mildew, rust and a leaf and stem spot that has eluded positive identification. Rust tends to attack certain varieties of Chewings fescue and can be controlled by applications of registered fungicides. The leaf and stem spot disease is mostly a problem in varieties of creeping red fescue. In 1995 large scale, replicated trials were conducted on two established red fescue fields with a known history of leaf spot infections. Two applications of Tilt plus Bravo resulted in significant seed yield increases over the untreated check. Predicting the need for fungicide applications and the proper time of application is not well known and additional research is needed.

In 1996 a replicated, small plot trial was conducted on an established field of 'Claudia' creeping red fescue. This variety has been susceptible to the leaf spot disease in previous years and was considered a good location for this trial. New fungicide products were being tested on other diseases and grass species in western Oregon and it was decided to try them on fine fescue to evaluate their effectiveness on the leaf spot disease. A list of treatment application rates and dates are shown in Table 1. The trial was arranged in a randomized complete block design with three replications. Individual plot size was 9 x 30 feet. The fungicides were applied in water at 20 GPA and the surfactant No Foam A @ 0.25% (volume basis) was added to all treatments except those having sulfur products.

Table 1. Products, application rates and dates for leaf spot control in Claudia fine fescue, 1996.

| Treatment | Application Dates | |
|---|---|---|
| | 5/24 | 6/18 |
| | -- (Product rate/acre) -- | |
| Check | --- | --- |
| Tilt (1x) | 6 oz | --- |
| Folicur (1x) | 6 oz | --- |
| Bravo (1x) | 2 pt | --- |
| Quadris (1x) | 3 oz | --- |
| Tilt + Bravo (1x) | 4 oz + 1.5 pt | --- |
| Folicur + Echo (1x) | 1 pt | --- |
| Tilt + Sulforix (1x) | 6 oz + 0.5 gal | --- |
| Tilt + BSP 103 (1x) | 6 oz + 0.5 gal | --- |
| Bravo (1x)/Tilt (1x) | 2 pt | 6 oz |
| Tilt (2x) | 6 oz | 6 oz |
| Crop growth stage | 90% headed | 100% headed and pollinating |
| Infection level | Trace | Light |

In 1996 the incidence of leaf spot was quite low and observing consistent differences between the various treatments was difficult. There were no significant differences observed between the various fungicides applied (Table 2). Although significant differences were calculated between the untreated check and fungicide treatments, a seed yield response was considered unlikely and, therefore, not evaluated.

Table 2. Visual evaluation of leaf spot control in Claudia fine fescue, 1996.

| Treatment | | Leafspot evaluation date 6/18 | 6/27 |
|---|---|---|---|
| | (Product rate/acre) | (% infected) | |
| Check | --- | 9 | 41 |
| Tilt (1x) | 6 oz | 2 | 11 |
| Folicur (1x) | 6 oz | 2 | 18 |
| Bravo (1x) | 2 pt | 1 | 11 |
| Quadris (1x) | 3 oz | 1 | 12 |
| Tilt + Bravo (1x) | 4 oz + 1.5 pt | 1 | 14 |
| Folicur + Echo (1x) | 1 pt | 2 | 14 |
| Tilt + Sulforix (1x) | 6 oz + 0.5 gal | 1 | 9 |
| Tilt + BSP 103 (1x) | 6 oz + 0.5 gal | 1 | 13 |
| Bravo (1x)/Tilt(1x) | 2 pt/6 oz | 1 | 12 |
| Tilt (2x) | 6 oz | 1 | 10 |
| LSD (0.05) | | 4 | 10 |

## RUST CONTROL IN PERENNIAL RYEGRASS AND TALL FESCUE

*G.A. Gingrich and M.E. Mellbye*

Rust is a major fungal disease infecting seed fields of perennial ryegrass and tall fescue in western Oregon. Fungicide applications are required on many fields to control rust and provide opportunity for obtaining adequate seed yields and quality. Many fields are treated two or more times each season. For the past twenty years growers have relied on the fungicide Tilt to provide rust control. Tilt is one of the sterol inhibitor fungicides and although it has been providing a high level of control there is industry concern that at some point, with such heavy reliance on one type of fungicide, rust resistance to Tilt and other sterol inhibitors may develop. In 1993 trials were established in perennial ryegrass to evaluate the potential for using lime sulfur alone and in combination with Tilt to provide another mode of action for rust control. As a result of that work Sulforix (calcium polysulfide) received a 24( c ) label and the following year Thiolux was also labeled for the suppression of rust in grass grown for seed in western Oregon. In 1994 and 1995 similar trials were conducted on perennial ryegrass and tall fescue. The results have been reported in previous Seed Production Research Reports.

In 1996 four fungicide trials were established, two in perennial ryegrass fields and two in fields of tall fescue. In addition to the sterol inhibitor fungicides and sulfur products tested in previous years, an experimental fungicide Quadris, a formulation of potassium polysulfide (BSP 103), and a high grade white mineral oil called Stylet Oil were included. Quadris, a new fungicide developed by the Zeneca Corp., is not a sterol inhibitor and thus provides new chemistry that may become a valuable and effective rust control option for grass seed growers.

Fungicide applications were first applied in mid May, just as rust began to show in the fields. A total of 2 or 3 applications were made at approximately 21 day intervals. The initial treatments were made near the early heading stage of growth. Each trial was arranged in a randomized complete block design with three replications. Individual plot size was 9 x 30 feet. Fungicides were applied in water at 20 GPA using a hand-held $CO_2$ backpack sprayer. The surfactant No Foam A @ .25% volume basis was added to all treatments except Stylet Oil and those using sulfur products. Herbicides and fertilizers were applied by the grower according to his normal practice. Treatment information and results of the visual evaluations are reported below. Rust infection levels were determined for each treatment on several dates prior to harvest using the Modified Cobb scale. In these trials seed yields were not taken and no attempt was made to estimate yield losses due to rust infection levels.

**Perennial ryegrass**

The trials on perennial ryegrass were located on established fields in Linn and Marion counties. Two different varieties were used in the trials, 'Cathedral' in Linn county and 'APM' in Marion county. The Cathedral had a lower incidence of rust than did the APM and thus had only two applications made rather than the three on the APM field. Table 1 shows the treatments applied, rates and application dates. In Table 2 Tilt at 6 oz./ac is used as the standard practice and is compared to tank mixes with other products and to the new fungicide products that do not yet have registrations for use in grass seed production. We also included a Tilt application at 4 oz./ac and at each location it provided nearly the same level of control as did the higher rate. The percent rust infection is reported for only two of the five evaluation dates. The mid June date is approximately a week after the second treatment and the July 11 evaluation is just prior to swathing. Generally there was no significant difference between treatments except in the untreated check plot. To determine the length of effective control, each of the systemic fungicides was also applied just once on the first date. Five evaluations were made to observe the progress of the rust infections throughout the growing season at each site (Tables 3 & 4). The single applications are compared to three applications of the sulfur and mineral oil products applied alone. Quadris provided slightly better control at the end of the season than did Tilt and Folicur at the Linn county field. However, in Marion county it was not quite as effective. The multiple applications of sulfur and mineral oil provided equal control to the other fungicides applied once. This demonstrates their ability to suppress rust, but also shows that they do not provide adequate control on their own.

**Tall Fescue**

Two first-year fields of tall fescue were used for the fungicide trials. They were two different varieties of turf type tall fescue, 'Crossfire II' at the Marion county site and 'Debutante' in Linn county. A maximum of two applications were made at each location (Table 5). Where multiple applications were made good rust control was obtained with all treatments. Table 6 shows the results of rust evaluations on two dates during the growing season. The mid June evaluation occurred approximately a week after the final treatment and the July evaluations were made just prior to swathing. Significant differences were observed only between the untreated check plot and the various fungicide treatments. Listed in Tables 7 & 8 are the comparisons of the three systemic fungicides and their ability to control rust over the growing season with a single application. All provided significantly better rust control when compared to the untreated check plot but none were able to provide adequate season long control. None were able to provide a longer period of control than another.

In summary, Tilt continues to provide a high level of rust control when proper applications are made. Folicur and Quadris appear to provide rust control comparable to applications of Tilt or Tilt in combination with other products. If sulfur products or Stylet Oil are used in combination with Tilt they should not be used to reduce the Tilt rate. They should be considered a supplement that provides another mode of action for rust control. To obtain adequate rust control more than one fungicide application must be made on susceptible varieties of tall fescue and perennial ryegrass most years.

*Acknowledgments: Partial support for this research was provided by Best Sulfur Products, Bayer Corp. and Ciba Inc.. Appreciation is expressed to the growers who allowed the plots to be located on their seed fields.*

Table 1. Products, rates and application dates for rust control trials on perennial ryegrass in Linn & Marion Counties, 1996. (Linn County site treated first two dates only).

| Treatment | Application dates | | |
|---|---|---|---|
| | 5/15 | 6/4 | 6/24 (Marion Co. only) |
| | (Product rate/acre) | | |
| Check | --- | --- | --- |
| Tilt 4 oz | 4 oz | 4 oz | |
| Tilt 6 oz | 6 oz | 6 oz | |
| Tilt + Bravo | 4 oz + 1.5 pt | 4 oz + 1.5 pt | 4 oz + 1.5 pt |
| Folicur | 6 oz | 6 oz | 6 oz |
| Folicur + Echo | 1 pt | 1 pt | 1 pt |
| Quadris | 3 oz | 3 oz | 3 oz |
| Quadris + Bravo | 3 oz + 1.5 pt | 3 oz + 1.5 pt | 3 oz + 1.5 pt |
| Quadris | 3 oz | --- | --- |
| Tilt 6 oz | --- | --- | |
| Folicur | 6 oz | --- | --- |
| BSP103 | 1 gal | 1 gal | 1 gal |
| Tilt + Sulforix | 4 oz + 2 qt | 4 oz + 2 qt | 4 oz + 2 qt |
| Tilt + Thiolux | 4 oz + 4 lbs | 4 oz + 4 lbs | 4 oz + 4 lbs |
| Stylet Oil | 1 qt | 1 qt | 1 qt |
| Tilt + Stylet Oil | 4 oz + 1 qt | 4 oz + 1 qt | 4 oz + 1 qt |
| Crop growth stage | early heading | mostly headed | pollinating |
| Infection level | trace | light | heavy |

Table 2. Stem rust infection in perennial ryegrass, two varieties. 1996.

| Treatment | Product/acre | Rust evaluation date: Cathedral 6/12 | Cathedral 7/11 | APM 6/14 | APM 7/11 |
|---|---|---|---|---|---|
| | | (% Infected) | | | |
| Check | ---- | 8 | 73 | 34 | 87 |
| Tilt | 4 oz | 0 | 8 | 2 | 8 |
| Tilt | 6 oz | 0 | 3 | 0 | 5 |
| Tilt + Bravo | 4 oz + 1.5 pt | 0 | 1 | 2 | 7 |
| Folicur | 6 oz | 0 | 5 | 3 | 6 |
| Folicur + Echo | 1 pt | 0 | 1 | 1 | 4 |
| Quadris | 3 oz | 0 | 1 | 3 | 4 |
| Quadris + Bravo | 3 oz + 1.5 pt | 0 | 1 | 3 | 5 |
| Tilt + Sulforix | 4 oz + 2 qt | 0 | 6 | 1 | 9 |
| Tilt + Thiolux | 4 oz + 4 lbs | 0 | 21 | 4 | 10 |
| Tilt + Stylet Oil | 4 oz + 1 qt | 0 | 7 | 1 | 5 |
| LSD (0.05) | | 3 | 21 | 8 | 12 |

Table 3. Stem rust infection in Cathedral perennial ryegrass, Linn County, 1996.

| Treatment | Product/acre | Rust evaluation date: 6/4 | 6/12 | 6/21 | 7/3 | 7/11 |
|---|---|---|---|---|---|---|
| | | (% Infected) | | | | |
| Check | ---- | 8 | 8 | 25 | 37 | 73 |
| Tilt (2x) | 6 oz | 1 | 0 | 1 | 2 | 3 |
| Quadris (1x) | 3 oz | 1 | 0 | 5 | 15 | 34 |
| Tilt (1x) | 6 oz | 2 | 0 | 6 | 21 | 40 |
| Folicur (1x) | 6 oz | 1 | 1 | 7 | 21 | 43 |
| BSP103 (2x) | 1 gal | 1 | 2 | 10 | 25 | 42 |
| Stylet Oil (2x) | 1 qt | 0 | 2 | 16 | 34 | 65 |
| LSD (0.05) | | 3 | 3 | 10 | 18 | 21 |

Table 4. Stem rust infection in APM perennial ryegrass, Marion county. 1996.

| Treatment | Product/acre | Rust evaluation date: 6/6 | 6/14 | 6/21 | 7/1 | 7/11 |
|---|---|---|---|---|---|---|
| | | (% Infected) | | | | |
| Check | ---- | 6 | 34 | 43 | 76 | 87 |
| Tilt (3x) | 6 oz | 0 | 2 | 3 | 10 | 8 |
| Quadris (1x) | 3 oz | 1 | 6 | 9 | 45 | 65 |
| Tilt (1x) | 6 oz | 2 | 6 | 13 | 45 | 70 |
| Folicur (1x) | 6 oz | 1 | 7 | 18 | 47 | 68 |
| BSP103 (3x) | 1 gal | 2 | 16 | 30 | 53 | 63 |
| Stylet Oil (3x) | 1 qt | 2 | 8 | 12 | 47 | 63 |
| LSD (0.05) | | 2 | 8 | 9 | 13 | 12 |

Table 5. Products, rates and application dates for rust control trials on tall fescue in Linn & Marion Counties, 1996.

| Treatment | Application Dates 5/15, 5/20 | 6/4 |
|---|---|---|
| | (Product rate/acre) | |
| Check | --- | --- |
| Tilt + Sulforix (2x) | 4 oz + 2 qt | 4 oz + 2 qt |
| Tilt (2x) | 6 oz | 6 oz |
| Tilt + Bravo (2x) | 4 oz + 1.5 pt | 4 oz + 1.5 pt |
| Folicur (2x) | 6 oz | 6 oz |
| Folicur + Echo (2x) | 1 pt | 1 pt |
| Quadris (2x) | 3 oz | 3 oz |
| Quadris (1x) | 3 oz | --- |
| Tilt (1x) | 6 oz | --- |
| Folicur (1x) | 6 oz | --- |
| Crop growth stage | early heading | fully headed |
| Rust infection level | trace | moderate to severe rust |

Table 6. Stem rust infection in tall fescue, two varieties, 1996.

| | | Rust evaluation date | | | |
|---|---|---|---|---|---|
| | | Debutante | | Crossfire II | |
| Treatment | Product/acre | 6/12 | 7/3 | 6/14 | 7/1 |
| | | (% Infected) | | | |
| Check | ---- | 38 | 79 | 24 | 73 |
| Tilt + Sulforix (2x) | 4 oz + 2 qt | 1 | 5 | 4 | 5 |
| Tilt (2x) | 6 oz | 4 | 11 | 2 | 3 |
| Tilt + Bravo (2x) | 4 oz + 1.5 pt | 2 | 3 | 2 | 4 |
| Folicur (2x) | 6 oz | 2 | 5 | 4 | 3 |
| Folicur + Echo (2x) | 1 pt | 0 | 2 | 2 | 4 |
| Quadris (2x) | 3 oz | 1 | 4 | 4 | 6 |
| LSD (0.05) | | 9 | 20 | 7 | 12 |

Table 7. Stem rust infection in Debutante tall fescue, Linn County, 1996.

| | | Rust evaluation date | | | |
|---|---|---|---|---|---|
| Treatment | Product/acre | 6/4 | 6/12 | 6/21 | 7/3 |
| | | (% Infected) | | | |
| Check | ---- | 33 | 38 | 70 | 79 |
| Tilt (2x) | 6 oz | 5 | 4 | 3 | 11 |
| Quadris (1x) | 3 oz | 4 | 3 | 13 | 42 |
| Tilt (1x) | 6 oz | 3 | 2 | 12 | 48 |
| Folicur (1x) | 6 oz | 3 | 2 | 11 | 43 |
| LSD (0.05) | | 21 | 9 | 12 | 20 |

Table 8. Stem rust infection in Crossfire tall fescue, Marion County, 1996.

| Treatment | Product/acre | Rust evaluation date 6/6 | 6/14 | 6/21 | 7/1 |
|---|---|---|---|---|---|
| | | (% Infected) | | | |
| Check | ----- | 13 | 24 | 35 | 73 |
| Tilt (2x) | 6 oz | 2 | 2 | 2 | 3 |
| Quadris (1x) | 3 oz | 2 | 6 | 5 | 33 |
| Tilt (1x) | 6 oz | 1 | 3 | 5 | 30 |
| Folicur (1x) | 6 oz | 1 | 2 | 6 | 23 |
| LSD (0.05) | | 4 | 7 | 11 | 12 |

# A MODEL FOR UNDERSTANDING STEM RUST EPIDEMICS ON TALL FESCUE AND PERENNIAL RYEGRASS IN THE WILLAMETTE VALLEY

*M.D. Azevedo*

Stem rust is a serious problem for tall fescue and perennial grass seed growers. Disease severity has ranged from light (for example 1993) to severe (1992) and if not controlled can cause seed yield losses of 40% or more (Welty and Barker, 1992; Welty and Azevedo, 1992). This year-to-year variability in disease severity makes it difficult to manage the disease economically and effectively. The timing of fungicide applications is critical to managing the disease.

The purpose of this investigation is to understand the factors favoring development of the disease and to use this knowledge to create a model that will predict both the occurrence and potential severity of stem rust in any given year. This information will allow for more efficient and effective use of fungicides for control of the disease.

**The Disease Cycle**

Stem rust symptoms are readily visible during late spring and early summer in the Willamette Valley. Fields that are heavily infected turn orange-brown in color and clouds of rust spores can be seen above the fields. After harvest of a severe rust year, rust can be found on green leaves in the stubble and on green plants adjacent to fields. In the fall as the grasses regrow, the amount of rust increases and fields may have an orange-brown cast much like the spring epidemic. As temperatures cool and rains increase, the presence of the rust is less evident. Fewer infections occur and the pustules change in appearance. Many of the summer pustules which were cinnamon-brown in color darken and eventually turn black. This indicates that the rust has reduced or stopped producing urediospores (the asexual spores that infect their grass hosts) and is producing teliospores (sexually produced spores which cannot infect grasses but infects an alternate host if it exists). The rust fungus overwinters in the grass plant and in the spring begins to produce urediospores which infect rapidly growing leaf and stem tissue to initiate the spring epidemic.

**The Model**

The development of this rust prediction model is based on the following assumptions:

1. Stem rust overwinters in its host.
2. There are no alternate hosts present in the Willamette Valley.
3. Temperatures during the fall, winter and spring are important to the development of the epidemic in the spring.
4. There is sufficient free-water (dew) on the leaves of the host plants for infections to occur throughout the spring and early summer.
5. The number of cumulative days without rain in the spring affects development of the epidemic.

The model was developed using maximum and minimum daily temperatures and rainfall data from the Hyslop Field Laboratory, Corvallis, Oregon. Initial pustule development data were collected from 1990-94 using trap plants of tall fescue and perennial ryegrass (Welty and Azevedo, 1992). In 1995-96, initial pustule data were based on field observations at Hyslop Field Laboratory, and Pickseed Research Farm, Tangent, Oregon.

The model is composed of two parts: the measurement of cumulative heat from day of year (DOY) 275 (October 2) to DOY 190 (July 9), and the cumulative days without rain once initial uredial pustule development occurs.

Cumulative heat is calculated as follows:

$$RHU_{cum} = \sum_{DOY=190}^{DOY=275} (\text{max. temp } ^{\circ}\text{C} - (\text{min. temp. } ^{\circ}\text{C} \div 2) - 5$$

Where: $RHU_{cum}$ = cumulative rust heat units.

This calculation gives a relative measurement of cumulative heat units at any given time between DOY 275 and DOY 190. For example, in 1992 on DOY 90 there had been 1136 RHU accumulated but in 1993 only 807 RHU. When relative rust severity for the years 1991-1996 are compared to $RHU_{cum}$, the years with the greatest RHUs by DOY 90 had the most severe rust infections (i.e., 1992>1994>1995-6>1991>1993). Initial rust pustule development in the spring occurred at about 1150 RHU for all years (Figure 1).

Although 1995 and 1996 had similar $RHU_{cum}$, the development of the rust epidemic after initial pustule formation was different. The epidemic in 1995 was characterized as having the exponential phase of the epidemic occur between DOY 140-160, while 1996 had a rapid increase in rust occur between DOY 160-180. This shift in the exponential phase of the epidemic can impact management of the disease. In 1995, the epidemic developed rapidly when many cultivars of tall fescue and perennial ryegrass were at or near bloom, while in 1996 most cultivars were in mid to late seed fill. Because of this, potential seed yield loss was greater in 1995 than in 1996. Differences in disease development between 1995 and 1996 can be explained by comparing the cumulative days without rain starting when RHU = 1150 (Figure 2). In 1995, the first extended period of days without measurable rainfall was from DOY 133-155, while in 1996 was from DOY 151-168. The spring of 1996 was the wettest in recorded history, with extended periods of measurable rainfall. These wet conditions appear to have slowed the epidemic by removing inoculum from the air column and washing infected leaves, thereby reducing or preventing spore dispersal.

The model appears to explain observed differences in stem rust development between 1991-96. Current efforts are being focused on validating the model with disease observations and weather information from growers fields throughout the Willamette Valley.

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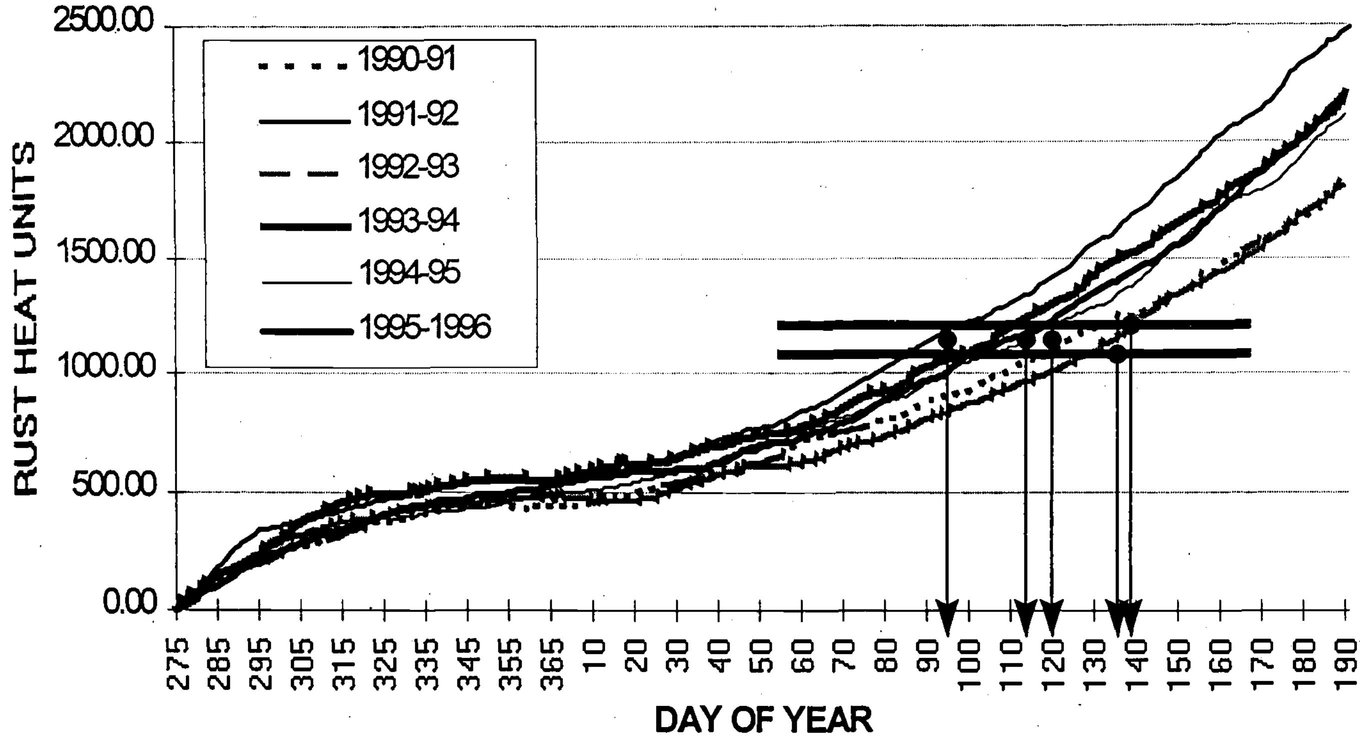


Figure 1. Cumulative rust heat units ($RHU_{cum}$) 1990-96 using the equation:

$$RHU_{cum} = \sum_{DOY=190}^{DOY=275} (\text{max. temp } ^{\circ}C - (\text{min. temp. } ^{\circ}C \div 2) - 5$$

This gives a comparative measurement of the amount of accumulated heat from October-July. Years with greater $RHU_{cum}$ had rust appear sooner in the spring. Dots with arrows represent the first observed uredial pustule development for the years 1991-95.

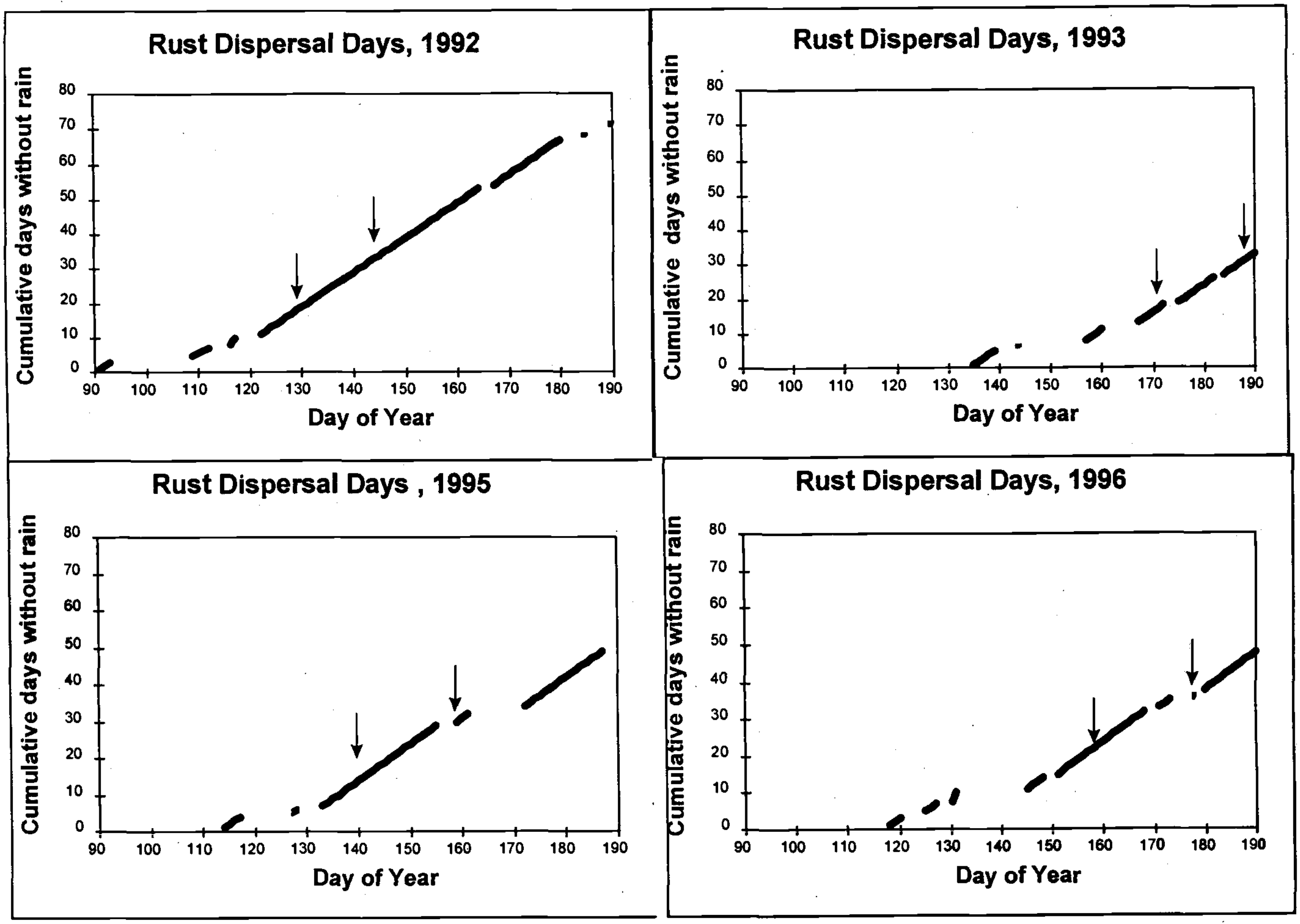


Figure 2. Rust dispersal days 1992-93 and 1995-96. Measurements began at 1150 $RHU_{cum}$. Arrows bracket the exponential phase of the rust epidemic.

## FUNGI FOUND ON IMPORTED RYEGRASS SEED

*S.C. Alderman*

Agricultural products such as grass seed that enter the U.S. must be inspected by officials of the animal and Plant Health Inspection Service (APHIS) to prevent the unwanted entry of agricultural pests. About three years ago, APHIS inspectors in Portland began to examine grass seed more closely than in the past. This closer examination is consistent with inspections at other ports of entry. In the inspection process, 500 grams of seed are visually examined under low power magnification to detect unwanted weeds, insects, pathogens, or fungi growing on the seeds.

When an APHIS inspector finds something new, such as an unrecognized fungus, samples are sent to APHIS specialists in Maryland. In the case of fungi, APHIS mycologists identify the fungus and determine if it has ever been reported in the U.S.. In cases where a new or unidentified fungus is detected, APHIS initiates a risk assessment evaluation to determine if there is any risk to U.S. agriculture. This includes risk to not only the crop that a suspect pathogen was found on but to any other crop that could be infected. During the period of examination and risk assessment, seed is not allowed into the U.S

During the past 2-3 years, fruiting bodies of fungi, found on ryegrass seed in shipments from Australia, Denmark, Japan, Netherlands, New Zealand, and the United Kingdom were sent to APHIS for examination and risk assessment. Fungi found on the seeds included *Ascochyta festucae* Punith., *Didymella graminicola* Punith., an unknown species of *Ascochyta, Didymella,* and *Mycosphaerella,* and four unknown species of *Phaeospheria.*

By September, 1996, APHIS had completed the risk assessment and concluded that the fungi from ryegrass pose a moderate risk, although yield reductions in ryegrass are not expected. Seed is being allowed into the U.S. while additional studies are continuing to determine species identity, pathogenicity, and host range of the suspect fungi. I am cooperating with APHIS to determine the pathogenicity and host range of the *Phaeospheria* species found on imported ryegrass seed. However, if other unrecognized fungi are found on import seed, these shipments may be subject to quarantine until examinations and risk assessment procedures are completed.

Ryegrass seed produced in Oregon is exceptionally clean, especially in comparison to import seed. I examined about 50 lots of Oregon produced ryegrass seed and did not find any of the fungi that were found on the import seed. We know very little about the species of fungi found on ryegrass seed. However, we know from closely related fungal species that cool temperatures and moist conditions (e.g. rainy weather) during seed maturation and harvest are favorable for fungal growth and development. Conditions in the Willamette Valley during harvest are relatively warm and dry, which could account for the high quality of our seed.

## *ANGUINA* IN ORCHARDGRASS

*S.C. Alderman, M.E. Mellbye and N.L. Adair*

Nematodes in the genus *Anguina* occur in the Willamette Valley on bentgrass, fine fescues and orchardgrass. *Anguina* species attacking grasses are commonly referred to as seed gall nematodes since infected seeds are transformed into galls. In bentgrass, the seed are replaced by black, 3-6 mm long galls and are easily visible in the panicle. In orchardgrass, galls are dark purple and similar to or smaller than healthy seeds. Visual detection is very difficult. In orchardgrass, a bacterium may colonize the galls, resulting in a yellowish colored gall that may ooze with a yellowish-colored slime.

Infection of bentgrass, chewings fescue, red fescue, or orchardgrass may result from attack by different species of *Anguina.* The number of *Anguina* species present in the Willamette Valley and their host range or host overlap has not been determined, primarily because of the tremendous difficulty in identifying *Anguina* at the species level. However, efforts are underway to identify the species occurring on orchardgrass.

Seed gall nematodes that attack grasses require a susceptible host plant to complete their life cycle. Host genera reported as susceptible to *Anguina agrostis* include *Agrostis, Apera, Arctagrostis, Dactylis, Festuca, Hordeum, Koeleria, Phalaris, Phleum, Poa, Puccinela, Sporobolus,* and *Trisetum.* Host genera reported as susceptible to *Anguina graminis* include *Agrostis, Dactylis, Deschampsia,* and *Festuca.* Removing host plants through clean fallow or rotation with a nonsusceptible crop for one year breaks the life cycle of *Anguina* and provides excellent control.

In reestablishing a field, the seed should be tested and found free of *Anguina* prior to planting. Seed storage is not a control option. The nematodes will survive for many years with stored seed. Under ambient conditions in my lab, *Anguina* from bentgrass has so far survived 5 years. I have heard statements from other labs of the nematodes surviving in stored seed more than 30 years.

Once a field is established, sanitation is an important means of keeping the field free of *Anguina.* The nematodes can be introduced into the field through contaminated soil, seed, or crop residues. In general, *Anguina* tends to occur in localized areas in the field and populations tend to increase gradually over several years. The longer a field is in production the greater likelihood of *Anguina* populations increasing and spreading within a field.

Yield losses due to *Anguina* in orchardgrass have not been observed. In most cases, the nematodes are occurring at low levels. However, presence of *Anguina* in seed has created some problems in seed exports where receiving countries require orchardgrass seed free of *Anguina.*

During 1996, 20 orchardgrass fields were sampled and tested for *Anguina.* No galls were visually detected among 400 seed heads from each field. The galls in orchardgrass are difficult to see based on a visual inspection. In a laboratory test of the seed, 50 grams of seed were soaked, ground in a blender, passed through various sieves, and nematodes collected on a very fine mesh sieve. *Anguina* was detected in 14 out of the 20 fields examined. A more extensive survey, based on all of the orchardgrass samples submitted to the OSU Seed Lab is under way. In addition, the effectiveness of fumigants for control of *Anguina* in orchardgrass seed is under investigation.

## SEVERITY OF BLIND SEED IN TALL FESCUE

*S.C. Alderman*

During 1994 and 1995 samples of tall fescue seed were obtained from the OSU seed lab for blind seed testing. To date, blind seed was detected in 51 cultivars of tall fescue. In 1995, blind seed was detected in 60 fields, which included 30 cultivars. In most cases, 1-3 fields for a given cultivar tested positive for blind seed. However, about one third of all the fields testing positive were cultivar Fawn.

The high occurrence of blind seed in Fawn is likely due to the early maturing habit of this cultivar, which tends to flower during the late spring rains. Cool, rainy weather, and moist soils are ideal for production of blind seed fruiting bodies and spores. In addition, rainy weather during seed development supports secondary spread of spores and increased disease development.

Fields tested positive will be followed over the next 2-3 years to determine the potential increase in blind seed disease. In Fawn tall fescue, the severity of blind seed increased with increasing age of the stand (Figure 1). A sharp increase in disease was noted in stands in production more than 5 years. However, levels of blind seed was similar during 1994 and 1995. Several additional years of data will be required to establish the potential increase of blind seed disease.

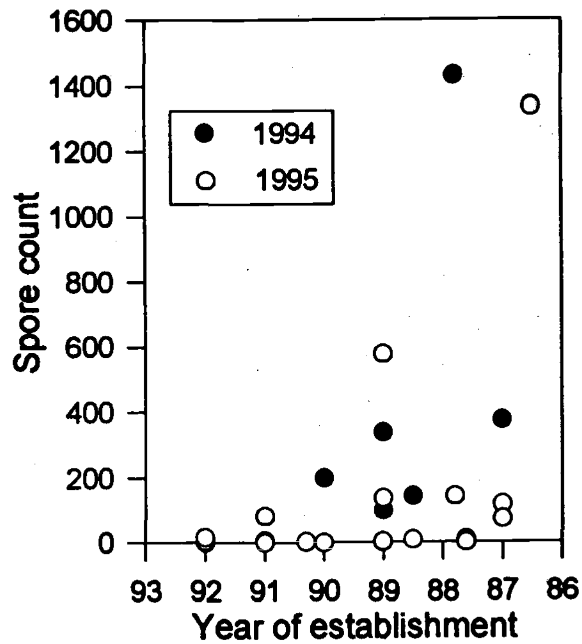


Figure 1. Relationship between year of establishment and blind seed level (based on spore count) during 1994 and 1995.

# BIOLOGICAL CONTROL OF WEEDS USING DELETERIOUS RHIZOBACTERIA

*L.F. Elliott, M.D. Azevedo, G.W. Mueller-Warrant, W.R. Horwath, and J.M. Lynch*

Weeds cause greater economic losses on agricultural lands than all other pests combined (Kremer and Kennedy 1996). The reduction in open field burning and decreased availability of herbicides for grass seed production has required a new look at weed control in seed grass stands. In the absence of field burning straw residue can negate established weed control practices especially with the use of herbicides (Altman et al., 1990; Neate and Rovira, 1993). There is a need to explore alternative weed management approaches.

Traditionally insects and fungi have been studied for biological control of weeds. More recently there has been interest in manipulating microbial interactions in the root rhizosphere (the zone immediately surrounding the root) for biological control of weeds. In this regard deleterious rhizobacteria (DRB) appear to have weed biocontrol potential. Their potential for biocontrol was first described on downy brome (Cherrington and Elliott, 1987) and several broadleaf weed seedlings (Kremer et al., 1990). Kennedy et al. (1991) obtained winter wheat yield increases up to 35% due to control of downy brome with the DRB D-7. Based on these investigations, we are conducting studies to determine if DRB can be used to control weeds such as downy brome, annual bluegrass, and roughstalk bluegrass in grass seed stands. Also, we are exploring the possible use of these bacteria for control of volunteer seedlings in mature grass stands. The effect of DRB appears to be primarily on seedling growth.

**Procedures**

Bacteria were plated from plant root surfaces on a medium selective for *Pseudomonas* sp. bacteria. The isolates are then tested for root growth inhibition on agar plates in the laboratory of annual bluegrass, downy brome, roughstalk bluegrass, and perennial ryegrass with primary focus on annual bluegrass. Those organisms showing significant root growth inhibition, usually 50% or greater, are preserved for testing in the growth chamber. Growth chamber tests are conducted in a 50% sand-soil mix. Pregerminated seeds are planted and sprayed with no organism or the organism being tested. The organism being tested is applied at the rate of $1 \times 10^8$ organisms per square meter (about $1 \times 10^7$ organisms per square foot). After a time period (usually about 5-6 weeks) the plants are harvested and the roots and shoots are measured and compared with the untreated control. For field testing, the organisms showing significant root growth inhibition are then tested in the field. The organisms are suspended in a buffer solution and this solution used to treat weed plot trials in the field. The organisms are applied at the rate of $1 \times 10^8$ organisms per square meter. The treatments are put out starting in late October through February as weather permits. We do not like to apply the organisms during warm, dry-weather because they die off rapidly under these conditions. In earlier studies, we have shown that organisms applied in this manner do colonize the roots of the targeted plants.

Several new isolates of deleterious rhizobacteria against *Poa annua*, and *Poa trivialis* have been obtained and the isolate efficacy is now being tested in the growth chamber.

Fourteen isolates that stop annual bluegrass seed germination have been obtained and about 20 others that inhibit annual bluegrass root growth. Inhibitory activity is the result of toxin production. The toxin produced by the seed germination inhibitors is excreted from the cells and appears to be stable for at least two weeks in the culture medium and much longer when frozen. Filtering through filters that remove proteins and lipopolysaccharides does not affect activity of the toxin(s). Preparations are being made to identify the toxin(s) using high performance liquid chromatography, dialysis, and high resolution mass spectrometry technology. Preliminary results indicate the organisms are of the *Pseudomonas* genus.

Most of our studies have focused on the isolation of DRB inhibitory to weeds from grass crop roots or from roots of weeds in the grass crop stand. We have isolated DRB inhibitory to annual bluegrass root growth from a variety of cropping systems and soils (Table 1). It was felt that DRB efficacy might be associated with the amount of crop rotation or farming practice. No clear trend was evident. The organic system appeared to show greater numbers of DRB inhibitory to annual bluegrass root growth than organisms from roots of plants growing in other cropping systems. The organic cropping system was much different from the others because it dealt primarily with vegetable crops.

The successful release and application of wild-type microorganisms into soil systems has been impeded because efficacy in the field is unpredictable. This unpredictability can range from full affectivity to no effect in the same set of plots. Development of inoculum technologies, understanding inoculum response in different cropping and soil systems, and determining environmental responses of inocula are essential to developing these weed biocontrol systems.

We conducted recent studies that showed inoculum efficacy is influenced by crop rotation, inoculum carrier, plant species, and inoculum (Table 2). The carrier is the material added to the inoculum to protect it from the environment. The carriers used in these treatments were: a protein, finely ground perennial ryegrass straw, and guar gum. Root weight was significantly affected by all treatments. Successful inoculum introduction for weed biocontrol in the field will require that these factors be considered.

Table 2. Analysis of variance for the variables root and shoot weight as affected by soil, inoculum, and carrier.

| | Significance Level | |
|---|---|---|
| Main Effect | Root Weight | Shoot Weight |
| Plant Species | *** | *** |
| Soil (crop rotation) | *** | NS |
| Inoculum | *** | NS |
| Carrier | * | *** |

NS = Nonsignificant interaction
* = Significant at the 0.05 probability level
*** = Significant at the 0.001 probability level

The timing of application of the annual bluegrass inhibitory organisms is important for positive results. The December 10 and January 20 applications of A21 and A17 (the organisms were applied to the same plots on these dates) significantly reduced annual bluegrass numbers by 20% (Table 3). The timing is important for two reasons: the organisms prefer cool-wet weather and are most effective against annual bluegrass just as the seed sprouts and the seedlings are very young. Obviously, 20% control is not adequate but does demonstrate there is a potential for this weed control approach. Studies are underway to determine if alternate carriers will extend the useful life of the biocontrol agents in the field. We are also studying the effect of culture production methods on field efficacy of the organisms. Laboratory studies have shown that growth phase of the organism strongly affects its activity.

Table 3. The effect of DRB on the establishment of *Poa annua* in a fallow field at Hyslop Field Station, Oregon State University. Data expressed as number of *Poa annua* plants per 6.4 $m^2$ plot.

| | Organism Application Date | | |
|---|---|---|---|
| Deleterious Rhizobacteria isolate | January 20 | December 10 and January 20 | March 7 |
| Control | 382 | 386 | 391 |
| A21 | 334 | 306 | 418 |
| A17 | 297 | 308 | 471 |
| B15 | 368 | 349 | 316 |
| LSD (0.05) | 82 | 73 | 133 |

The application of the DRB D7 on November 9, 1994 and February 7, 1995, for control of downy brome in Kentucky bluegrass resulted in 70 and 67% control of downy brome, respectively, however, the results were confounded by BEACON and POST applications the previous cropping season. While these weed control results are not satisfactory, they are encouraging. The results also point out the need to test responses to joint herbicide-biocontrol agent studies.

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Table 1. Origin of DRB isolates and percent of total isolates inhibiting annual bluegrass root length 50 to 74%, 75-89%, and greater than 90%.

| Species DRB isolated from | Soil type[1] | Crop system | Percent of total isolates inhibiting annual bluegrass roots 50-74% inhibition | 75-89% inhibition | >90% inhibition |
|---|---|---|---|---|---|
| Poa | DaA | ryegrass | | 12 | 4 |
| Poa | DaA | corn | 6 | 24 | 2 |
| Poa | WoA | wheat | 10 | 12 | 2 |
| barley | WoA | barley | 4 | 6 | 2 |
| Poa | WoA | road edge | 8 | 22 | 2 |
| Poa | WeA | organic | 12 | 26 | |
| Poa | Ma | organic | | 44 | 6 |
| Poa | Ca | triticale | | 6 | |
| triticale | Ca | triticale | 2 | 28 | |
| Poa | WoA | wheat | | 30 | |
| wheat | WoA | wheat | | 14 | |

[1]DaA = Dayton-Amity soil series (Silty clay loam)
WoA = Woodburn (Silt loam)
WeA = Willamette (Silt loam)
Ma = Malabon (Silty clay loam)
Ca = Camas (gravely sandy loam)

# EFFECTS OF VARIOUS TYPES OF POST-HARVEST RESIDUE MANAGEMENT ON KENTUCKY BLUEGRASS SEED YIELD IN CENTRAL OREGON, ON-FARM RESULTS FROM 1991-1996

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## Introduction

The inter-mountain regions of Idaho, Washington and Oregon provide a stable supply of high quality Kentucky bluegrass (*Poa pratensis L.*) seed. Early in the development of Kentucky bluegrass (KBG) seed production systems, growers became aware of the importance of post-harvest residue removal. Open field burning (OFB) was adopted as the standard practice for post-harvest residue removal, primarily for suppression or elimination of diseases. In addition to disease control, however, post-harvest OFB has appeared directly responsible for maintenance of high yield and high quality seed production of KBG in the Pacific Northwest. Previous studies not reviewed here strongly indicated that removal of straw residue increases seed yields in KGB through enhanced floral initiation in fall tillers, presumably related to enhanced light impingement upon grass crowns and tillers – in general, the greater exposure of the crown, the greater the response. This practice is universally implemented by growers of KBG in central Oregon. Because of increased concern for the effects of burning on air quality, ways of economically removing post-harvest debris without generating noxious and unsightly smoke still are being sought.

The primary focus of this study was to evaluate the most advanced technology in mechanical removal of post-harvest residue. We intended to identify what extent of residue removal was feasible with the best available methods, and the response of the crop with respect to fertile tiller numbers and seed yield. Secondarily, it is important to place cost of production figures on alternative methods, certainly with respect to altered yields, but also with respect to altered costs of implementation and other secondary effects such as changes in weed or other pest occurrence and control which non-thermal residue management may require. For this report, we only address the plant response and yield issue.

The most common practice of open field burning (OFB) leaves the field absent of any non-combustible debris and also eliminates debris around the crown of the plant. Mechanical residue removal can be accomplished by using various methods. Each method varies in the amount and efficiency of soil cleansing. Equipment used in this study included a needle-nose wheel rake (NNR), which has stiff tines to scratch the residue and thatch and remove debris from around the crowns; and a redesigned close-clipping and vacuuming machine (CC) both developed by Rear's Manufacturing in Eugene, Oregon. This machine enabled us to clip and vacuum remove the stubble to a 1 inch height. With NNR, the bulk of the residue is windrowed, which is baled or otherwise disposed. The NNR was introduced into the study in 1994, so was not as well investigated as other equipment. Other equipment tested included a conventional flail mower (FC), a mulching flail (FM) and a propane flamer (PF). The mulching flail, also produced by Rears, intended to render the residue into a very finely ground product, was introduced into a companion study in 1995, but was not included in the study reported here. Propane flaming was tested because it produced relatively little smoke after vacuum sweep or rake treatments, and is further discussed below. Several of these items were used in various combination treatments.

A number of years ago in grass seed fields in central Oregon, the full post-harvest straw load was burned. Field burning with full straw load resulted in rapid, hot fires. In more recent years, however, the common grower practice has been to bale a substantial amount of the grass seed straw and sell or utilize this straw as animal feed. Thus, only enough straw fuel is left in the field to carry a fire under normal conditions. Consequently, under windy or certain other conditions, modern open field burning in central Oregon often leaves unburned skips in fields. To provide for uniform residue removal, a common practice is to follow an open field burn with a propane flamer to finish the thermal residue removal. Propane flamers are common and available equipment items in central Oregon, used in peppermint and some other crop production in the region, thus this item was included in combination with some mechanical tools. Further, due to the practice of baling prior to residue management, baling was included as a preliminary treatment to all other treatments of this investigation. The OFB treatment we utilized, further described below, may vary from OFB treatments described from other KBG regions, especially where a full straw load is burned.

We note that the timing of post-harvest residue management varies among regions, which may have important implications on the relative impact of residue management options. For example, in Union County, Oregon, past research indicated that delays in post-harvest residue removal and post-harvest irrigation beyond the period of seed combining (in early-mid August) resulted in less yield the following season. Presumably, in that region, maximizing the length of time for fall regrowth favors higher fertile tiller development and subsequent yield (Tom Chastain, personal communication). In contrast, in central Oregon, seed combining occurs in mid-late July and growers commonly wait until mid-August to early September to employ residue management and to re-irrigate. In central Oregon, this leaves at least 2 and usually 3-5 wk during which the grass plants lie more or less dormant and un-irrigated. The growing season in Union County is somewhat shorter than in central Oregon, so immediate irrigation and promotion of fall regrowth following seed combining proves advantageous. In central Oregon, growers believe that if they irrigate and encourage regrowth too early (e.g. early to mid-August), or if untimely rains occur, fall regrowth becomes too rank and subsequent seed yields are lessened. Further, the extra irrigations are costly in themselves. There is no research to confirm the central Oregon system optimizes production, but it is likely that the belief and experience of local farmers has high validity. Thus, in our research we combined at the same time as the central Oregon growers, and imposed residue management at about the same time that these growers burned their fields, after which the fields were irrigated.

**Methods**

In central Oregon, grass seed is produced primarily in the Culver and Agency Plains sub-regions, both of which are relatively uniform with respect to soil type and irrigation method, and with respect to farming practices among neighboring farmers. For the data reported here, in each of three successive years, two paired on-farm sites were established (on separate but nearby commercial farms) in 1991 in farmers' fields on the Agency Plains to evaluate the full compliment of the latest technology for mechanical post-harvest residue removal on KBG seed production. The experimental design in each field was a randomized block design with three or four replications. All six fields were within a few miles of each other, located on Madras Loam soil. All fields were level sufficient to furrow irrigate, but the KBG seed crops in each field were sprinkler irrigated on flat ground during the course of this study. In previous experimentation, we have found a high degree of crop uniformity with such fields.

It was felt that the degree to which a grass seed variety was rhizomatous might influence its response to residue management, so one field in the pair was planted with an aggressive variety (highly rhizomatous) and the other field with a non-aggressive variety (less rhizomatous). Similarly, two more paired fields were added in 1992 and in 1993 (for a total of six fields) for comparison over time. Harvest data were collected from the second, third and fourth harvest years for each pairing. Beginning in 1994, the oldest two fields from each year of planting were deleted from the study. Thus, the last harvest was from two fields in 1996. The actual varieties utilized are listed in Figure 1.

Residue management treatments are shown in Figure 1. Specific dates for planting and harvest are not shown here. Harvest and residue management were conducted within a day or so of the comparable commercial activity in each field. In general, for both commercial and trial areas, harvest occurred in the last half of July, and residue management occurred in the last half of August, with a gap of 3-4 weeks between harvest and residue management. Once begun, all residue management treatments were completed within a three day period for each field. Following harvest, irrigation was resumed within a few days after residue management was completed.

As discussed above, prior to any additional post-harvest residue management, a large portion of the crop residue was removed by baling. For OFB, following such baling, the remaining straw usually was sufficient to carry a fire depending on various weather conditions and whether any crop re-growth has occurred. We did not attempt to measure the fuel load, however. If OFB was insufficient for removal of all residue, any remaining residue was removed by propane flaming (PF). Thus, for our experimental purposes, the standard "field treatment" consisting of baling followed by OFB (and followed by PF if necessary). No full-straw OFB treatment was included. This standard treatment was compared with several alternative methods of stubble management as listed in Figure 1. Other than residue management treatments, all other management practices were as per the commercial farm methods.

The treatment plot size was 100 x 22 ft. Alleys between plots were mowed prior to swathing, and plots were windrowed down the middle by the farmer. Plots were harvested with an International 503 combine, adjusted for gathering all seed from the harvested 100 foot strip. All "dirty" seed was collected directly from the auger into a plastic barrel. Sub-samples were collected from the auger periodically, and were cleaned at the USDA facilities at Oregon State University, Corvallis. For each plot, cleaned seed weight per acre was calculated from the plot size, dirty-seed weight per plot, and the proportion of clean seed per dirty seed sub-sample.

Data were collected for vegetative tiller development, fertile tiller development, seed yield, and seed quality. For the first several years of this study, seed germination and 1000 seed weights were determined. As nearly no variability occurred with respect to residue management treatments, this was discontinued later in the trial and the data are not reported here.

**Results & Discussion**

Mean clean seed yield data from second through fourth year harvests from each of the six fields involved is shown in Figure 1. Vegetative and fertile tiller data are not included here, but the number of fertile tillers were closely correlated with yield.

Additionally, for each field, the mean clean seed weights for the second through fourth years were transformed into percentages of the second year seed yield for open field burn treatment (OFB). In this manner, data from the three aggressive and non-aggressive variety plantings were averaged together on a percentage basis. The mean percentage for each treatment for the three aggressive and non-aggressive variety-fields also is shown in Figure 1. A statistical analysis was conducted using the three mean relative yields for each of 2$^{nd}$ , 3$^{rd}$ and 4$^{th}$ harvest years as replicates. Clearly, the analysis can be questioned on the basis of different sets of years involved, on the basis of differences between varieties within the aggressive and non-aggressive categories, on the basis of differences among fields and on the basis of differences among farmer management practices. With our experience and knowledge of local conditions, we would argue that field and farmer variations are reasonably and acceptably uniform. We might also argue that if statistical trends were found in spite of yearly and variety differences, then the statistics must be rather robust, but we recognize the criticisms of performing this analysis. [In fact, a companion study is underway to circumvent these criticisms, in which single non-aggressive and aggressive varieties are being grown at a single location at the COARC Madras research farm, over three years of planting, with residue managed similar to that reported here.]

As expected, seed yields declined with age of stand, as shown in Figure 1. Overall, yields for aggressive varieties declined somewhat similarly to non-aggressive varieties, although the decline in yield was greater for the third harvest year for non-aggressive vs. aggressive varieties. Except as noted below, the aggressive and non-aggressive growth types seemed to respond similarly to various residue management treatments.

Except for one field ('Bristol,' 1994-1996), the bale-only treatment consistently resulted in the least (or near to the least) seed yields, as well as the lowest number of fertile tillers (data not shown). Except for this same field, highest yields, as well as most fertile tillers (data not shown) were produced using OFB, under which treatment residue was presumably completely removed. In many fields and years, the differences between OFB and bale-only treatments was statistically significant ($P \leq 0.05$). With few exceptions, all mechanical and mechanical plus propane flaming combinations of residue management resulted in seed yield intermediate to OFB and baling alone (Figure 1), as well as intermediate fertile tiller numbers; in some of these cases these differences were significantly different ($P \leq 0.05$) from either the OFB treatment or the bale-only treatment, or both. In general, three-year averages demonstrate that open field burning results in substantially more seed yield over time (Figure 1).

In Figure 1, data from all treatments including the NNR are shown averaged together. Specifically, a Bale-Flail-Needle-Nose Rake combination was included as a post-harvest treatment in the summers prior to harvest years 1992-93-94 and 1993-94-95, but not in 1994-95-96, in both the aggressive and non-aggressive varieties. In 1994-95-96, a Bale-Needle-Nose Rake treatment and a Bale-Needle-Nose Rake-Propane treatment were included. Additionally, a

Bale-Flail-Propane treatment was included only in the 'Merit' trial in 1993-94-95, which is not shown in Figure 1.

Because the NNR treatments were not identical in all variety-fields, yet their yields, when comparable, were very similar, all three variations using the NNR treatments are represented in Figure 1 by the same symbol. For the 1994-95-96 sites, the NNR data shown are an average of the nearly identical yields between the similar treatments Bale-Needle-Nose Rake and Bale-Needle-Nose Rake-Propane. For the remaining four variety-fields, the NNR treatment consisted of a Bale-Flail-Needle-Nose Rake treatment, which was performed at those variety fields only.

In the 'Merit' trial harvested in 1993-94-95 (not shown in Figure 1), the yields for the Bale-Flail-Propane treatment were just above that for OFB in 1993, between the two Crew Cut treatments in 1994, and below the Bale Only treatment for 1995. This treatment was included only in this one field.

In the exceptional field noted above, planted to 'Bristol' in 1993 and harvested in the second through fourth crop in 1994 through 1996, the bale only treatment yield was highest and OFB treatment yield was lowest, a near-reversal in yield performance, for the 1994 and 1995 harvests, whereas they followed the pattern of other fields for the 1996 harvest. No explanation is offered for this exceptional and inverted performance during 1994 and 1995 (resulting from residue management imposed in 1993 and 1994, respectively). We have noted, however, that 'Bristol' has performed unusually in another set of trials on the COARC station (data not shown), so perhaps 'Bristol' and 'Rugby,' in spite of each having aggressive growth habits, may not be directly comparable. Information on the uniformity or variability of response among bluegrass varieties would be useful and perhaps should be tested.

Fertile tiller numbers followed the same trends relative to treatments as seed yields (data not shown). Fall and spring vegetative tiller numbers showed no differences among treatments, with the exception that in the bale-only treatment there were fewer tillers (data not shown). In 1993 and 1994, thousand seed weight and seed germination percentages (data not shown) were comparable among all treatments for each field ($P \leq 0.05$), and were unaffected by residue management; these data were discontinued for 1995 and 1996.

No detailed economic analysis has been performed on these data at this time. Our yield data indicate that, in central Oregon, mechanical means of residue management resulted in generally lowered yields compared to OFB. This, combined with the fact that OFB is less expensive than all the mechanical means of residue removal evaluated, suggests that no alternative treatment utilized to date would be acceptable in central Oregon as long as OFB is an available tool.

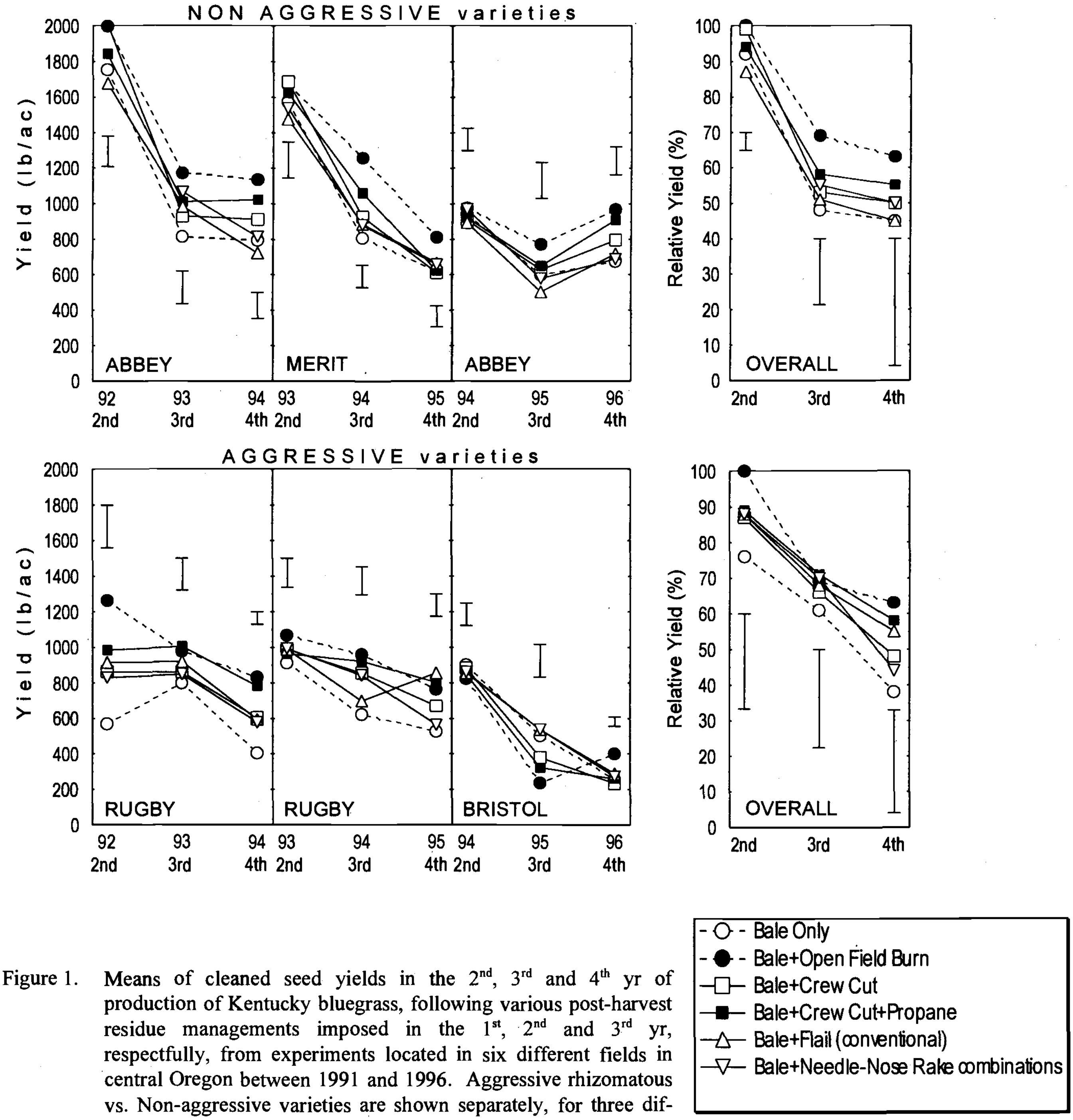


Figure 1. Means of cleaned seed yields in the 2nd, 3rd and 4th yr of production of Kentucky bluegrass, following various post-harvest residue managements imposed in the 1st, 2nd and 3rd yr, respectfully, from experiments located in six different fields in central Oregon between 1991 and 1996. Aggressive rhizomatous vs. Non-aggressive varieties are shown separately, for three different yr of planting. Each trial included a replicated, randomized block experimental design with 3 replications; least significant differences (LSD, P≤5%) among treatment means are shown for each yr within each trial. The overall means for the 2nd, 3rd and 4th yr harvests are shown for each growth type, after converting actual yields to relative yields based on the percentage of the 2nd yr's yield in the Open Field Burning treatment for each trial. The validity of using LSD for the overall means is discussed in the text. Data from several Needle-Nose Rake treatments were combined for this figure, and are discussed in the text. Data from a Bale-Flail-Propane treatment used in only one field is not shown in the figure.

# KENTUCKY BLUEGRASS SEED EVAPOTRANSPIRATION IN CENTRAL OREGON

*A.R. Mitchell, S.M. Griffith, and C.L. Yang.*

**Abstract**

The water requirements for Kentucky bluegrass (*Poa pratensis* L.) seed production during the spring months were studied for seed the first, second and third year of seed production and to develop a crop coefficient (Kc) relationship for evapotranspiration (ET) relative to reference ET. Both aggressive ('Glade') and nonaggressive ('South Dakota') Kentucky bluegrass cultivars were compared for water use, dry matter, and seed yield. Daily crop water use was calculated by measuring the daily changes in soil water content from Watermark soil sensors that were buried at several depths and multiplexed to an automatic data logger. There were no significant differences in crop water use, final shoot dry mass, and the third seed-crop yield between cultivars. Cumulative growing-season water use calculated by the water balance equation was 14.4, 12.8, and 10.8 inches in 1994, 1995, and 1996, respectively. Seasonal crop water use determined by the multiplexed system was comparable to those based on water balance calculations. Early in the season, the crop coefficient (Kc) was 0.7, which was reflective of a mid-season crop-growth stage; after anthesis, the Kc values declined to 0.3 at harvest.

**Introduction**

The water requirements for Kentucky bluegrass seed production have not been directly studied and published estimates of crop water use, or evapotranspiration (ET), do not agree. Using three sources of data for central Oregon as examples, Kentucky bluegrass seed production water use was listed as 35.9 inches by Cuenca et al. (1992), as 14.6 inches by the Bureau of Reclamation (1995; based on a five-year average), and as 5.9 inches by Watts et al. (1968). This large discrepancy needs to be examined and resolved with field measurements that substantiate water use estimates.

The objective of this study was to determine the crop water use of Kentucky bluegrass seed production for aggressive and nonaggressive cultivars. It is useful to make crop ET comparable across multiple growing seasons and locations by expressing values relative to potential evaporation. For this purpose, the secondary objective was to develop a crop coefficient (Kc) relationship for the crop water use of Kentucky bluegrass grown for seed.

**Materials and Methods**

Water use was measured on Kentucky bluegrass cultivars 'Glade' and 'South Dakota' grown for seed production at the Central Oregon Agricultural Research Center, Madras, Oregon. The cultivars were selected based on their contrasting aggressivity, in terms of their rhizome and tiller production characteristics: Glade the most aggressive, and South Dakota the least. The soil was a Madras loam (fine-loamy, mixed, mesic, Xerollic Duragid).

Plots (10 ft by 20 ft) were sown in rows at 1-ft centers in the fall of 1993. The experimental design was a randomized complete block with four replications, with three replications used for measuring crop water use. Seasonal water use, biomass, and seed yield differences between cultivars were tested using ANOVA as a randomized block design, and differences in water use between cultivars were determined by a Fisher's T-test.

The trial was maintained according to common practices for weed and pest control, irrigation, and fertilizer application. Sprinklers arranged in a 30-ft by 30-ft grid were equipped with 9/64-inch diameter nozzles and operated at 45 psi. Irrigation was applied as soon as water was available in the spring.

A 1-$m^2$ section of each plot was hand-harvested for dry matter and seed yield determination. Samples were weighed for dry matter after drying at 150° F, and stored for later threshing of the seed. Post-seed harvest residue management consisted of close-clipping the crop near to the ground and mechanically removing residue.

An automated weather station located within 150 ft of the experimental plots provided hourly weather data for precipitation and the calculation of reference evapotranspiration (ETref). The Kimberly-modified Penman equation was used to calculate ETref of an alfalfa crop according to Wright (1982). The weather station was managed by the US Bureau of Reclamation as part of their AgriMet network of weather stations.

Daily ET measured by the sensors (ETsensor) was calculated according to the method of integrating changes in soil water content into daily depletion, as outlined in Mitchell and Shock (1996). Daily ETsensor estimates could not be based directly on sensor readings during and immediately following precipitation or irrigation events since the sensors do not detect evaporation of water directly from leaf surfaces. For days with significant precipitation or irrigation, we assumed the magnitude of ET to be equal to that of the previous day.

For comparison with the sensor method, total seasonal ET was estimated using water balance equation (ETwb) from early March to July 1 according to

$$ETwb = I + P + \Delta S - D - R$$

where I was irrigation, P was precipitation, and ΔS was the difference in soil water storage between the initial (March) and final (July) measurement dates. Runoff, R, was assumed to be negligible. Drainage from the profile, D, was calculated for periods of high soil water content that occurred in 1996 using a numerical water flow model (Simunek et al., 1992) with hydraulic properties of the Madras loam determined from earlier measurement.

The crop coefficient (Kc) was calculated as the ratio of ETsensor to ETref. We estimated Kc by fitting polynomial equations to the Kc data from five-day periods throughout the season.

**Results**

Above-ground shoot dry mass did not differ significantly ($\alpha = 0.05$) between Glade and South Dakota during the first through the third year of seed production, whereas the first and second year seed yields (1994) were greater for nonaggressive South Dakota compared to Glade (Table 1). In contrast, third-crop (1996) seed yield did not differ significantly between cultivars (Table 1). Lower first-year seed yield of Glade was not usual considering the long floral induction requirement for Glade which is necessary for maximum fertile tiller production and seed yield.

Table 1. Kentucky bluegrass dry matter and seed yield by cultivar.

| | 1994 | 1995 | 1996 |
|---|---|---|---|
| | ------------(lb/acre) ---------- | | |
| Seed Yield | | | |
| Glade | 84 * | 284 * | 463 |
| South Dakota | 335 | 731 | 502 |
| Dry Matter | | | |
| Glade | 8848 | 10798 | 6591 * |
| South Dakota | 10357 | 10395 | 8919 |

*Significant at the 0.05 probability level

Precipitation and irrigation amounts are listed as components of the ETwb calculations in Table 2. Irrigation was managed so that soil water in the profile was above 4.5 inches for the 20-inch depth of soil (Figures 1 and 2). In 1994, seasonal ETsensor values did not differ significantly between the Glade (14.5 inches) and South Dakota (14.3 inches) (Table 2). In 1996, ETsensor was not statistically different between cultivars, and differed by only 0.9 inches, or 6 percent of the total.

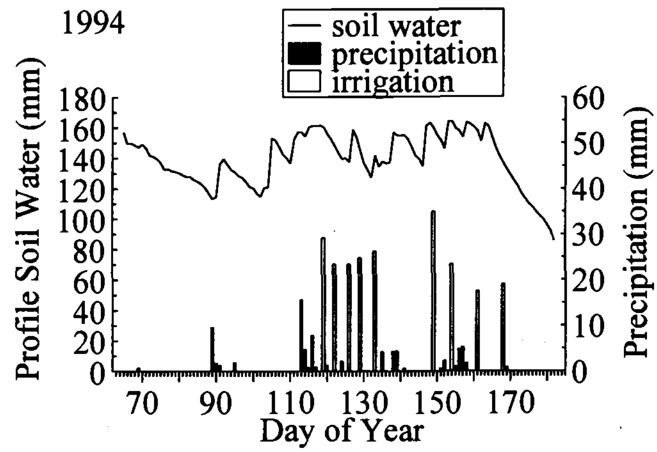


Figure 1. Depth of water in 600-mm soil profile, and precipitation and irrigation events in 1994.

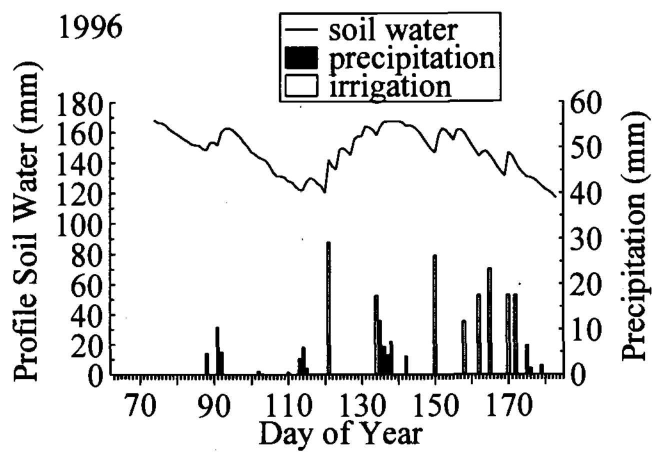


Figure 2. Depth of water in 600-mm soil profile and precipitation and irrigation events in 1996.

The ETwb data was in close agreement with the ETsensor values. In 1994, the ETwb (14.5 inches) was virtually identical to the average ETsensor (14.4 inches). In 1996, the ETwb (10.8 inches) was also comparable to the ETsensor (10.1 inches).

The Kc curve (Figure 3) demonstrates the relationship between ETsensor and ETref as well as the difference between years 1996 and 1994. The general form of Kc curves consists of initial, crop development, mid-season, and at-harvest stages (Doorenbos and Pruitt, 1977). In Figure 3, the initial Kc value for Kentucky bluegrass was relatively high (0.7), indicating that the grass did not experience the same initial stages as most field crops (Doorenbos and Pruitt, 1977). This is not surprising, however, because of the Kentucky bluegrass growth the previous September prior to dormancy in winter. When the Kentucky bluegrass broke dormancy in the spring, the crop rows were already over 6 inches wide and volunteer seedlings were growing in the margins; all of which contribute to crop water use.

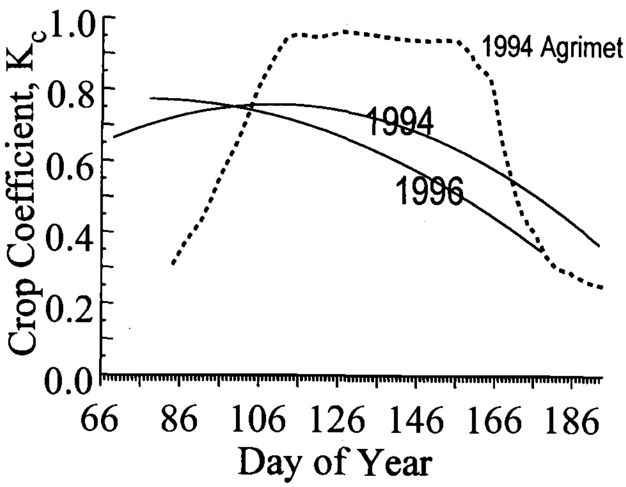


Figure 3. Kc values from AgriMet and ETsensor.

At midseason, the Kc remained at 0.7 until late May in both years. During this period, most of the volunteer seedlings succumb to competition from the established bluegrass, and the Kc during midseason remained stable at 0.7. The Kc began its decline at approximately day 150 in both years, which corresponds with anthesis, the reproductive stage of Kentucky bluegrass. The Kc values continued to decline once irrigation ceased two weeks prior to harvest.

**Discussion**

The various estimates of Kentucky bluegrass seed water use in the literature differ from our field measurements due to different estimates of the cropping periods and Kc. Watts et al. (1968) arrived at a low cumulative ET value when using Blaney-Criddle monthly ET estimates and assuming a growing season (or period of water use) from mid-April to mid-June, although our data have shown that bluegrass starts using water earlier in the year (Figures 1 and 2.) Cuenca et al. (1992) calculated high ET values when using the modified Blaney-Criddle method (Doorenbos and Pruitt, 1977) with the assumption that the growing season was the entire year. Their Kc values appear to be based on Kc values of turfgrass, for which considerable research has been done. However, unlike grass seed, turfgrass is regularly cut and is at full cover, which gives it a high Kc near 1.0. In contrast, Kentucky bluegrass seed followed the water-use pattern of grain, in which Kc decreases late in the season as the plant shifts from vegetative growth to reproductive growth.

The Bureau of Reclamation's AgriMet ET estimates (ETagrimet) were based on daily calculated Epenman from weather station data in conjunction with Kc values that started in early March and ended in mid June (Bureau of Reclamation, 1994). The ETagrimet values were closer to the ETsensor data than the estimates previously cited (see Table 2). The ETagrimet was higher than the ETwb, which, in turn, was equal or greater than the ETsensor measurement. The seasonal ETagrimet values were higher because of a different Kc relationship that had a higher mid-season Kc and a more-gradual decrease in Kc after anthesis, as shown in Figure 3 from Bureau of Reclamation (1994). In comparison with the ETsensor-derived Kc, the AgriMet Kc is lower initially, but greater in mid season. These Kc discrepancies cancel each other to some extent, but overall the ETagrimet calculations are slightly higher than the ETsensor and ETwb for the season.

Future research should focus on the late-season irrigation in September and October that is necessary to produce fertile tillers in the dry autumn climate of the Northwest, although it was not included in our analysis. Like the spring season data collected here, there is a need for actual measurements of late-season crop water use and irrigation requirements.

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Table 2. Components of water budget averaged over cultivars, and ET by water balance, sensors, and AgriMet estimates.

| Year | Irrigation | Precipitation | Soil Moisture Storage | Drainage | ETwb | ETsensor | Etagrimet |
|---|---|---|---|---|---|---|---|
| | (inches) | | | | | | |
| 1994 | 8.7 | 3.4 | 2.3 | 0 | 14.4 | 14.4 | 14.8 |
| 1995 | 6.1 | 4.4 | 2.3 | 0 | 12.8 | n/a | 14.1 |
| 1996 | 6.3 | 3.6 | 2.0 | 1.1 | 10.8 | 10.1 | 14.3 |

# KENTUCKY BLUEGRASS VARIETY TOLERANCE TO BEACON

*G.W. Mueller-Warrant, D.S. Culver, S.C. Rosato and F.J. Crowe*

Twelve popular varieties of Kentucky bluegrass were seeded August 28-29, 1996, at the Central Oregon Agricultural Research Center in Madras to evaluate possible differences in tolerance to Beacon (primisulfuron). Beacon plus 1% crop oil concentrate was applied October 8 at full (0.75 oz product/acre) and half rates, December 3 at full rate, and split applied at half rate both dates. The full rate was also applied March 24, 1997, to plots that had served as extra untreated checks until that time. Weed populations were relatively light except for volunteer barley along one edge of the field. Variety mainplots were 16 x 150 ft long, with three replications, and herbicide treatment subplots were 8 x 50 ft long. Crop injury was evaluated March 24 by measuring plant diameter (row width) at ten randomly chosen locations per plot. Plant height was also approximately equal to row width at this stage of growth. For each variety, plant size in Beacon-treated plots was expressed relative to size in the untreated checks in each replication.

Beacon stunted the growth of seedling Kentucky bluegrass, and occasionally thinned the stands. Degree of stunting was affected by application date and rate (Table 1) and by variety (Table 2). Maximum injury occurred when the full rate was applied October 8 or split-applied between October 8 and December 3. However, Beacon provided good control of volunteer barley and downy brome, and the stunting caused by competition in those occasional small patches where weeds were densest was more severe than that caused by any of the herbicide treatments. The full rate applied December 3 caused much less injury than when it was applied October 8 or split-applied between both dates, and reductions in plant size from the December 3 full rate treatment were generally non-significant compared to the untreated checks. 'Baron,' 'Abbey,' 'Monopoly,' 'Viva' and 'Merit' were the most tolerant varieties, showing only 12 to 18% reductions in plant size in response to the two most severe treatments. The seven remaining varieties showed 25 to 38% reductions in size from these treatments, and had much more noticeable gaps in their stands. 'Bartitia' was the most sensitive variety, and new seedings of it should probably not be treated when only one month old. However, even Bartitia possessed adequate tolerance by three months after seeding, and probably could be treated sooner if weed populations warranted it. Growers should be cautious when treating new Kentucky bluegrass stands with Beacon until they have had personal experience treating their own varieties on their own soils. All varieties appear to be stunted at least briefly with Beacon, but have good potential to recover. Possible effects of these treatments on seed yield will be measured this summer.

Table 1. Effect of Beacon application date and rate on Kentucky bluegrass seedling size March 24, 1997.

| Beacon application rate and date | Avg. seedling size† |
|---|---|
| (1.0X = 0.0352 lb ai/acre) | (% of untreated check) |
| Untreated check | 100.0 |
| 0.5X on Oct. 8 | 82.9 |
| 1.0X on Oct. 8 | 77.4 |
| 0.5X on Oct. 8 / 0.5X on Dec. 3 | 77.4 |
| 1.0X on Dec. 3 | 87.8 |
| LSD(0.05) | 5.3 |

† Seedling size (row width) averaged over all 12 varieties.

Table 2. Kentucky bluegrass variety response to the most damaging Beacon treatments.

| Kentucky bluegrass variety | Size of untreated seedlings | Size of treated seedlings† |
|---|---|---|
| | (inches) | (% of untreated check) |
| Baron | 2.23 | 88.2 NS |
| Abbey | 2.35 | 87.2 NS |
| Monopoly | 2.85 | 85.2 + |
| Viva | 2.36 | 84.0 + |
| Merit | 2.80 | 82.3 * |
| Georgetown | 3.11 | 75.1 ** |
| Wildwood | 2.23 | 74.8 ** |
| Ascot | 1.95 | 74.2 ** |
| Midnight | 2.69 | 74.0 ** |
| Bristol | 2.40 | 74.0 ** |
| Shamrock | 2.41 | 68.2 ** |
| Bartitia | 2.37 | 61.7 ** |

† Seedling size (row width, March 24) averaged over the two most damaging treatments, full rate applied October 8 and half rate split-applied October 8 and December 3. Full rate = 0.0352 lbs ai/acre. +,*,** indicates size reduced relative to untreated checks at the P=0.10, 0.05, and 0.01 probability levels, respectively. NS indicates non-significance.

# EVALUATION OF HERBICIDES FOR CONTROL OF ROUGHSTALK BLUEGRASS AND INJURY TO KENTUCKY BLUEGRASS

*M.D. Butler*

Research to evaluate herbicides for control of roughstalk bluegrass in Kentucky bluegrass was initiated in 1993. A wide variety of herbicide combinations were screened during the 1994-1995 season. The objective of this project was to evaluate in replicated plots the most promising fall and spring-applied herbicides from 1994-1995. Herbicides evaluated in combination included Sinbar, Karmex, Beacon, Goal, Lexone, and Assert.

Combinations of Sinbar at 0.25 and 0.5 lb/a, Karmex at 2 lb/a, Beacon at 0.38 and 0.75 oz/a, Lexone at 2.7 and 5.3 oz/a, Goal at 15 fl oz/a, and Assert at 0.75 pt/a were applied October 14 to two roughstalk bluegrass fields. Herbicides were evaluated for control of established and seedling plants, and to two Kentucky bluegrass fields to determine crop injury. Spring applications were made April 3 and April 26. Treatments included a spring application of Sinbar at 0.25 lb/a plus Karmex at 2 lb/a following a fall application of Lexone at 2.7 oz/a plus Goal at 15 fl oz/a, a split application of Beacon at 0.38 oz/a, and split application of Beacon at 0.38 oz/a plus Karmex at 0.5 lb/a followed by Beacon at 0.38 oz/a. Treatments were applied with a $CO_2$ pressurized, hand-held, boom sprayer at 40 psi and 20 gal/a water. Plots 10 ft x 20 ft were replicated three times in a randomized complete block design. A nonionic surfactant was applied at 1 qt/100 gal in combination with all herbicides. Visual evaluation for control of established and seedling roughstalk bluegrass and crop injury based on reduction in plant biomass to Kentucky bluegrass was conducted January 5, 1996. Pre-harvest evaluation of percent reduction in seed set was conducted for roughstalk bluegrass June 23, and for Kentucky bluegrass June 26, 1996.

The effect of full-applied herbicides on established and seedling roughstalk bluegrass and injury to Kentucky bluegrass are summarized in Table 1. Seedling roughstalk bluegrass was more easily controlled than established plants. Of the fall-applied herbicides Sinbar at 0.5 lb/a plus Karmex at 2 lb/a provided the greatest control of roughstalk seedling and established plants at 89 percent and 39 percent control, respectively. Beacon at 0.38 oz/a plus Karmex at 2 lb/a provided 86 percent control of roughstalk seedling plants but only 9 percent control of established plants. Treatments that included Goal produced 20 percent injury to Kentucky bluegrass, more than other treatments. Spring, split-applications of Beacon at 0.38 oz/a provided 81 percent control while Beacon at 0.38 oz/a plus Karmex at 0.5 lb/a provided 84 percent control of seedling and established roughstalk bluegrass.

No difference among treatments could be detected by visual evaluation of seed set prior to harvest for either roughstalk bluegrass or Kentucky bluegrass, except for the two spring split-applications. Despite the serious damage, what plants remained did established seed heads. Presumably they were late enough that they did not produce viable seed. Research over the last 3 years points to the combination of Sinbar and diuron as the best fall-applied treatment for control of roughstalk bluegrass. This first year of data on spring applied Beacon, and combination of Beacon and diuron appear promising, but further research is required.

Table 1. Effect of fall-applied herbicide applications October 14, 1996 on established and seedling roughstalk bluegrass at two locations, and crop injury to Kentucky bluegrass at two locations near Madras and Culver, Oregon.

| Treatments[2] | Rate | Roughstalk bluegrass control[1] Seedling plants | Established plants | Injury to Kentucky bluegrass |
|---|---|---|---|---|
| | (product/a) | (%) | | |
| Sinbar + Karmex | 0.5 lb + 2.0 lb | 89 a[3] | 39 a | 9 |
| Sinbar + Beacon | 0.5 lb + 0.38 oz | 83 a | 3 b | 12 |
| Sinbar + Goal | 0.5 lb + 15 oz | 80 a | 8 b | 20 |
| Sinbar + Lexone | 0.5 lb + 5.3 oz | 80 a | 17 ab | 7 |
| Sinbar + Assert | 0.5 lb + 0.75 lb | 70 a | 15 ab | 15 |
| Sinbar + Karmex | 0.25 lb + 2.0 lb | 80 a | 20 ab | 9 |
| Lexone + Goal | 2.7 oz + 15 oz | 74 a | 1 b | 20 |
| Beacon + Karmex | 0.38 oz + 2.0 lb | 86 a | 9 b | 10 |
| Untreated | ---- | 0 b | 0 b | 0 |

[1] Data are the average of two fields; Saber and Cypress.
[2] Data are the average of two fields; Merit and SR 2100.
[3] Mean separation with Honesty Significant Difference at $P \leq 0.05$.

# EVALUATION OF PREEMERGENCE HERBICIDES ON CARBON-BAND PLANTINGS OF ROUGHSTALK BLUEGRASS SEED CROPS

*M.D. Butler*

Carbon-banding grass seed crops at planting to protect emerging seedlings from herbicide damage is gaining popularity in central Oregon. Experimentation has focused particularly on roughstalk bluegrass. The objective of this project was to evaluate Karmex, Lexone, and Sinbar applied preemergence alone, and in combination, on carbon-banded roughstalk bluegrass in three commercial fields near Madras and Culver, Oregon.

Commercial equipment was used to place a 1.5 inch-wide band of carbon over the seed row at the rate of 35 lb/treated acre in combination with Solution 32 at 45 gal/a. Treatments included Karmex at 2.5 and 5 lb/a, Lexone at 0.3 and 0.7 lb/a, Sinbar at 0.6 and 1.2 lb/a, Karmex at 2.5 lb/a plus Lexone at 0.3 lb/a, and Karmex plus Sinbar each at 0.6 lb/a. Treatments were applied preemergence with a $CO_2$ pressurized, hand-held, boom sprayer at 40 psi and 20 gal/a water at the Roff farm September 7, at the DuRette farm September 8, and at the Grote farm October 4. Plots 10 ft x 30 ft were replicated three times in a randomized complete block design. Treatments were evaluated for crop injury, stand reduction, and percent control of common groundsel, China lettuce, buttonweed, henbit, cheatgrass, volunteer wheat, and volunteer barley. Visual evaluations were conducted at all locations during January and February.

The effect of herbicides applied over carbon banding on crop injury and stand reduction are provided in Table 1. Herbicide efficacy on various weed species by location is shown in Table 2.

A tank mix of Karmex (2.5 lb/a) plus Lexone (0.3 lb/a) provided overall weed control of 95 percent. Sinbar at 1.2 lb/a provided 96 percent weed control or better for all weeds except common groundsel, which was only 33 percent controlled. The tank mix of Karmex (0.6 lb/a) plus Sinbar at (0.6 lb/a) provided 94 percent control or better for all weeds except common groundsel at 40 percent. Karmex at 2.5 lb/a provided inadequate control of all weed species evaluated, except 87 percent control of common groundsel and volunteer wheat. The greatest crop injury and stand reduction resulted from Sinbar at 1.2 lb/a, followed by Lexone at 0.7 lb/a, Karmex at 0.6 lb/a plus Sinbar at 0.6 lb/a, and Sinbar at 0.6 lb/a. The least amount of crop injury and stand reduction in roughstalk bluegrass resulted from Karmex at 2.5 lb/a, followed by Karmex at 5 lb/a and Lexone at 0.3 lb/a. From this first year of data, it appears that a combination of Karmex (2.5 lb/a) and Lexone (0.3 lb/a) provided the best combination of weed control and crop safety.

Table 1. Effect of preemergence herbicide applications on carbon-banded roughstalk bluegrass near Madras and Culver, Oregon.

| | | Weed control[1] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | DuRette farm | | | | | Roff farm | Grote farm |
| Treatments | Rate | Common groundsel | China lettuce | Buttonweed | Henbit | Cheatgrass | Volunteer wheat | Volunteer barley |
| | (product/a) | (%) | | | | | | |
| Karmex | 2.5 lb | 87 ab[2] | 20 c | 63 a | 0 b | 20 b | 87 a | 23 bc |
| Karmex | 5.0 lb | 93 a | 100 a | 100 a | 100 a | 65 a | 83 a | 53 ab |
| Lexone | 0.3 lb | 93 a | 0 c | 92 a | 100 a | 67 a | 90 a | 67 ab |
| Lexone | 0.7 lb | 97 a | 83 ab | 97 a | 100 a | 94 a | 81 a | 69 ab |
| Sinbar | 0.6 lb | 0 c | 43 bc | 100 a | 100 a | 90 a | 95 a | 96 a |
| Sinbar | 1.2 lb | 33 bc | 97 ab | 100 a | 100 a | 99 a | 96 a | 99 a |
| Karmex + Lexone | 2.5 lb + 0.3 lb | 92 a | 97 ab | 100 a | 100 a | 91 a | 97 a | 85 a |
| Karmex + Sinbar | 0.6 lb + 0.6 lb | 40 abc | 100 a | 100 a | 100 a | 94 a | 90 a | 95 a |
| Untreated | --- | 0 c | 0 c | 0 b | 0 b | 0 b | 0 b | 0 c |

[1] Visual evaluations were conducted January 18, 1996 at the DuRette farm, and February 16, 1996 at the Roff and Grote farms.
[2] Mean separation with Honestly Significant Difference at $P \leq 0.05$.



Table 2. Effect of preemergence applications treatments on carbon-banded roughstalk bluegrass near Madras and Culver, Oregon.

| | | Crop injury[1] | | | Stand reduction[1] | | |
|---|---|---|---|---|---|---|---|
| Treatments | Rate | DuRette farm | Roff farm | Grote farm | DuRette farm | Roff farm | Grote farm |
| | (product/a) | (%) | | | | | |
| Karmex | 2.5 lb | 0 c[2] | 0 c | 8 b | 0 b | 0 b | 7 b |
| Karmex | 5.0 lb | 0 c | 15 abc | 8 b | 2 b | 12 b | 5 b |
| Lexone | 0.3 lb | 0 c | 13 abc | 20 b | 0 b | 8 b | 12 b |
| Lexone | 0.7 lb | 17 bc | 32 ab | 17 b | 8 b | 32 ab | 7 b |
| Sinbar | 0.6 lb | 20 bc | 23 abc | 18 b | 12 b | 22 b | 10 b |
| Sinbar | 1.2 lb | 92 a | 38 a | 75 a | 92 a | 60 a | 85 a |
| Karmex + Lexone | 2.5 lb + 0.3 lb | 7 bc | 10 bc | 17 b | 0 b | 7 b | 8 b |
| Karmex + Sinbar | 0.6 lb + 0.6 lb | 30 b | 30 ab | 17 b | 10 b | 32 ab | 11 b |
| Untreated | --- | 0 c | 0 c | 0 b | 0 b | 0 b | 0 b |

[1] Visual evaluations were conducted January 18, 1996 at the DuRette farm, and February 16, 1996 at the Roff and Grote farms.
[2] Mean separation with Honestly Significant Difference at $P \leq 0.05$.

# ERGOT LEVEL EFFECT OF SEED STOCK ON DISEASE INCIDENCE IN KENTUCKY BLUEGRASS

*M.D. Butler, F.J. Crowe and S.C. Alderman*

Ergot (*Clavicpes purpurea*) is an important flower-infecting pathogen which is particularly damaging to Kentucky bluegrass seed production. The objective of this study was to determine if there is a direct correlation between the number of sclerotia present in seed at planting and incidence of the disease in following years.

'Coventry' Kentucky bluegrass seed was infested with 0, 0.05, 0.5, 1, 2, and 3 percent ergot sclèrotia by weight. This seed was planted August 23, 1995 in 14 ft x 14 ft plots replicated 4 times at the Central Oregon Agricultural Research Center, Madras location. Plots were separated by 10 foot borders planted with 'Stephens' wheat to provide isolation and prevent movement of secondary spores by wind and insects between plots.

One hundred panicle samples were harvested from each plot on July 9, 1996. Samples were evaluated for percent of panicles with sclerotia, average sclerotia per panicle, and total sclerotia per 100 panicle sample.

This is the second year that there have been no differences in the number of sclerotia present at harvest between the different levels of ergot-infested seed at planting (Table 1). Possible explanations would include the possibility that the 10 foot borders of wheat may not have been sufficient to prevent cross contamination between plots, or alternately, spores could have come from outside the trial area.

The first year the plots were sprinkler-irrigated twice a week prior to harvest, and it appeared that a moist, high-humidity microclimate developed in the protected pockets of grass surrounded by the three-foot high wheat. This would have provided near optimum conditions for ergot infection during flowering. However, during this season plots were irrigated once a week, with the plots remaining relatively dry. Despite the dryer conditions, a moderate level of ergot developed in the plots, but was not significantly correlated with the level of inoculum. After two years, data from this research project is inconclusive concerning the effect of ergot level in seed stock on incidence of the disease the following year.

Table 1. Effect of sowing various levels of ergot-infested seed on incidence of the disease at the Central Oregon Agricultural Research Center, Madras location, during 1995-1996.

| Percent infestation of sown seed | Panicles with Sclerotia | Sclerotia per sample |
|---|---|---|
| | (%) | (number) |
| 0 | 36 | 122 |
| 0.05 | 22 | 103 |
| 0.5 | 18 | 66 |
| 1 | 18 | 47 |
| 2 | 31 | 104 |
| 3 | 23 | 134 |
| LSD .05 | NS | NS |

# EVALUATION OF FUNGICIDES FOR CONTROL OF ERGOT IN KENTUCKY BLUEGRASS

*M.D. Butler, F.J. Crowe and S.C. Alderman*

Ergot, caused by the fungus *Claviceps purpurea*, is an important flower-infecting pathogen in grass seed production regions of the Pacific Northwest. Of the grass species grown for seed in Oregon, Kentucky bluegrass is particularly affected by ergot. Traditional control has been through open field burning, which has partially suppressed the disease.

Previous fungicide evaluations in central Oregon during 1992 to 1995 indicate excellent ergot control with Punch, for which there are no plans for registration in the United States. Suppression of ergot has been provided by Tilt and Folicur. As a result of this research, and similar fungicide evaluations by William Johnston at Washington State University, ergot suppression was added to the Tilt label in 1995 through a 24(c) special local need registration. Folicur registration for use on grass seed is expected.

During the 1996 season fungicides evaluated for control of ergot were conducted in a commercial field of 'Gnome' Kentucky bluegrass on the Agency Plains north of Madras, and in a 'Coventry' Kentucky bluegrass plot at the Central Oregon Agricultural Research Center, Powell Butte location. The Powell Butte location was infested with ergot at 1 sclerotia/ft$^2$ on March 25, 1996. Fusilazole (Punch, Dupont), propiconazole (Tilt, Ciba), azoxystrobin (Quadris, Zeneca), and Orthorix (Best Sulfur Products) were evaluated during the 1996 season. Surfactants Penaturf, Sylgard 309, and a combination of Halt, sulfur, and copper (Unitec) were also evaluated in combination with fungicides or as the second of a double application.

Plots 10 ft x 20 ft were replicated five times in a randomized complete block design. Materials were applied using a 9-foot $CO_2$ pressurized boom sprayer with 8003 TwinJet nozzles at 40 psi and 30 gal/a water. Sylgard 309 at 16 fl oz/100 gal and R-56 at 1 pt/100 gal were applied with in combination with all fungicides, except as indicated in the tables. Treatments were applied at the Agency Plains location on June 5 and June 19, and at the Powell Butte site on June 15 and June 26, 1996. The first treatments were applied at early anthesis on the Agency Plains and at the initiation of anthesis at Powell Butte. Plots in the commercial field on the Agency Plains were covered with 4 mil polyethylene to prevent contamination during aerial application of Tilt on June 18 and June 27, 1996.

One hundred panicle samples were randomly collected from each plot on July 8 on the Agency Plains and July 15 at Powell Butte. Number of panicles with sclerotia, total sclerotia per sample, panicles with honeydew, and seed weight were determined per sample for each plot.

Results of the evaluation of fungicides for control of ergot are provided in Table 1 for the Agency Plains location, and Table 2 for Powell Butte. The level of ergot infection at both locations was very low, making separation between control provided by the different fungicide treatments difficult. Tilt at 8 oz/a and split 4 oz/a applications provided the greatest control when evaluating panicles with sclerotia at the Agency Plains location. Results for Quadris were mixed, with a trend for excellent control at the Powell Butte location, but poor results on the Agency Plains. Weight per sample and percent germination were unaffected by fungicide treatments.

Table 1. Evaluation of fungicides applied for ergot control to 'Gnome' Kentucky bluegrass on the Agency Plains near Madras, Oregon on June 5 and June 19, 1996.

| Fungicide treatments | Rate of product June 5 | Rate of product June 19 | Panicles with sclerotia | Seed weight per 100 panicles | Seed germination |
|---|---|---|---|---|---|
| | (fl oz/a) | | (%) | (g) | (%) |
| Punch | 28[1] | | 0.6 ab[6] | 5.7 | 85 |
| Tilt | 8 | | 0.4 b | 5.6 | 84 |
| Tilt + Penaturf | 8 | 48 | 0.8 ab | 5.5 | 84 |
| Tilt + Silgard | 8 | 32[2] | 1.4 ab | 5.3 | 80 |
| Tilt + Tilt | 4 | 4 | 0.4 b | 5.8 | 69 |
| Tilt + Tilt | 8 | 8 | 0.8 ab | 5.8 | 81 |
| Tilt + Tilt | 8[3] | 8[3] | 0.6 ab | 5.6 | 73 |
| Tilt + Tilt | 6[4] | 6[4] | 0.8 ab | 4.9 | 85 |
| Tilt/Penaturf + Tilt/Penaturf | 8/48 | 8/48 | 0.8 ab | 5.0 | 86 |
| Tilt/Orthorix + Tilt/Orthorix | 8/64 | 8/64 | 1.0 ab | 5.7 | 74 |
| Tilt /Halt + Tilt/Halt | 8/16[5] | 8/16 | 1.2 ab | 5.4 | 78 |
| Quadris + Quadris | 4[3] | 4[3] | 1.2 ab | 5.5 | 87 |
| Untreated | --- | --- | 2.6 a | 5.0 | 87 |

[1] Silgard at 16 fl oz/100 gal and R-56 at 1 pt/100 gal applied with all treatments except Tilt + Penaturf, Tilt + Silgard and the arial application of Tilt at 6 oz/a.
[2] fl oz/100 gals
[3] crop oil concentrate (COC) applied at 1% in combination with fungicides
[4] applied by air in combination with 8 oz/100 gal Celexone sticker in10 gal/a water
[5] includes 16 fl oz each of copper and sulfur products in combination with Halt
[6] Means in the same column with different letters are significantly different at $P \leq 0.05$

Table 2. Evaluation of fungicides applied for ergot control to 'Coventry' Kentucky bluegrass at the Central Oregon Agricultural Research Center, Powell Butte location, Oregon on June 15 and June 26, 1996.

| Fungicide treatments | Rate of product June 15 | Rate of product June 26 | Panicles with sclerotia | Seed weight per 100 panicles | Seed germination |
|---|---|---|---|---|---|
| | --------- (fl oz/a) ----------- | | ---- (%) ---- | ------ (g)------- | ----(%)---- |
| Punch | 28[1] | | 0.2 b[5] | 3.6 a | 88 |
| Tilt | 8 | | 1.2 b | 3.9 a | 87 |
| Tilt + Penaturf | 8 | 48 | 0.2 b | 4.1 a | 84 |
| Tilt + Silgard | 8 | 32[2] | 0.8 b | 4.1 a | 79 |
| Tilt + Tilt | 4 | 4 | 0.6 b | 3.6 a | 81 |
| Tilt + Tilt | 8 | 8 | 0 b | 3.8 a | 91 |
| Tilt + Tilt | 8[3] | 8[3] | 0.2 b | 4.1 a | 86 |
| Tilt/Penaturf + Tilt/Penaturf | 8/48 | 8/48 | 0 b | 2.4 b | 72 |
| Tilt/Orthorix + Tilt/Orthorix | 8/64 | 8/64 | 0.2 b | 4.1 a | 80 |
| Tilt /Halt + Tilt/Halt | 8/16[4] | 8/16 | 0.4 b | 4.6 a | 82 |
| Quadris + Quadris | 4[3] | 4[3] | 0 b | 4.4 a | 80 |
| Untreated | --- | --- | 2.4 a | 4.4 a | 83 |

[1] Silgard at 16 fl oz/100 gal and R-56 at 1 pt/100 gal applied with all treatments except Tilt + Penaturf and Tilt + Silgard.
[2] fl oz/100 gals
[3] crop oil concentrate (COC) applied at 1% in combination with fungicides
[4] includes 16 fl oz each of copper and sulfur products in combination with Halt
[5] Mean in the same column with different letters are significantly different at $P \leq 0.05$

# EFFECT OF ROW SPACING ON SEED YIELD OF TUFTED HAIRGRASS

*D.C. Darris and M.A. Stannard*

**Introduction**

Tufted hairgrass [*Deschampsia cespitosa* (L.) Beauv.] is a long lived, perennial bunchgrass that occurs naturally throughout the Pacific Northwest. At low elevations, this species commonly occurs in seasonal wetlands, coastal estuaries, and moist meadows, as well as along streambanks and the shores of ponds and lakes. While it is being commercially increased for restoration and other land amenity plantings, little is known about the agronomic requirements for seed production. Optimal row spacing or stand density is one of the more important factors that needs to be determined. Therefore, the objectives of this experiment were to determine the effect of row spacing on seed yield of tufted hairgrass, and secondly, compare seed yields of two dissimilar ecotypes (accessions) of tufted hairgrass.

**Methods and Materials**

The trial was established at the Plant Materials Center, Corvallis, Oregon in May 1991. The experimental design was a randomized complete split block with four replications. Whole plots consisted of six row spacings: 6, 12, 18, 24, 30 and 36 inches and subplots consisted of two accessions: 9019731 and 9019737 of tufted hairgrass. Each subplot measured 6 ft wide and 20 ft long. Accession 9019731 originated from a wild stand in Tillamook Co., OR, near the mouth of the Miami River, and 9019737 came from Linn Co., OR, along the Calapooia River.

Seeding rate was 60 pure live seeds per linear foot. Sprinkler irrigation water was applied the first year only to aid in establishment. All plots were uniformly managed (1991-1995), including fertilization (50 lb N/a each fall, 50 lb N/a, each spring, 15 lb sulfer/a [spring 1992-1993 only]) and weed control (2,4 D and dicamba, spring 1991-1993). Soil type was a moderately well drained Woodburn silt loam.

All plots were sampled for seed yield at maturity on June 29-30, 1993 and July 2-3, 1995. Sampling consisted of clipping all culms within a one meter square quadrat. After harvesting, all plots were windrowed, the residue baled and removed, and each stand mowed to a height of 2-3 inches. Plots were similarly treated in 1992 and 1994, but no yield data was collected. Analysis of variance (ANOVA) was performed on the seed yield variable. Accession means were compared with a two tailed T-test at a probability level of 0.05.

**Results and Discussion**

Row spacing significantly affected the seed yields of 9019731 and 9019737 tufted hairgrass in both 1993 and 1995 (Tables 1 and 2). In both years, seed production increased as row spacing increased from 6 to 36 inches. However, significant differences primarily occurred between the first two or three narrowest spacings (6, 12 and 18) and the widest spacings of 24 to 36 inches for both individual accession means and combined means.

Table 1. Seed yields of tufted hairgrass relative to row spacing, 1993.

| Row Spacing | Accession 9019731 | Accession 9019737 | All plots |
|---|---|---|---|
| (in.) | (lb/a) | | |
| 6 | 96 c[1] | 94 c | 95 c |
| 12 | 186 bc | 310 b | 248 bc |
| 18 | 269 bc | 540 a | 405 ab |
| 24 | 342 ab | 561 a | 451 a |
| 30 | 387 ab | 616 a | 502 a |
| 36 | 528 a | 596 a | 561 a |

[1] Means within a column followed by the same letter are not significantly different by Fisher's protected LSD values (P=.05).

Table 2. Seed yields of tufted hairgrass relative to row spacing. 1995 data.

| Row Spacing | Accession 9019731 | Accession 9019737 | All plots |
|---|---|---|---|
| (in.) | (lb/a) | | |
| 6 | 92 b[1] | 90 c | 91 d |
| 12 | 180 ab | 187 bc | 184 c |
| 18 | 202 ab | 315 ab | 257 b |
| 24 | 321 a | 337 a | 329 a |
| 30 | 308 a | 398 a | 353 a |
| 36 | 262 a | 411 a | 337 a |

[1] Means within a column followed by the same letter are not significantly different by Fisher's protected LSD values (P=.05).

Surprisingly, seed yields did not decline at the widest spacing of 36 inches, despite substantial bare ground (open canopy) between rows. Tufted hairgrass is normally found growing in wet, sunny areas on small, individual hummocks that are usually widely spaced. This suggests the species has a high light requirement for growth and reproductive development. Such a requirement is more likely to be met in wider row spacings that maximize light penetration into the canopy. The maintenance of high seed productivity in spite of the high amount of bare ground associated with wide row spacings may also indicate that this species exhibits a high degree of lateral root distribution. In this experiment, high soil fertility levels were maintained and weed control was excellent each year regardless of row spacing, suggesting that competition from weeds for space and nutrients was not a factor. However, over time, the lack of canopy coverage and shading of the soil surface at the 36 inch spacing could provide the greatest opportunity for weed invasion.

In terms of the differences between the two accessions, 9019737 seed yields were similar to 9019731 for all spacings in both years with the exception of the 18, 24, and 30-inch row spacings in 1993 (Table 3). Yields of 9019737 in 1993 were 100%, 64%, and 60% higher than 9019731 at these three spacings.

Based on this experiment, recommended row spacing for seed production of tufted hairgrass on upland, nonirrigated fields is 24-36 inches. Given the lack of registered herbicides for weed control in native grasses, these wider spacing are more suitable for mechanical row cultivation. They in turn provide substantial benefit in terms of higher seed yields. In the future, investigation of additional yield affecting factors such as optimal soil fertility, residue management and soil moisture management is needed.

Table 3. Comparison of mean seed yields between 9019731 and 9019737 tufted hairgrass at each of six row spacings, 1993 and 1995.

| Accession | Row spacing (inches) 6 | 12 | 18 | 24 | 30 | 36 | Mean |
|---|---|---|---|---|---|---|---|
| | (lb/a) | | | | | | |
| | 1993 | | | | | | |
| 9019731 | 96 a[1] | 186 a | 269 a | 342 a | 387 a | 528 a | 296 |
| 9019737 | 94 a | 310 a | 540 b | 561 b | 616 b | 596 a | 444 |
| | 1995 | | | | | | |
| 9019731 | 92 a | 180 a | 202 a | 321 a | 308 a | 262 a | 228 |
| 9019737 | 90 a | 187 a | 315 a | 337 a | 398 a | 411 a | 290 |

[1]Pairs of means followed by the same letter are not significantly different by two tailed T-test values (p=0.05).

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Kevin Turner, First Vice President
George Pugh, Second Vice President
Don Hector, Treasurer
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