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Edited by Nicole Anderson, Carol Mallory-Smith, and Darrin Walenta

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The following authors have contributed to this report.

Central Oregon Agricultural Research Center—OSU
J.F. Spring, Agronomist, Central Oregon Seeds, Inc., Madras, OR

Department of Crop and Soil Science—OSU
N.P. Anderson, Professor, Extension Seed Production Specialist
B.C. Donovan, Faculty Research Assistant
N. Kaur, Assistant Professor, Extension Entomology Specialist
S. Mahoney, Undergraduate Extension Intern
D.J. Maliszewski, Faculty Research Assistant
C.A. Mallory-Smith, Professor Emeritus
R.J. Mc Donnell, Associate Professor
C.H. Richart, Faculty Research Assistant
G. Tiwari, Graduate Student
A.A. Tomasek, Assistant Professor, Extension Soil and Water Quality Specialist
A.R. Willette, Faculty Research Assistant

Department of Integrative Biology—OSU
D.R. Denver, Professor
D.K. Howe, Senior Faculty Research Assistant

Extension Service—OSU
K.C. Tanner, Field Crops Extension Agent, Linn, Benton, and Lane Counties
D.L. Walenta, Extension Agronomist, Union, Baker, and Wallowa Counties

North Willamette Research and Extension Center—OSU
D.M. Lightle, Assistant Professor (Practice)

National Forage Seed Production Research Center, Corvallis, OR—USDA-ARS
L.C. Breza, Postdoctoral Fellow
S.J. Dorman, Research Entomologist
J.M. Moore, Research Soil Scientist
K.M. Trippe, Research Microbiologist

COMPARATIVE EFFICACY OF PYRETHROID INSECTICIDES AGAINST SYMPHYLANS IN TALL FESCUE SEED CROPS

A.R. Willette, N.P. Anderson, S.J. Dorman, and N. Kaur

Introduction

The garden symphylan (*Scutigerella immaculata* Newport) is a serious soil arthropod pest whose root feeding affects the yield potential and survival of several high-value crops in western Oregon, particularly during crop establishment (Umble and Fisher, 2003). Recent research efforts (Willette et al., 2023; Bateman et al., 2023) have evaluated various insecticide products that represent diverse modes of action for the management of symphylans in both tall fescue [*Schedonorus phoenix* (Scop.) Holub] and perennial ryegrass (*Lolium perenne* L.) seed crops. In both trials, a liquid fertilizer-ready formulation (LFR) of bifenthrin (Capture LFR) emerged as a promising candidate for symphylan management using preplant incorporation. These results prompted us to further evaluate the comparative efficacy of various pyrethroid products formulated as emulsifiable concentrates (EC) and other insecticides identified in previous laboratory or field evaluations.

Materials and Methods

In March 2023, the trial was established in a symphylan-infested commercial tall fescue field in Linn County, OR. Soil type on the site is Malabon/Conser silty clay loam. The trial design included six insecticidal treatments and an untreated control arranged in a randomized complete block with three replications (Table 1). Plots were 12 feet x 25 feet. Tall fescue (var. 'Dynamite G-LS') was planted at 9 lb/acre using a John Deere 8300 double run metering, double disk opener, at 12-inch row spacing. The seeding depth was approximately 0.35 inch.

Immediately after planting, insecticide treatments were applied using a broadcast method with a CO_2-pressurized backpack sprayer applying 20 gal/acre spray volume at 22 psi through AM11002 nozzles. Approximately 0.75 inch of rainfall was recorded within 48 hours of insecticide application, which facilitated insecticide incorporation.

Symphylan abundance data were collected using the potato bait method successfully used in past studies by deploying three bait stations per plot 10, 28, and 38 days after treatment (DAT) (Willette et al., 2023). Plant density was measured in each plot at 52 DAT by counting the number of tall fescue plants per 3.2-foot length of a randomly selected row within each plot. Data were analyzed using ANOVA, and means were separated using Fisher's protected LSD ($P \leq 0.05$) (SAS Institute, Inc., 2023).

Results and Discussion

At 10 DAT, no differences in mean symphylan counts were detected in plots due to insecticide treatment (Table 1). Symphylan counts at 28 DAT indicated a reduction in symphylans in plots treated with all pyrethroid insecticide treatments, i.e., Bifender LFC, Bifenture 2EC, Brigade 2EC, Capture LFR,

Table 1. Trade name (active ingredient), rate, IRAC class, mean symphylan counts, and plant density in an insecticide efficacy trial conducted in a spring-planted tall fescue field in Linn County, OR, 2023.

Trade name (active ingredient)	Rate	IRAC class	------ Mean symphylan count per plot[1] ------			Plant density[1]
	(fl oz/a)		10 DAT	28 DAT	38 DAT	52 DAT
Untreated control	—	—	5.0 a	24.0 a	30.7 a	12.7 c
Bifender LFC (bifenthrin)	7.4	3	0.7 a	6.7 bc	9.0 b	52.0 ab
Bifenture 2EC (bifenthrin)	6.4	3	0.3 a	0.0 c	1.7 b	68.0 a
Brigade 2EC (bifenthrin)	6.4	3A	3.0 a	2.0 c	6.7 b	31.7 bc
Capture LFR (bifenthrin)	6.8	3A	1.7 a	3.0 c	1.3 b	48.3 ab
Torac (tolfenpyrad)	21.0	21A	3.3 a	21.3 ab	24.7 a	46.0 ab
Warrior II (lambda-cyhalothrin)	1.92	3	0.3 a	2.0 c	10.3 b	35.0 bc
P-value	—	—	0.1154	0.0122	0.001	0.012

[1] Means within a column followed by a common letter are not different ($P = 0.05$).

and Warrior II, compared to Torac and the untreated control (Table 1). At 38 DAT, all insecticide treatments except Torac showed increased symphylan suppression compared to the untreated control (Table 1). Corresponding to the symphylan suppression, plots with Bifenture 2EC treatments had a higher plant density (Table 1), followed by other pyrethroid insecticide treatments, Bifender LFC, Capture LFR, and Torac, than the untreated control.

Our primary objective of comparing the efficacy of pyrethroid products formulated as EC with other previously tested products, such as LFR products, resulted in no observable differences. We propose that future work on grass seed symphylan suppression should examine the effects of different bifenthrin formulations mixed with carbon at planting, with either in-furrow or T-band application methods.

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INDUSTRY SURVEY OF CURRENT PRACTICES AND PERSPECTIVES ON CLOVER SEED WEEVIL MANAGEMENT IN WHITE CLOVER SEED PRODUCTION

N. Kaur, K.C. Tanner, G. Tiwari, N.P. Anderson, D.M. Lightle, and S.J. Dorman

Introduction

Clover seed weevil (CSW), *Tychius picirostris*, has emerged as a serious insect pest in Oregon white clover seed production systems due to challenges associated with managing this insect pest (Kaur et al., 2020; Kaur et al., 2021). Insect control in white clover seed crops in Oregon depends largely on chemicals. Over the past two decades, clover seed producers have relied heavily on bifenthrin (trade names Brigade 2EC, Discipline 2EC, Battalion 2EC, etc.), a broad-spectrum type-1 pyrethroid insecticide. Growers began reporting reduced efficacy (field failures) of Brigade 2EC in 2017, and researchers observed poor control of Brigade treatments in field trials (Mattsson et al., 2021). Subsequent laboratory tests for insecticide resistance revealed high levels of bifenthrin resistance in Linn County CSW populations (Tiwari et al., 2024). Industry-wide dissemination of these research findings to diverse stakeholders was necessary to reduce reliance on bifenthrin-based insecticides by developing effective insecticide resistance management guidelines incorporating rotation of insecticide mode of action groups.

Materials and Methods

Presentations were made at three Extension and grower meetings in 2023 and 2024 to provide information on CSW biology and management recommendations for improved weevil control. These events included an OSU Extension coffee hour (Zoom, April 15, 2023), an Insect Pest Workshop for Seed Crops (Linn County Extension office, December 1, 2023), and the Annual Clover Grower Meeting (Wilsonville, OR, January 31, 2024.)

Attendees at these events were surveyed using electronic polling tools. The poll questions were designed to gather input from growers and industry partners about their perceptions of current management strategies for seed weevil and insecticide resistance management. For this report, the results from the first survey (April 15, 2023) are presented separately because this event included education efforts based on the 1 year (2022) of laboratory and field studies reporting insecticide resistance. We combined results from the other events conducted in late 2023 and early 2024 (December 1, 2023, and January 31, 2024), which included dissemination of laboratory and field results from both years (2022 and 2023). The surveys allowed us to identify current knowledge gaps and the adoption of new management practices. For each survey question, a “not applicable” or “I do not grow or advise on this crop” response option was included, and those respondents were not included in the results. The number of respondents for which the questions were applicable is indicated for each question (*n*) in the tables. Survey respondents included representatives who grow or make agronomic recommendations for white clover seed crops in the Willamette Valley (Linn County).

Results and Discussion

The survey results identified CSW as a pest in white clover seed production systems. In survey 1, 84% of respondents agreed that CSW is a major pest problem, and 84% reported experiencing poor control of seed weevil in the past 5 years. Yield losses of 20% or more were reported by 77% of respondents, while 23% of respondents indicated less than 10% yield loss due to CSW (Table 1).

Other questions in both surveys centered on current management practices, including the number of insecticide applications, product selection and usage, and perception of integrated pest management or resistance management strategies. The key findings are presented in Tables 1 and 2 and are discussed below.

Insecticide use and application frequency for seed weevil control

- Two-thirds (67%) of respondents in survey 1 indicated that at least two Brigade applications were made during each growing season for seed weevil control (Table 1), while 33% of respondents reported making only one insecticide application for seed weevil control per growing season (Table 1).
- In survey 2, when asked about insecticide application frequency prior to their learning about insecticide resistance to bifenthrin products, a similar response was captured. Seventy-three percent of respondents indicated that they used to make at least two insecticide applications using Brigade, while 27% reported making only one Brigade application for seed weevil control during the growing season (Table 2).

- When asked to name the products used, registered commercial formulations of bifenthrin (Brigade 2 EC, Group 3A) were found to be used by 100% of respondents, and malathion (Malathion 8 Aquamul, Group 1B) was found to be used by approximately 80% of respondents in both surveys (data not shown). Vantacor (Group 28) is also registered for use in white clover seed crops in Oregon, but only 24% of respondents indicated using Vantacor for seed weevil control during the 2023 growing season.

Reasons behind poor/failed seed weevil control

- Among the factors associated with poor control, 42% of respondents to survey 1 indicated insecticide resistance as the main factor. Additional factors included using a lower-than-recommended label rate (9%) or poor spray coverage (15%). Poor application timing in relation to both adult and larval monitoring was also identified as a contributing factor by 18% of respondents (Table 1).
- During survey 2, besides insecticide resistance (28% of respondents), poor spray coverage (24%), using a lower-than-recommended label rate (19%), and poor application timing (22%) were also identified as contributing factors to poor or failed seed weevil control with insecticide treatments (Table 2).

Plans for insecticide resistance mitigation

- The survey responses (Tables 1 and 2) show that growers and industry representatives are aware that CSW is resistant to bifenthrin products, the causes of this resistance, and the strategies they can use to manage resistance. This bodes well both for adopting insecticides with new modes of action when they become available and for utilizing best management practices for application timing and spray coverage.
- The impact of the recent research and Extension work on CSW was shown in the difference between respondents' past management and their plans for future management. Past management efforts have relied heavily on bifenthrin products, but nearly two thirds (64%) of respondents plan to stop using bifenthrin for CSW control. All of the remaining respondents planned to adjust their management by increasing the use of other products, and none of the respondents planned to continue using bifenthrin as before (Table 2).

Conclusions

These results provided helpful information for OSU Extension and research faculty to identify knowledge gaps and to design future educational programs to disseminate current OSU management guidelines for seed weevil management in white clover seed crops. Industry-wide training for the development of effective chemical control plans and rotational strategies will be an ongoing effort.

Vantacor offers a new mode of action (Group 28) and has systemic activity, making it an ideal tool for CSW management. We found a lower utilization rate of this insecticide in current grower practices. In the near future, our goal is to continue generating efficacy data that supports the registration of effective new chemistries and to develop an understanding of Vantacor's utility for CSW control. As an alternative to bifenthrin, improving efficacy of Vantacor will provide growers with another insecticide option, which will help reduce resistant CSW populations.

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Table 1. Survey questions, answers, and response rate for survey 1 (n = total respondents).

Is clover seed weevil a major pest problem in white clover seed crops that you manage? (n = 25)

Yes	84%
No	16%

In the past five years, have you ever experienced poor clover seed weevil control or field failure using Brigade 2EC or other bifenthrin-based products? (n = 25)

Yes	84%
No	16%

On average, how much yield do you estimate is lost due to seed weevil? (n = 13)

10%	23%
20% or more	77%

How many insecticide applications do you make to white clover for seed weevil control during the growing season? Participants were asked to list the products they use in a text box. (n = 9)

1	33%
2	67%

What might have contributed to the poor control/field failures of CSW in your production systems? Choosing multiple options was allowed. (n = 25)

Insecticide resistance development	42%
Poor spray coverage	15%
Using a lower spray rate than suggested on the label	9%
Poor timing of application	18%
Other reasons	16%

What steps can you take to mitigate insecticide resistance? Choosing multiple options was allowed. (n = 25)

Rotate modes of action to reduce selection pressure	21%
Optimize insecticide application timing	29%
Ensure good coverage and proper application method	2%
Use products with prolonged residual activity	21%

Table 2. Survey questions, answers, and response rate for survey 2 (n = total respondents).

Before learning about bifenthrin resistance, how many bifenthrin sprays did you typically apply to a white clover field? (n = 22)

1	27%
2 or more	73%

What do you plan on after learning that bifenthrin products are no longer effective against seed weevil in our area? (n = 42)

I do not plan to use bifenthrin for seed weevil control in the near future	64%
I will increase the use of other products for CSW control, but will probably continue to apply bifenthrin as well	36%
I plan to continue using bifenthrin as I have in the past	0%

Did you use Vantacor for CSW control in 2023? (n =21)

Yes	24%
No	76%

What might have contributed to the poor control/field failures of CSW in your production systems? Choosing multiple options was allowed. (n = 22)

Insecticide resistance development	28%
Poor spray coverage	24%
Using a lower spray rate than suggested on the label	19%
Poor timing of application	22%
Other reasons (changing climate, no field burning, loss of chlorpyrifos)	7%

What steps can you take to mitigate insecticide resistance? Choosing multiple options was allowed. (n = 25)

Rotate modes of action to reduce selection pressure	32%
Optimize insecticide application timing	28%
Ensure good coverage and proper application method	28%
Use products with prolonged residual activity	12%

EFFECT OF SPRING DEFOLIATION AND TRINEXAPAC-ETHYL (PALISADE EC) PLANT GROWTH REGULATOR ON ANNUAL RYEGRASS SEED CROPS

D.J. Maliszewski, B.C. Donovan, and N.P. Anderson

Introduction

Annual ryegrass (*Lolium multiflorum* L.) is a forage and restoration crop globally and an important seed crop in Oregon. Current seed yields in annual ryegrass are only 15–33% of potential. One of the major reasons for yield reduction is lodging during anthesis, which reduces successful pollination and fertilization. Using field management techniques that reduce lodging could increase seed yields.

The plant growth regulator (PGR) trinexapac-ethyl (TE), trade name Palisade EC, has been shown to reduce lodging by inhibiting gibberellic acid receptors when applied at the two-node growth stage (BBCH 32). This inhibition reduces stem elongation and spike length in annual ryegrass plants, while retaining the same number of spikelets as untreated plants (Chastain et al., 2014; Chastain et al., 2015). The reduction has been shown to increase seed yield in annual ryegrass (Trethewey et al., 2016).

Defoliation has been shown to be an effective tool to combat lodging when timed strategically (Rolston et al., 2010). When defoliation is combined with PGRs, lodging can be further reduced (Rolston et al., 2012), especially in crops that produce a large amount of above-ground biomass, such as annual ryegrass. Current PGR recommendations are 3.0 pt Palisade EC/acre on annual ryegrass seed crops in Oregon. This recommendation has had positive effects on Oregon's annual ryegrass seed yields (Anderson et al., 2023). The aim of this study was to determine whether there is an effective upper limit to the Palisade EC application rate on annual ryegrass with and without spring defoliation by mowing or grazing.

Materials and Methods

Annual ryegrass (cv. 'Gulf') was planted at a rate of 10 lb/acre in 10-inch row spacings at Oregon State University's Hyslop Research Farm in October 2022. The experiment was organized in a randomized complete block with a split plot design. The main plots (spring defoliation treatments) were 55 feet x 50 feet, while the subplots (Palisade EC treatments) were 11 feet x 50 feet. Fertilizer was applied and incorporated (40 lb N/acre of 33-0-0-12) prior to planting, followed by application in the spring (140 lb N/acre of 40-0-0-5) when 200 growing degree days had accumulated. Routine herbicide treatments were applied as needed for management of grass and broadleaf weeds.

Spring defoliation treatments were carried out two times using a tractor-mounted 8-foot flail mower set to a 3-inch cutting height. The first defoliation treatment was applied when plants initially reached the two-node stage (BBCH 31–32) on April 14. The second defoliation was applied once the plants had regrown to the two-node stage on April 25.

Palisade EC was applied at a rate of 0 (untreated control), 2, 4, 6, and 8 pt/acre using a custom-built bicycle sprayer. The nondefoliated plots were treated with Palisade EC at the two-node stage on April 25. Plots that received the spring defoliation treatment were allowed to regrow to the two-node stage after the second flailing before they received the Palisade EC treatments on May 3.

At peak flowering (BBCH 65), two 1 ft^2 biomass samples were collected randomly (cut 2 cm above ground level) from each plot and placed in a drying room set at 48.9° for 24 hours. The dry biomass samples were then weighed to determine total above-ground biomass, and fertile tillers were counted. Ten fertile tillers were randomly selected from each sample to determine average tiller length and spike length. Percent lodging ratings were taken just prior to swathing on June 16.

Seed moisture was monitored separately for defoliation and no-defoliation plots because crop maturity was noticeably different between the two. Once seed moisture reached 45%, the plots were swathed using a modified John Deere 2280 swather (no-defoliation treatments, June 20, 2023; defoliation treatments, June 22, 2023). All plots were harvested on June 28, 2023 using a Hege 180 plot combine.

Harvest weights were recorded, and subsamples were collected from harvested seed. Seed was cleaned using a Clipper M2B cleaner to determine percent cleanout and to calculate clean seed yield. Two subsamples were collected from harvested seed to determine 1,000-seed weight using an electric seed counter and laboratory balance. Once these weights were determined, harvest index (HI), the ratio of seed yield to above-ground biomass, was calculated.

An analysis of variance (ANOVA) for a randomized complete block was performed using the program Statistix 10 (Analytical Software). Statistical groups were determined using an LSD of 0.05.

Results and Discussion

Results from the ANOVA indicated no interaction for seed yield between spring defoliation and PGR treatments (*P* = 0.1071) (data not shown). This was surprising, as previous studies have reported strong interactions between the two spring management practices (Anderson et al., 2019). Interactions occurred only for seed number (*P* = 0.0307) and lodging (*P* = 0.0000).

In the current study (results shown in Table 1), the no-defoliation treatment resulted in a 19.5% seed yield increase compared to the spring defoliation treatment. Interestingly, cleanout was 21.5% higher in the no-defoliation plots compared to the defoliation treatment, which likely accounts for the higher clean seed yield in the no-defoliation treatment. Seed weight and seed number were both greater with no defoliation, by 8.6 and 13.4%, respectively.

Not surprisingly, the no-defoliation treatment had 44.7% more total above-ground biomass compared to the defoliation treatment, resulting in the defoliation treatment having a 48% higher HI. While there was no difference in number of fertile tillers between spring defoliation treatments, results showed fertile tiller height and spike length to be 29.3% and 10.6% shorter, respectively, when spring defoliation occurred. The reduction in fertile tiller height likely resulted in 48% less lodging in the defoliation treatment.

The application of TE PGRs (Palisade EC) increased clean seed yields by 29.4% compared to the untreated control. There were no differences in seed yield among the Palisade EC rates (2, 4, 6, and 8 pt/acre). Palisade EC rates at 4 pt/acre or higher resulted in more cleanout than the untreated control and 2 pt/acre Palisade treatment. Seed weights were reduced by all Palisade EC rates; however, seed number was increased with all Palisade EC rates, likely contributing to the increase in seed yield from PGR applications. These results further validate the hypothesis that seed number influences seed yield more than seed weight in cool-season grass seed crops.

All Palisade EC applications increased fertile tiller number and decreased spike length, compared to the untreated control. Although there were no differences in total above-ground biomass among PGR treatments, the HI was 25.9% greater when Palisade EC was applied. This is an indication of greater reproductive efficiency when TE-containing PGRs are used in annual ryegrass seed crops. Tiller height reduction was correlated to Palisade EC rate. The higher the Palisade EC rate, the

Table 1. Effect of spring defoliation and trinexapac-ethyl plant growth regulator (PGR)[1] on seed yield and growth components in 'Gulf' annual ryegrass, 2022.

	Seed yield	Cleanout	Seed weight	Seed number	Biomass	Fertile tillers	Tiller height	Spike length	HI[2]	Lodging (June 16)
	(lb/a)	(%)	(mg seed^{-1})	(no m^{-2})	(kg ha^{-1})	(no ft^{-2})	(cm)	(cm)	(%)	(%)
Spring defoliation treatment										
No mow	2,583.0 b	2.33 b	2.69 b	110,296 b	14,924 b	120	97.0 b	17.8 b	19.9 a	67.0 b
2X mow	2,079.0 a	1.83 a	2.46 a	95,547 a	8,260 a	132	68.6 a	15.9 a	29.4 b	42.2 a
P =	0.0047	0.0388	0.0493	0.0156	0.0008	0.1221	0.0034	0.0026	0.0015	0.0284
PGR treatment										
Untreated control	1,685.4 a	1.73 a	2.96 d	64,147 a	11,303.0	102 a	114.5 d	20.1 e	18.1 a	94.4 d
Palisade EC 2 pt/a	2,386.8 b	1.59 a	2.66 c	100,543 b	11,541.0	116 ab	88.1 c	17.8 d	24.7 b	83.1 c
Palisade EC 4 pt/a	2,596.2 b	2.31 b	2.51 b	115,465 c	12,978.0	141 c	79.9 bc	16.6 c	24.3 b	49.4 b
Palisade EC 6 pt/a	2,548.0 b	2.34 b	2.41 a	118,139 c	11,280.0	134 bc	70.9 b	15.3 b	29.0 b	25.6 a
Palisade EC 8 pt/a	2,438.1 b	2.43 b	2.35 a	116,313 c	10,858.0	138 c	60.9 a	14.0 a	27.0 b	20.6 a
P =	0.0000	0.0000	0.0000	0.0000	0.3614	0.0019	0.0000	0.0000	0.0134	0.0000

[1] Palisade EC

[2] Harvest index (HI) is the ratio of seed yield to above-ground biomass.

shorter the tiller, resulting in less lodging. The 8-pt Palisade EC/acre rate reduced lodging by 73.8%.

Previous studies conducted in Oregon have shown a seed yield interaction between spring defoliation and PGRs. The weather conditions in the spring of 2022 were abnormally cool, and biomass accumulation was less than normal. It is possible that less total above-ground biomass contributed to a lack of interaction between the two spring management practices. There also appears to be a correlation between spike length and seed number, as well as between spike length and seed yield. It would be interesting to quantify seed shattering among PGR treatments that result in different spike lengths to determine whether a more compact spike contributes to less seed loss at harvest and higher seed yields. Overall, it is apparent that the use of TE-containing PGRs, such as Palisade EC, increase seed yield and should be considered for use in Oregon's annual ryegrass seed crops, regardless of whether spring defoliation occurs or not.

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SOIL CARBON STOCK RESPONSE TO SUBSURFACE DRAINAGE IN THE NORTH WILLAMETTE VALLEY

L.C. Breza, J.M. Moore, A.A. Tomasek, and K.M. Trippe

Introduction

Subsurface drainage, or tile drainage, is a water management tool that Willamette Valley farmers use to mitigate high water tables in their fields. Although some cool-season grasses can tolerate wet soil, many other grasses grown for seed cannot. Thus, wet soils can compromise yields and limit crop choice. Subsurface drainage allows farmers to plant a wider variety of crops, extends the growing season, and provides earlier and more reliable equipment access to historically wet fields.

Because tile drainage plays such an important role in land management, nearly 30% of cropland in the Willamette Valley has subsurface drainage, and growers regularly install new tile lines in previously untiled fields. Tile installations may target especially wet areas or span the entirety of a field, depending on the soil type and topography. Additionally, farmers may install tile drainage in fields with steeper slopes to help minimize erosion via surface runoff.

High soil heterogeneity and rolling topography across the northern Willamette Valley generally result in farmers utilizing subsurface drainage both for mitigating high water tables and for minimizing surface runoff. Furthermore, the northern Willamette Valley landscape often has poorly draining soils adjacent to moderately or well-draining soils within a single field. Thus, a field with subsurface drainage can contain soils of varying drainage classes, soil texture, and soil carbon (C) concentrations.

Many of the soil series located in the northern Willamette Valley have cumulative soil organic carbon (SOC) ranging from about 1 to 5% in the 0–60 cm depth, with an average SOC content of approximately 3% (soil survey staff). Generally, the greater the SOC content in agricultural land, the more productive it is, and preserving SOC has become increasingly important. For example, preventing C loss and building SOC via management are major focuses of the recent United States Department of Agriculture (USDA) Climate Smart initiative. This initiative has encouraged the incentivization and monetization of "carbon farming" by agricultural production companies. Therefore, understanding how different management practices, such as tile drainage, influence soil C stocks has implications for Willamette Valley farmers, as well as farmers outside the region.

Our research aimed to understand the response of soil C to subsurface drainage in Willamette Valley soils. There are three possible soil C outcomes resulting from drainage. Drainage may decrease soil C due to increased aeration, microbial activity, and mineralization of existing soil C. In contrast, lower water tables may lead to increased root biomass and microbial biomass deeper in the soil profile, increasing soil C. Alternatively, there could be no change detected in response to drainage.

Here we report results from the continuation of a 2-year study initiated in 2022 that investigates the response of soil C to subsurface drainage. The 2022 study focused on poorly drained soils in the south Willamette Valley, while the present study targeted moderately well-drained soils in the north Willamette Valley.

Materials and Methods

Soil collection and analysis

Soils were collected in April and May 2023 from 14 grass seed production fields near Monmouth, OR. We targeted moderately well drained soils, which included Woodburn (fine-silty, mixed, superactive, mesic Aquultic Argixerolls), Carlton (fine-silty, mixed, superactive, mesic Aquultic Haploxerolls), and Coburg (fine, mixed, superactive, mesic Oxyaquic Argixerolls) soil series. Map units containing one of the target soil types were identified in each field. Soil properties are shown in Table 1.

Field treatments included newly tiled (fewer than 5 years since tile drain installation, n = 4), old tile (more than 15 years since tile drain installation, n = 5), and untiled (no history of tile drainage, n = 5). The fields selected for this study have a history of grass seed crops. At the time of sampling, four fields were planted with tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort.], four with perennial ryegrass (*Lolium perenne* L.), one with meadowfoam (*Limnanthes alba* Hartweg ex. Benth), one with red clover (*Trifolium pratense* L.), and two fields were left fallow.

Table 1. Average clay, silt, and sand percentage and the texture class of each target soil series at 0–15, 15–30, and 30–60 cm.

Soil depth	Component	Carlton	Coburg	Woodburn
0–15 cm	Clay (%)	25.6	32.1	26.0
	Silt (%)	51.0	55.2	65.8
	Sand (%)	23.4	12.6	8.2
	Texture	Silt loam	Silty clay loam	Silt loam
15–30 cm	Clay (%)	26.5	33.5	27.7
	Silt (%)	50.0	54.9	64.8
	Sand (%)	23.5	11.6	7.5
	Texture	Silt loam/loam	Silty clay loam	Silty clay loam
30–60 cm	Clay (%)	28.7	34.7	29.7
	Silt (%)	44.8	52.3	62.8
	Sand (%)	26.5	13.1	7.5
	Texture	Clay loam	Silty clay loam	Silty clay loam

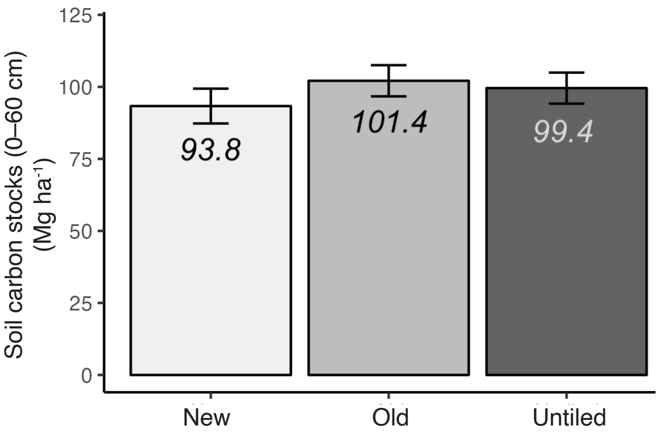

Figure 1. Cumulative soil C was not different between tile drainage treatments ($P = 0.344$). Bars represent standard error around the mean.

Nine cores were collected in each field within each sampling zone. Samples were collected to 1 m deep with an ATV-mounted hydraulic soil probe (Giddings Machine Company, Inc.), and plastic liners were used within a stainless steel soil probe (4.25 cm diameter) to extract intact soil cores. Cores were processed upon collection and segmented at standard soil depths of 0–15 cm, 15–30 cm, and 30–60 cm. Bagged soil was transported on ice packs and stored at 4°C.

Each sample was air dried, finely ground, and analyzed for total C and nitrogen (N) (LECO CN828). Prior to grinding, all vegetation was removed manually with tweezers. A texture analysis was performed on each sample by wet sieving air-dried soil of less than 2 mm and separating the resulting sample into two size fractions: greater than 53µm and less than 53µm. The larger size fraction was oven dried at 60°C, and the dry mass comprised the sand fraction. The smaller size fraction was analyzed for silt and clay composition by completing a particle size analysis via laser diffraction (Mastersizer 2000).

Statistical analysis

Mixed-effects models were used to analyze the response of soil C stocks to drainage treatments and incorporated clay content as a covariate to account for the potential influence of clay on C stocks. To analyze differences in soil C stocks across different soil types, similarly structured mixed-effects models were used. Similar statistical analyses were performed on total soil N. Soil N values were log+1 transformed to ensure the data fit the model's assumptions. All statistics were performed in the open-source computing software R.

Results and Discussion

There were no statistically significant differences in cumulative soil C among the three tile drainage treatments (Figure 1, $P = 0.344$), and clay was a predictor of soil C ($P < 0.0001$, data not shown). Although not statistically significant, there was a trend of slightly higher C stocks in old and untiled fields compared to newly tiled fields. This trend could indicate an initial loss of soil C after subsurface installation in new tile fields, followed by a recovery of soil C in old tile fields as the system stabilizes over time. However, increased replication of field treatments is needed to verify this trend. Cumulative N was not different between tile drainage treatments ($P = 0.183$), and clay was a significant predictor of soil N ($P < 0.001$, data not shown).

In our 2022 survey of C stocks in the southern Willamette Valley, which targeted the Dayton series, a poorly drained soil, similar results were found in that there were no differences among the drainage treatments (Breza et al., 2023). Similarly, in 2023, we found no difference in cumulative C stocks in moderately well-drained soils in the north valley. These findings suggest that subsurface drainage has no effect on soil C stocks even across different soil series with differing drainage properties. These results align with a recent study conducted in a primarily corn-soy system that found minimal tile drainage effect on soil C stocks at multiple sampling depths (Saha et al., 2024).

It is well understood that soil type and texture strongly influence soil C concentrations. Soil series was a moderate predictor of soil C stocks within the sampling zone (Figure 2, *P* = 0.056), with Coburg having the greatest cumulative soil C content. Coburg soils also had the greatest clay content (Table 1). These results suggest that soil C content in Willamette Valley grass seed fields is largely driven by soil texture and landscape geomorphology and that subsurface drainage may have little impact on total C stocks over the long term. This finding prompts the question of whether certain soil types are more susceptible to C accumulation or loss via subsurface drainage.

While soil type and texture impact soil C content, other agricultural management practices combined with subsurface drainage can potentially alter soil C. For example, tile-drained fields under no-tillage can alter soil physical properties and improve SOC stocks (Kumar et al., 2014), while tilled fields with subsurface drainage can promote dissolved organic C loss via water discharge (Manninen et al., 2018). However, Saha et al. (2024) found no interaction between tile drainage and tillage, crop rotation complexity, or cover crops. As such, the interaction between other management forms and tile drainage is likely system and soil dependent.

Conclusions

In summary, no differences in soil C stocks were detected in fields with new, old, or no tile drainage. However, soil type and texture influenced soil C regardless of drainage treatment. These findings are favorable for Willamette Valley growers because they indicate that subsurface drainage likely has little to no effect on soil C stocks over the long term. Nonetheless, potential interactions between different management practices (e.g., tillage, crop rotation history) and subsurface drainage remain understudied, and understanding these nuances will be important for providing farmers with best practice recommendations.

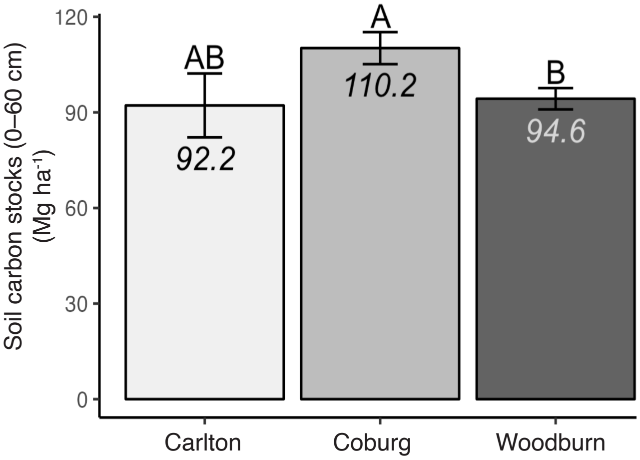

Figure 2. Cumulative soil carbon within each sampled soil series. Bars represent standard error of the mean; pairwise differences used significance level of alpha = 0.06.

A continuation of this work will use an equivalent soil mass approach to normalize C stocks on a mass per unit area basis to account for changes in bulk density throughout the soil profile (Wendt and Hauser, 2013). The next step in this work will investigate different C pools and where soil C accumulates within the soil to better understand how subsurface drainage impacts C cycling under shorter time frames.

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Acknowledgments

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EVALUATING DIPHACINONE AND CHLOROPHACINONE RODENTICIDES IN BAIT BOXES FOR VOLE CONTROL IN GRASS SEED CROPS

K.C. Tanner and S. Mahoney

Introduction

Gray-tailed voles (*Microtus canicaudus*) are a major pest of grass seed crops in the Willamette Valley, OR (Verhoeven and Anderson, 2021). Like many vole species, gray-tailed vole populations cycle between periods of low numbers and periods of high numbers that cause substantial crop damage and yield losses. Zinc phosphide rodenticide baits are the only registered products for vole control in grass seed crops in Oregon, and only 26% of growers reported being satisfied with the effectiveness of zinc phosphide baits (Verhoeven and Anderson, 2021). An extended period of elevated vole population numbers occurred from 2019 through early 2023, illustrating the need for additional control options for growers.

Compared to other types of pesticides, rodenticides carry a higher risk of poisoning for humans, pets, and mammalian wildlife because these groups have many biological similarities to rodents. Birds can also be highly sensitive to rodenticides. Registration of alternative rodenticide products for grass seed crops will likely require application methods that mitigate the risk of nontarget poisonings. One option is to use tamper-proof bait boxes. These boxes are designed to allow rodents to enter the box and feed on bait, while preventing other wildlife, pets, and children from accessing the rodenticide. Previous work by Salisbury and Anderson (2021a, 2021b) showed that voles were willing to enter bait boxes and feed on chicken feed and other rodenticide baits, especially in the spring.

Diphacinone and chlorophacinone are two active ingredients used in rodenticides that have a different mode of action than zinc phosphide. When voles eat zinc phosphide-containing bait, it reacts with acid in the vole's stomach to produce toxic phosphine gas, which acts quickly by causing cell death in the heart, lungs, and liver. A vole can consume a lethal amount of zinc phosphide in a single feeding. Diphacinone and chlorophacinone interfere with blood clotting and cause death by uncontrolled bleeding. Rodents generally need to consume these baits over several feedings to receive a lethal dose. This study tested five rodenticide bait products containing diphacinone and chlorophacinone in tamper-proof bait boxes in a first-year tall fescue field for 8 weeks.

Materials and Methods

Study design

The study was conducted in a vole-infested tall fescue stand in Linn County, OR, that was planted in spring 2022. The study design was a randomized complete block design with four replicates. Each plot was a single vole colony with a filled bait box placed in the center, or a colony with no bait box. Vole colonies were selected along four 350-foot transects spaced 100 feet apart. Colonies used in the study were approximately 50 feet apart and within 25 feet of the transect. Boxes were placed in the field on April 13, 2023 and were monitored for 8 weeks.

Treatments

Five rodenticide baits and three checks were tested in this study. The bait treatments included Ramik Green (diphacinone; Neogen), Ramik Brown (diphacinone; Neogen), PCQ-Ag (diphacinone; Motomco), Rozol (chlorophacinone; Liphatech), and DoubleTap (chlorophacinone; Liphatech). The checks included a nonlethal check (a bait box with pelleted Payback Egg Layer chicken feed; CHS), no-box check (a vole colony that was monitored but had no bait box), and a grower standard (zinc phosphide bait applied below ground).

Bait box and vole activity measurements

Motomco Tomcat Titan bait boxes with Tomcat Titan iQ trays were used for this trial. Titan boxes have a heavy brick in the base and a locking mechanism. Rodent activity in the box is detected by the sensor in the iQ tray, and these data can be downloaded over a Bluetooth connection. Boxes were checked weekly. Activity data were downloaded, boxes were inspected for visible signs of vole activity, and the remaining bait was collected and replaced with fresh, preweighed bait each week. All plots were inspected for signs of vole activity and photographed each week.

Previous studies (Salisbury and Anderson, 2021a, 2021b) showed that baits can gain or lose moisture, causing an increase or decrease in weight, without any bait consumption. To control for these factors, additional samples (one sample of each bait type) were placed in moisture check bait boxes at the field site. The entrances of the moisture check bait boxes were covered with window screen to allow air flow but prevent voles from entering. After collection in the field, all bait samples were stored in a ziplock bag with a desiccant packet until they reached a constant weight. Weight loss by the experimental samples was adjusted by the weight change observed in the moisture check samples.

Measuring crop damage

To evaluate the impact of the bait treatments on crop growth, aerial imagery was collected with a drone on April 13 and May 25, 2023, following the methods reported by Tanner (2023). The aerial imagery was used to measure changes in crop height and normalized differential vegetation index (NDVI), a measure of canopy closure and crop health, in a 6.6-foot diameter circular area surrounding each vole colony. Vole colonies had differing levels of damage, so the effect of treatments on crop growth was measured by subtracting values measured on April 13 (before treatment) from values measured on May 25 (during the study).

Statistical analysis

Statistical tests were performed in R statistics software. Data were not normally distributed and contained a large number of zeros and high outliers. Attempts to transform the data to meet normality assumptions of parametric statistical methods were not successful. Differences between treatments were tested with the nonparametric Kruskal-Wallis rank-sum test. The Dunn post-hoc test with Holm correction for multiple comparisons was used when the Kruskal-Wallis test indicated differences between groups.

Results and Discussion

Field observations

Signs of vole activity, such as droppings, clipped leaves, and fresh digging, were present throughout the study period. Combined with data from the bait box iQ sensors, it is clear that voles were present and active during the study. However, we did not observe any patches of clipped reproductive tillers in the field as harvest approached. In recent years, fields with heavy yield losses due to vole damage had large areas where voles had cut the majority of reproductive tillers. Growers and field agronomists reported that vole activity and crop damage declined sharply during the time of the study. The observations in this study likely occurred as populations were declining.

Box visits and bait consumption

Visits and bait consumption were recorded for all boxes over the 8-week study period. Cumulative data for the full study period are shown in Table 1. The boxes recorded averages of 33–119 total visits over the 8-week study period and 0.6–2.1 oz of bait consumption (Table 1). A summary of weekly vole visits and bait consumption is shown in Figure 1. It was common for bait boxes to have few or no visits or little to no bait consumption during a given week, but large numbers of visits and relatively high bait consumption were also common. Some boxes recorded very high numbers of visits, with 7 boxes recording more than 50 events in a week. Bait consumption of at least 0.7 oz in 1 week was observed for 15 boxes.

Table 1. Total bait box visits and bait consumption by gray-tailed voles in a vole-infested tall fescue stand, Linn County, OR, 2023.[1]

Bait	Total visits (mean ± SD)[2]	Total bait consumption (mean ± SD)[2]	Observations with visits	Observations with bait consumption
	(no.)	(oz)	(%)	(%)
Chicken feed	42 ± 3	0.6 ± 0.1	81	75
Ramik Brown	119 ± 74	1.4 ± 1.0	81	44
Ramik Green	89 ± 57	2.0 ± 1.8	94	44
PCQ Ag	100 ± 59	1.3 ± 1.0	81	75
Rozol	33 ± 13	1.6 ± 0.6	78	63
DoubleTap	99 ± 38	2.1 ± 1.0	94	84

[1] Total visits and total bait consumption are the average total number of visits or total amount of bait consumed, respectively, per bait box throughout the 8-week study period (n = 4 bait boxes per bait treatment). Each of the 4 bait boxes per treatment was checked weekly for 8 weeks, totaling 32 observations. Observations with visits and observations with bait consumption show the percentage of observations with at least one event recorded by the bait box or bait consumption greater than zero (after correcting for moisture loss).

[2] SD = standard deviation

Statistical tests for differences in visits produced conflicting results. Kruskal-Wallis test was significant, but Dunn post-hoc test was not significant after correcting for multiple comparisons. Some evidence suggested a difference between DoubleTap and Rozol (Figure 1, left, $P < 0.1$), but more data are needed to conclude that any bait performed better than the others. There was greater consumption of DoubleTap than Ramik Brown (Figure 1, right, $P < 0.05$), but no other statistical differences between treatments. Based on consumption data in Table 1, there is no evidence that any of the baits was less attractive than the chicken feed check.

Drone data

Crop growth was stunted in the severely damaged vole colony areas, as evidenced by minimal changes in crop canopy height and NDVI values during the study period. These areas remained shorter than the surrounding crop, and bare soil continued to be visible between crop rows. Nearby areas with less severe vole damage appeared to recover by harvest time, with increases in crop height and NDVI and a strong stand of seed heads. There were no differences in crop growth among treatments (data not shown). The lack of differences among treatments is likely due to the lack of late spring tiller clipping observed in this study.

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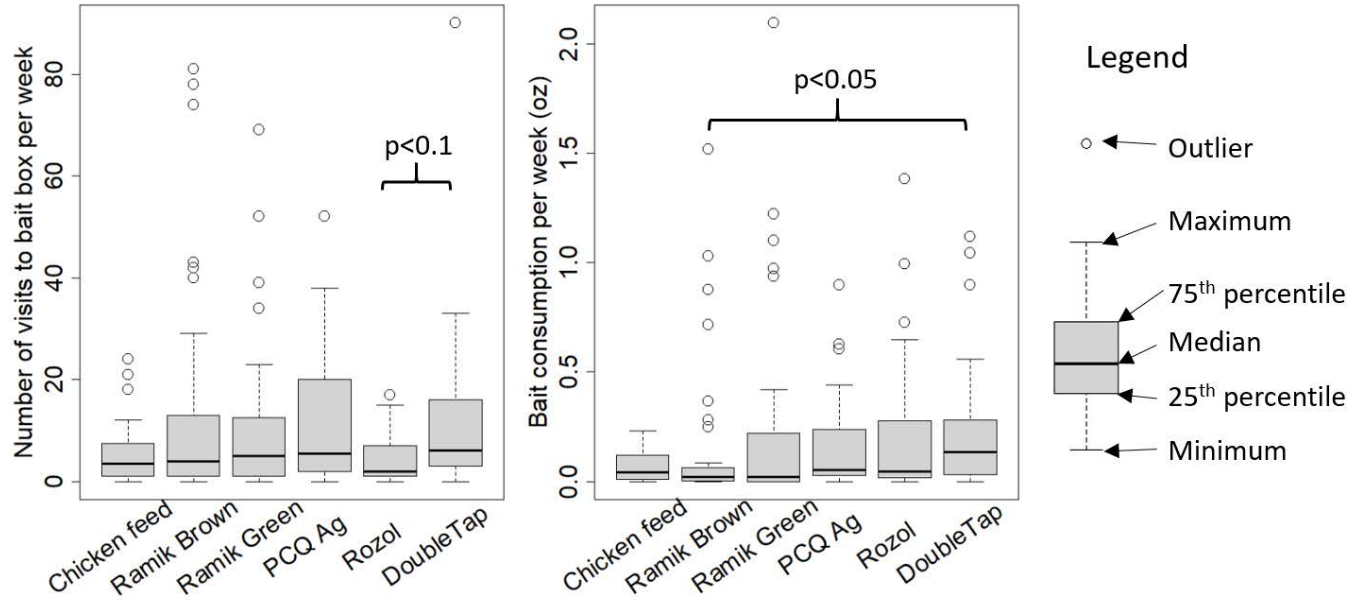

Figure 1. Box plots of the number of visits to the bait boxes (left) and amount of bait consumed (right) for each type of bait. Statistically significant differences between pairs of treatments are indicated with a bracket and significance level.

LETHALITY OF THREE SPECIES OF *PHASMARHABDITIS* NEMATODES TO GRAY FIELD SLUGS IN A MICROCOSM STUDY

C.H. Richart, D.K. Howe, D.R. Denver, and R.J. Mc Donnell

Introduction

The gray field slug (*Deroceras reticulatum*) is the most important slug pest of grass seed production in the Willamette Valley, OR. Control measures focus heavily on the use of chemical molluscicides, but growers report considerable variation in the efficacy of the most widely used active ingredients, and only 29.5% reported that they were satisfied with bait performance (Mc Donnell and Anderson, 2018). Hence, there is an urgent need to develop alternative management strategies for use by producers in the region.

Biological control is one such option, i.e., the use of a pest's natural biological enemies (e.g., nematodes) to control it. In Europe, the nematode *Phasmarhabditis hermaphrodita* was used as a commercial biocontrol product (Nemaslug) from 1994 to 2022 to manage slug pests in crops (Rae et al., 2023). In April 2022, *Phasmarhabditis californica* was also commercialized and is now available as Nemaslug 2.0 in the United Kingdom and some other European countries. Since 2017, surveys conducted by our team have resulted in the discovery of *P. hermaphrodita, P. californica,* and a third species, *P. papillosa,* in various locations throughout Oregon (Howe et al., 2020). These discoveries have resulted in increased interest in using these nematodes as biocontrol agents of pest slugs. The objective of this study was to compare the lethality of U.S. strains of *P. hermaphrodita, P. californica,* and *P. papillosa* to the gray field slug in microcosm studies.

Materials and Methods

Microcosms consisted of plastic containers 24 cm high, 39 cm long, and 30 cm wide with vented lids. Approximately 0.2 ft^3 of autoclaved (270°F, 10 psi, 90 minutes) SS#4 potting soil was added to each container. Annual ryegrass (var. 'Bounty') seeds were planted on November 8, 2021 and consisted of 2 rows of 100 seeds planted 5 inches apart. Microcosms were watered as needed throughout the experiment—about every 6 days, although more frequently at the start of the study. Test slugs were collected on November 3, 2021 from a grass seed production field located in Linn County. Ten gray field slugs were added to each container, and all treatments and controls were replicated three times.

Treatments were administered on November 19, 2021. Nematodes were applied at a rate of 30 infective juveniles (IJs) per cm^2 (the recommended application rate for Nemaslug). Slug-Fest (liquid metaldehyde) was used at the labeled rate (47 fl oz/acre). Treatments were compared to a negative control, i.e., annual ryegrass with slugs and no molluscicidal treatment.

Microcosm containers were maintained in the OSU research greenhouses for the duration of the study. Mortality was assessed daily from November 20, 2021 through January 20, 2022. Recording mortality was not always straightforward, as slugs often buried in the substrate, making them difficult to detect. Thus, both living and dead slugs were tallied daily, and measured mortality was often corrected by inference. For example, if on day 5 seven dead slugs and three living slugs were found in a container, and on day 6 only six dead slugs and three living slugs were found in the same container, slug mortality for day 6 would be recorded as seven.

For numerous periods, an ANOVA was calculated to assess whether significant between-group mortality variation existed in our data. For data sets where ANOVA analyses returned an F statistic greater than the F critical value, the Tukey-Kramer q statistic was calculated pairwise for each group. These statistics were compared using a studentized q table using an alpha value = 0.05 to reject the null hypothesis of no difference between groups.

Results and Discussion

Slug mortality commenced soon after the start of the study, with major mortality initiating in *P. papillosa* after 1 week and the other two nematode treatments following soon thereafter (Figure 1). Between-group mortality variation was tested (using Tukey-Kramer q statistic) every day from November 24 to December 8, 2021 (the period during which the vast majority of mortality in nematode treatments occurred, Figure 1), on December 20, 2021, and on December 31, 2021 (chosen to maximize the difference between Slug-Fest treatments and the negative control).

All differences in slug mortality among nematode treatments occurred between November 25 (6 days after application) and December 4 (15 days after application). Mortality differences between *P. papillosa* and both *P. hermaphrodita* and *P. californica* were more common than differences between *P. hermaphrodita* and *P. californica* (Table 1). All nematode treatments resulted in greater mortality than Slug-Fest and negative control treatments throughout much of this timeframe. Surprisingly, mortality in the Slug-Fest treatment did not differ from the negative control throughout the entirety of this study.

In conclusion, all three nematode species caused 100% gray field slug mortality and outperformed Slug-Fest in this study. *Phasmarhabditis papillosa* was the first treatment to cause complete slug mortality, followed by *P. hermaphrodita* and *P. californica.*

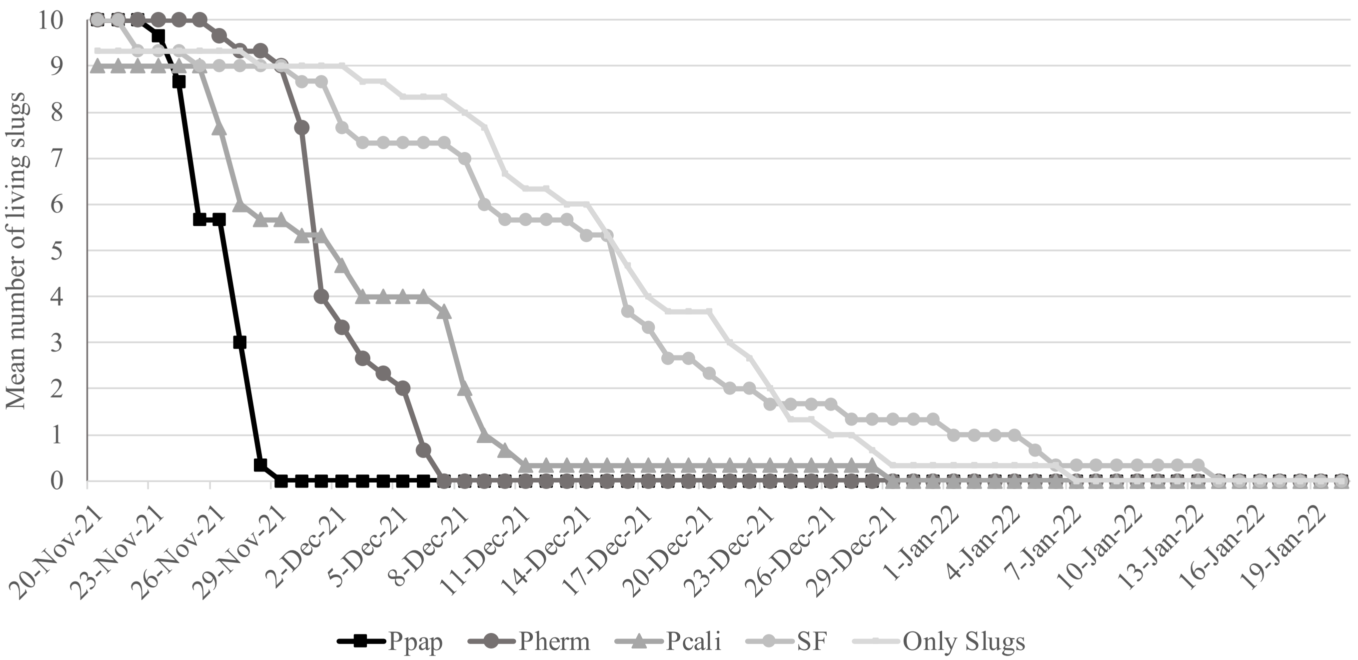

Figure 1. Mean number of living gray field slugs in microcosm containers treated with *Phasmarhabditis papillosa* (Ppap), *Phasmarhabditis hermaphrodita* (Pherm), *Phasmarhabditis californica* (Pcali), Slug-Fest (SF), and slugs only. Nematodes were used at a rate of 30 infective juveniles/cm^2 (recommended application rate for Nemaslug). Slug-Fest was used at a rate of 47 fl oz/acre (label rate). Error bars omitted for purposes of clarity.

Table 1. Gray field slug mortality among treatments and control across time.[1]

Treatments	Nov. 25	Nov. 26	Nov. 27	Nov. 28	Nov. 29	Nov. 30	Dec. 1	Dec. 2	Dec. 3	Dec. 4	Dec. 5	Dec. 6	Dec. 7	Dec. 8	Dec. 20
Ppap–Pherm	*	*	*	*	*	*	*	*	-	-	-	-	-	-	-
Ppap–Pcali	-	-	-	*	*	*	*	*	*	*	-	-	-	-	-
Ppap–SF	-	*	*	*	*	*	*	*	*	*	*	*	*	*	-
Ppap–only slugs	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Pherm–Pcali	-	-	-	*	*	-	-	-	-	-	-	-	-	-	-
Pherm–SF	-	-	-	-	-	-	*	*	*	*	*	*	*	*	-
Pherm–only slugs	-	-	-	-	-	-	*	*	*	*	*	*	*	*	-
Pcali–SF	-	-	-	*	*	-	*	-	-	-	-	-	-	*	-
Pcali–only slugs	-	-	-	*	*	-	*	*	*	*	*	*	*	*	*
SF–only slugs	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

[1] Asterisks indicate a difference in slug mortality between treatments/controls on that date. Hyphens indicate that there was no difference in slug mortality between treatments/controls on that date. Differences are based on Tukey-Kramer q scores with a critical value of 4.654 using alpha = 0.05. Ppap = *Phasmarhabditis papillosa*, Pherm = *Phasmarhabditis hermaphrodita*, Pcali = *Phasmarhabditis californica*, and SF = Slug-Fest.

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PREEMERGENT HERBICIDES FOR DOWNY BROME CONTROL IN ESTABLISHED KENTUCKY BLUEGRASS GROWN FOR SEED

D.L. Walenta and J.F. Spring

Introduction

Downy brome (*Bromus tectorum*) is a problematic winter annual grass weed in irrigated Kentucky bluegrass (KBG) seed production in eastern Oregon. Season-long control of downy brome in established KBG is not possible with a single application of any currently registered herbicide. The general consensus among KBG seed producers is that best management practices for downy brome should include a preemergent (PRE) herbicide application in late summer and a postemergent (POST) application to small seedlings (no more than one or two tillers) in early fall. In some cases, a late POST application prior to the onset of winter may be necessary if downy brome emergence is delayed or a late flush occurs. Postemergent herbicide applications in late winter or early spring are not typical since, by that time, downy brome plants are well established and difficult to control. Hand-rogueing escapes in early spring is a standard practice used in conjunction with herbicide application for downy brome management.

Availability of registered herbicides, research data, and recommendations for use in herbicide selection and the design of application sequence strategies are limited for downy brome control in established KBG grown for seed. The most common PRE herbicides used for downy brome control include Prowl H2O (5 pt/acre) and/or a tank-mix of Prowl H2O (3 pt/acre) plus Outlook (1 pt/acre). Other registered herbicides include Dual II Magnum, Nortron, and Eptam, but these products are not widely used due to the lack of research data related to their utility for downy brome control in established KBG seed production. In recent field trials, Alion has demonstrated potential for downy brome control, but it is not currently registered for use in KBG seed crops.

The objective of this trial was to compare KBG crop safety and downy brome control with registered PRE and POST herbicides (Prowl H2O, Outlook, Dual II Magnum, Nortron, Eptam, Beacon, and Outrider) and an unregistered PRE herbicide (Alion) when applied as components of fall sequential programs in established, irrigated KBG grown for seed. Trials were conducted in the Grande Ronde Valley of northeastern Oregon (Union County).

Note: The active ingredient indaziflam (Alion) applied in this study is not registered for use in Oregon KBG seed production. Evaluation of this product is for experimental purposes only and is not a recommendation for commercial use.

Materials and Methods

A small-plot trial was established in a commercial seed production field of KBG (cv. ‘Merit’) in Union County, OR, on September 16, 2022, following harvest of the first seed crop. Postharvest residue was managed by nonthermal practices, which included raking/baling the straw followed by heavy harrowing. The trial was arranged in a randomized complete block design with four replications. Plot dimensions were 10 feet x 30 feet. Preemergent herbicide applications were made September 16, 2022 after postharvest residue management and before the first irrigation event in the fall. Early postemergent (EPOST) herbicide applications were to be applied in the early fall to actively growing downy brome in the one- to two-leaf stage. Herbicide treatments were applied with a 10-foot hand-held CO_2 sprayer delivering 16 gpa at 35 psi. Environmental conditions at the time of herbicide application are summarized in Table 1. Herbicide treatment application rates are presented in Table 2.

Visual evaluations of KBG crop injury, downy brome control, and downy brome plant density were made April 28, 2023. KBG seed yield was not measured in this trial. The field was taken out of production in 2023 following the second seed harvest due to increased downy brome infestation. A cover crop of tillage radish, turnip, and spring barley was planted in early September 2023. General observations were made in October 2023 to determine whether any of the herbicide treatments included in the trial caused cover crop injury.

Analysis of variance was performed to test herbicide treatment effects on KBG crop injury and downy brome control and density. Herbicide treatment means were separated by Tukey’s all-pairwise comparison at 5% level of significance.

Table 1. Crop growth stage and weather conditions at time of herbicide application to Kentucky bluegrass (KBG).

Application timing	Preemergence (PRE) Sep. 16, 2022
KBG growth stage	Regrowth starting
Downy brome growth stage	Not yet emerged
Air temperature (°F)	69
Relative humidity (%)	40
Cloud cover (%)	None
Wind velocity (mph)	0–8 from N-NW
Soil temperature, surface (°F)	69
Soil temperature, 1 inch (°F)	70
Soil temperature, 2 inch (°F)	71
Soil temperature, 4 inch (°F)	78
1st irrigation event after PRE application	Sep. 27, 2022, wheel line, 8-hour set = 3 inches

Table 2. Preemergent herbicide treatments and application rates.

Trade name	Active ingredient	Application rate
		(product/a)
Untreated	—	—
Prowl H2O	pendimethalin	5.0 pt
Prowl H20 + Outlook	pendimethalin + dimethenamid	3.0 pt + 1.0 pt
Prowl H2O + Dual II Magnum	pendimethalin + S-metolachlor	3.0 pt + 21.0 oz
Alion	indaziflam	2.0 oz
Alion + Prowl H2O	indaziflam + pendimethalin	2.0 oz + 3.0 pt
Prowl H2O	pendimethalin	3.0 pt
Eptam 7E	EPTC	3.5 pt

Results and Discussion

Dry early- to mid-fall conditions (lack of rainfall) in 2022 delayed downy brome emergence and negatively impacted activity of PRE herbicides despite timely herbicide application and supplemental water provided by irrigation in late September. Since downy brome emerged and developed several tillers over winter, EPOST herbicide treatments were not applied in spring 2023, as by that time downy brome exceeded the optimal growth stage for postemergence control.

KBG crop injury from herbicide treatments was not observed in this trial (data not shown). The light and variable downy brome infestation across the trial site made visual evaluation of control impossible. Alternatively, downy brome plant density was determined by counting individual plants within each plot and then converting to density/ft^2 (Figure 1).

No significant differences in downy brome plant density were observed among herbicide treatments. This result might be attributed to the dry fall conditions that led to late emergence (approximately 2–3 months following application).

At the time of herbicide application, distinct rows were still visible in the KBG stand. Soil surface conditions in the interrow space were variable, ranging from bare soil to complete cover with fine postharvest residue. Interception of PRE herbicides by remaining residue on the field may have negatively impacted downy brome control.

Visual observations of cover crop injury were made on October 19, 2023. Herbicide treatments including Alion (indaziflam) thinned the stand of all species within the mix by 80% or more (data not shown).

In this trial, PRE herbicides such as Prowl H2O + Outlook, Alion + Prowl H2O, and Alion alone showed potential utility for downy brome control in established KBG. Additional investigation of underutilized herbicides is warranted to determine their potential for downy brome control. For example, Nortron (ethofumesate) has both PRE and EPOST activity and may have potential utility for downy brome control in a sequential application program.

Further research is needed to explore whether multiple heavy harrowing could expose more soil surface between rows than a single harrowing event in young established KBG stands (first and second seed harvest years). Research is also needed on the timing and frequency of postharvest irrigation to improve soil-active herbicide efficacy.

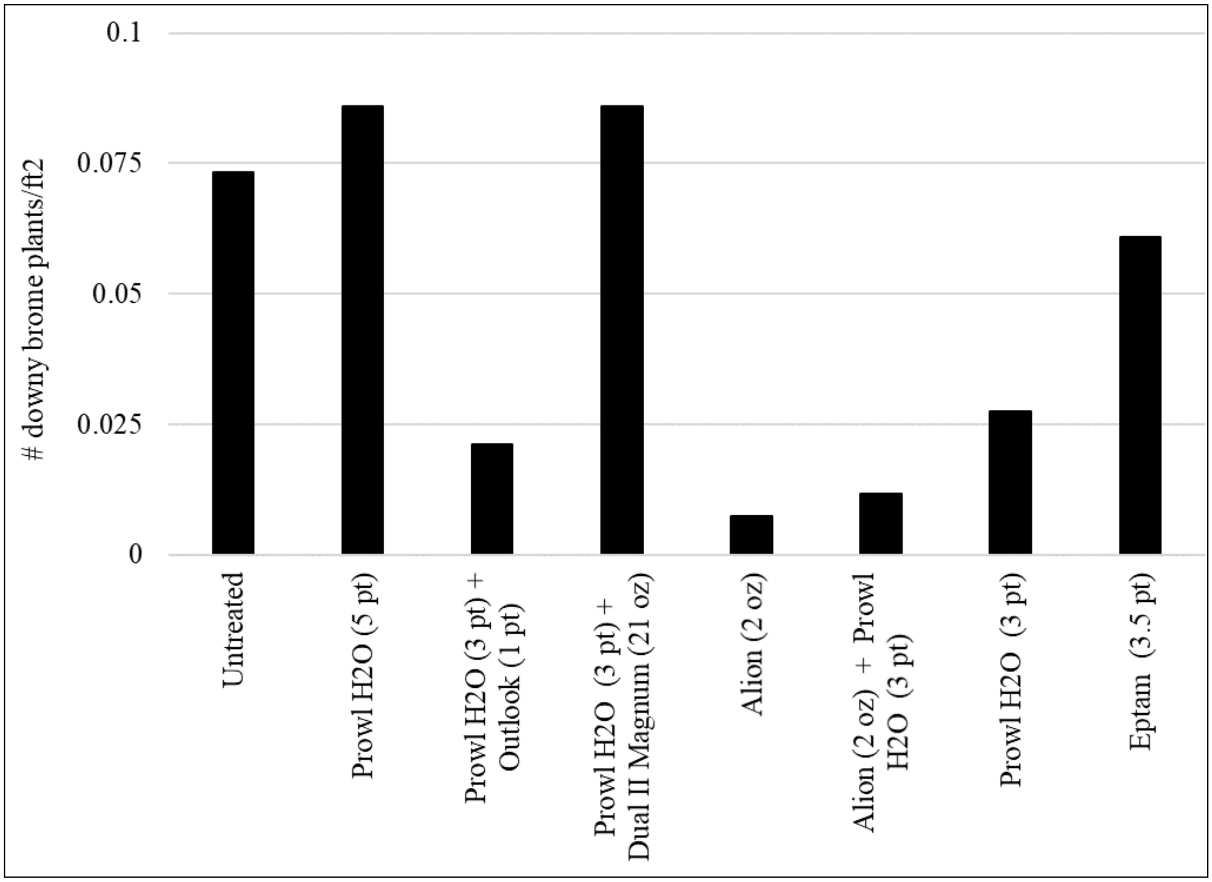

Figure 1. Downy brome density (number of plants/ft^2) in spring 2023 following fall preemergent herbicide application in established Kentucky bluegrass grown for seed in northeastern Oregon (Grande Ronde Valley).

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RESIDUE MANAGEMENT INFLUENCE ON DOWNY BROME CONTROL IN ESTABLISHED KENTUCKY BLUEGRASS GROWN FOR SEED

D.L. Walenta

Introduction

Timely and effective management of postharvest residue is key to preparing an established Kentucky bluegrass (KBG) stand to achieve optimal seed yield potential in the next crop. Previous research has demonstrated that residue management strategies can maintain seed yield and quality in the absence of open field burning. However, straw removal must be thorough, and stubble height must be reduced prior to crop regrowth in the fall (Chastain et al., 1997). Currently, the primary residue management method utilized by KBG seed growers in the Grande Ronde Valley (GRV) of Oregon involves removing the straw by raking/baling and then propane-flaming the field to reduce stubble height and open up the plant crown for tiller development.

The optimal window for managing postharvest residue with propane-flaming occurs soon after harvest (July–August), as KBG stand regrowth typically occurs by late August–September (Walenta et al., 2004). In some years, however, wildfire smoke intrusion into the GRV degrades air quality to a level that prohibits thermal (propane-flame and open field burn) residue management activities during the regulated field burn season (July 15–September 30). In this situation, mechanical removal (baling) is the only option, but a substantial amount of fine residue is left on the field surface.

Control of downy brome (*Bromus tectorum*) is difficult to achieve with preemergent (PRE) herbicides following postharvest residue management due to interception of applied herbicide by ash and/or unburnt residue on the field surface. To improve field surface conditions for PRE herbicide application, it is necessary to harrow and/or irrigate the field to disperse ash/unburnt residue. The effectiveness of these technique is variable and contributes to poor herbicide performance, especially when crop rows have closed in older KBG stands. Further research is warranted to investigate postharvest residue and irrigation water management strategies that can improve PRE herbicide control of winter annual grass weeds.

The objectives of this study were to:

- Compare downy brome control with sequential herbicide application following two post-harvest residue management techniques: bale only (nonthermal) and bale + propane-flame (thermal).
- Evaluate residual herbicide control of downy brome and crop safety in the subsequent winter wheat crop.

Note: The active ingredients indaziflam (Alion) and pyroxasulfone (Zidua) applied in this study are not registered for use in KBG seed crops in Oregon. Product evaluations are for experimental purposes only, not for commercial use.

Materials and Methods

Objective 1

The study was initiated in 2021 in a commercial seed production field of KBG cv. 'Full Moon' following the third seed harvest. Postharvest straw was raked and baled in late July. The entire field, including the study site, was irrigated with 0.5 inch irrigation water on August 12.

The study design was a randomized complete block in a split-block arrangement. Main blocks were bale + propane flame and bale-only residue management treatments. Propane-flamed blocks were flamed and harrowed with a pasture harrow on August 9. The bale-only block was not propane-flamed and was not harrowed. Subplots were herbicide treatments with four replications.

Environmental conditions at the time of herbicide application are summarized in Table 1. Herbicide treatment subplots were 8 feet x 25 feet. An 8-foot hand-held CO_2 sprayer calibrated to deliver 21 gpa at 36 psi was used to apply herbicides. Downy brome control and KBG crop injury evaluations were made on September 16, 2021 (34 days after PRE application) and May 3, 2022 (226 days after PRE application). KBG seed yield was not measured in this study.

Objective 2

After the fourth seed harvest in July 2022, the KBG stand was taken out of production. When KBG attained 3–6 inches regrowth, the stand was sprayed out with glyphosate, and the field was rototilled 2 weeks later. Winter wheat was conventionally seeded with a double disc drill on October 20, 2022. The study area was

Table 1. Crop/weed growth stage and weather conditions at time of herbicide application to Kentucky bluegrass (KBG).

Application timing	Aug. 13, 2021 Preemergence (PRE)	Aug. 31, 2021 Early postemergence (EPOST)
KBG growth stage	No regrowth	3–6 inches regrowth
Downy brome growth stage	Not yet emerged	1–3 leaf
Air temperature (°F)	56	60
Relative humidity (%)	69	45
Cloud cover (%)	None, heavy smoke haze	None, smoke haze
Wind velocity (mph)	0–2 from N	0–4 from N
Soil temp., surface (°F)	56	78
Soil temp., 1 inch (°F)	58	70
Soil temp., 2 inch (°F)	62	61
Soil temp., 4 inch (°F)	65	60
1st irrigation event after PRE application	1 inch applied Aug. 16 (3 days after application)	0.5 inch applied Aug. 31 (4 hours after application)

restaked and monitored for residual downy brome control and winter wheat crop injury from potential herbicide carryover. Winter wheat crop injury and *Bromus tectorum* density evaluations were made on May 4, 2023. Winter wheat grain yield was not measured in this study.

Analysis of variance was performed to test residue management and herbicide treatment effects and their interaction on crop injury and downy brome control. Herbicide treatment means were separated by Tukey's all-pairwise comparison method at 5% level of significance.

Results and Discussion

There were no significant interactions between residue management technique and herbicide treatment effects on KBG/winter wheat crop injury or downy brome control within either crop. Herbicide treatment differences were observed in KBG (fall 2021) for downy brome control; treatments that provided acceptable control included Alion applied at the PRE application date at either 2 or 3 fl oz/acre (Table 2). By spring 2022, the downy brome infestation had increased to severe levels, and there were no differences among herbicide treatments. However, KBG injury observed the previous fall was not detectable the following spring (data not shown).

There was no crop injury in recrop winter wheat (spring 2023) from any herbicide treatments applied during the last cycle of KBG seed production (Table 3). The herbicide treatments were applied 13–14 months prior to planting the winter wheat. Crop injury potential may have been minimized by tillage utilized to prepare the field for planting winter wheat, which may have diluted the herbicide within the soil disturbance zone. The downy brome infestation in the winter wheat crop was light and variable, so plant density was determined for each plot (200 ft^2). Differences in plant density were detected, but it was not possible to attribute those differences to herbicide treatments applied previously to KBG.

Conclusions

Postemergent (POST) herbicide options are extremely limited for control of winter annual grass weed species in KBG seed crops. Therefore, it is critical to maximize efficacy potential of PRE herbicides for these weed species.

The results of this study suggest that further investigation is needed to explore harrowing techniques and irrigation management strategies that might more effectively disperse ash/fine residue and allow applied herbicide to reach the soil surface in an established KBG stand. For example, indaziflam requires 48 hours of binding time on dry soil to prevent movement into the crop root zone (Bayer Crop Science). Recent research has also demonstrated that certain soil-active herbicides can be desorbed from winter annual grass litter with simulated rainfall (Clark et al., 2019). If sufficient irrigation water could be delivered soon after herbicide application, it might be possible to move indaziflam or other soil-active herbicides to the soil surface in KBG seed production fields that received either thermal or nonthermal postharvest residue management. If such strategies can be developed, it might also be possible to extend the window for downy brome control in the fall by applying two different PRE herbicides in sequence (Table 2).

Table 2. Crop injury and downy brome control in established Kentucky bluegrass (KBG) grown for seed with sequential herbicide applications under thermal and nonthermal postharvest residue management techniques.

Tmt	Herbicide treatment	Product rate/a	Timing	Sep. 16, 2021[1]			
				KBG crop injury		Downy brome control	
				Bale only	Bale + propane	Bale only	Bale + propane
				(%)		(%)	
1	Check	Untreated		0 b	1	0 b	0 d
2	Prowl H2O // Beacon	5 pt 0.76 oz	PRE EPOST	2 ab	1	42 ab	46 c
3	Zidua WG // Outrider	1.85 oz 0.76 oz	PRE EPOST	9 a	5	50 ab	37 c
4	Prowl H2O // Outrider	5 pt 0.76 oz	PRE EPOST	2 ab	2	31 ab	34 c
5	Alion	1 fl oz	PRE	0 b	0	35 ab	49 bc
6	Alion	2 fl oz	PRE	0 b	0	44 ab	71 ab
7	Alion	3 fl oz	PRE	0 b	0	72 a	75 a
8	Prowl H2O // Alion	5 pt 1 fl oz	PRE EPOST	0 b	0	0 b	0 d
9	Prowl H2O // Alion	5 pt 2 fl oz	PRE EPOST	0 b	0	22 ab	7 d
10	Prowl H2O // Alion	5 pt 3 fl oz	PRE EPOST	0 b	0	18 ab	0 d
	LSD (0.05)	—	—	6	ns	65	23

[1] Numbers followed by the same letter are not significantly different at LSD ($P = 0.05$).

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Table 3. Crop injury and downy brome density in recrop winter wheat following sequential herbicide application in established Kentucky bluegrass under thermal and nonthermal postharvest residue management techniques.

				---------------------- May 4, 2023 ----------------------			
Tmt	Herbicide treatment	Product rate/a	Timing	Winter wheat ------ crop injury ------		Downy brome --------- density[1, 2] --------	
				Bale only	Bale + propane	Bale only	Bale + propane
				---------- (%) ----------		------------ (%) ------------	
1	Check	Untreated		0	0	3	2 b
2	Prowl H2O // Beacon	5 pt 0.76 oz	PRE EPOST	0	0	18	6 ab
3	Zidua WG // Outrider	1.85 oz 0.76 oz	PRE EPOST	0	0	10	19 a
4	Prowl H2O // Outrider	5 pt 0.76 oz	PRE EPOST	0	0	6	3 b
5	Alion	1 fl oz	PRE	0	0	17	4 ab
6	Alion	2 fl oz	PRE	0	0	7	2 b
7	Alion	3 fl oz	PRE	0	0	4	5 ab
8	Prowl H2O // Alion	5 pt 1 fl oz	PRE EPOST	0	0	2	8 ab
9	Prowl H2O // Alion	5 pt 2 fl oz	PRE EPOST	0	0	1	2 b
10	Prowl H2O // Alion	5 pt 3 fl oz	PRE EPOST	0	0	2	1 b
	LSD (0.05)	—	—	ns	ns	ns	15

[1] Mean of four replications.

[2] Numbers followed by the same letter are not significantly different at LSD (*P* = 0.05).

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Business Address

Oregon Seed Council
28415 SW Villebois Dr. N
Wilsonville, OR 97070

Tel: (503) 585-1157
E-mail: Megan@MAC-Consulting-LLC.com
www.oregonseedcouncil.org

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