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ACCASE RESISTANCE IN DOWNY BROME POPULATIONS FROM FINE FESCUE FIELDS: A FOLLOW-UP SURVEY

Renan N. D. Favera, Carol A. Mallory-Smith, Darrin L. Walenta, Pete Berry, and Victor H. V. Ribeiro

Introduction

Downy brome (*Bromus tectorum* L.) is a challenging species to manage in fine fescue (*Festuca* L. spp.) seed production in northeastern Oregon. Postharvest preemergence herbicide options are limited and often ineffective due to any ash remaining on the field surface following thermal residue management and/or insufficient rainfall or irrigation for herbicide activation in the fall. In years when air quality conditions (e.g., wildfire smoke) prevent standard thermal postharvest residue management (e.g., bale + propane flame) activities, herbicide effectiveness is further impacted by any fine fescue residue remaining on the field surface. Therefore, additional measures (e.g., hand rogueing) are necessary to control downy brome infestations after emergence. Currently, two postemergence herbicides are registered for use in fine fescue: fluazifop (Fusilade DX) and sethoxydim (Poast), both of which belong to Group 1 [acetylcoenzyme A carboxylase (ACCase) inhibitors]. However, the lack of postemergence herbicide options with different modes of action created reliance upon the ACCase-inhibiting herbicides, which has contributed to the selection of ACCase-resistant downy brome populations.

The first recorded case of an ACCase-resistant downy brome population was identified in a creeping red fescue (*F. rubra* L.) seed production field, near La Grande, OR, where fluazifop had been used repeatedly for over seven years (Ball et al., 2007). This population was cross-resistant to sethoxydim, as well as other ACCase-inhibiting herbicides not even registered for use in fine fescue, such as quizalofop (Assure II) and clethodim (Select Max). Fifteen years later, we initiated a survey of fine fescue seed production fields in the same region of northeastern Oregon in response to increased grower reports of failed control with ACCase-inhibiting herbicides, which resulted in the identification of nine downy brome populations confirmed to be ACCase-resistant (Ribeiro et al., 2023). The results from this initial survey of fine fescue seed production fields demonstrated that continued selection pressure from ACCase-inhibiting herbicide use led to an increased frequency of resistance in downy brome populations. In the 2022 survey, we found results similar to the first recorded resistance case, where the nine populations exhibited cross-resistance patterns to the different ACCase inhibitor herbicides including fluazifop, sethoxydim, quizalofop and clethodim.

The evolution of ACCase-resistant populations has further complicated downy brome management in fine fescue seed production. Therefore, the objective of this study was to expand upon the initial 2020 survey by conducting a more in-depth investigation into the herbicide resistance status of downy brome populations in fine fescue fields within the Grande Ronde Valley of northeastern Oregon. Specifically, we screened 17 downy brome populations collected from fine fescue fields in 2022 for resistance to fluazifop and sethoxydim, two herbicides commonly used in fine fescue seed production.

Materials and Methods

Plant material

In 2022, 17 downy brome populations were collected at physiological maturity from commercial fine fescue seed production fields in Union County. Ten mature plants were randomly collected from each field, placed in individual paper bags, and labeled with a unique sample name and corresponding geographical coordinates. Panicles were manually threshed to collect seeds, which were then stored in envelopes at room temperature until screenings began. A known herbicide-susceptible downy brome population (“S”) collected at the Central Oregon Agricultural Research and Extension Center (44.68077°N, -121.14932°W), near Madras, OR, was included for comparison. For the resistance screenings, seeds from each of the 10 plants collected per population were combined into one composite sample per population.

Herbicide resistance screenings

The experiment was conducted in two trials in a greenhouse at Oregon State University, Corvallis, OR, using a randomized complete block design with four replications. Plants were grown at 75/65°F day/night, with LED light supplementation (471µmol m^{-2} s^{-1}) to maintain a 15-hour photoperiod. Herbicide rates of 0, 1, and 2 times (X) the recommended labeled rates were tested. The 1X rates for fluazifop (8 fl oz/A) and sethoxydim (2.5 pts/A) were based on fine fescue recommendations. Herbicides were applied with crop

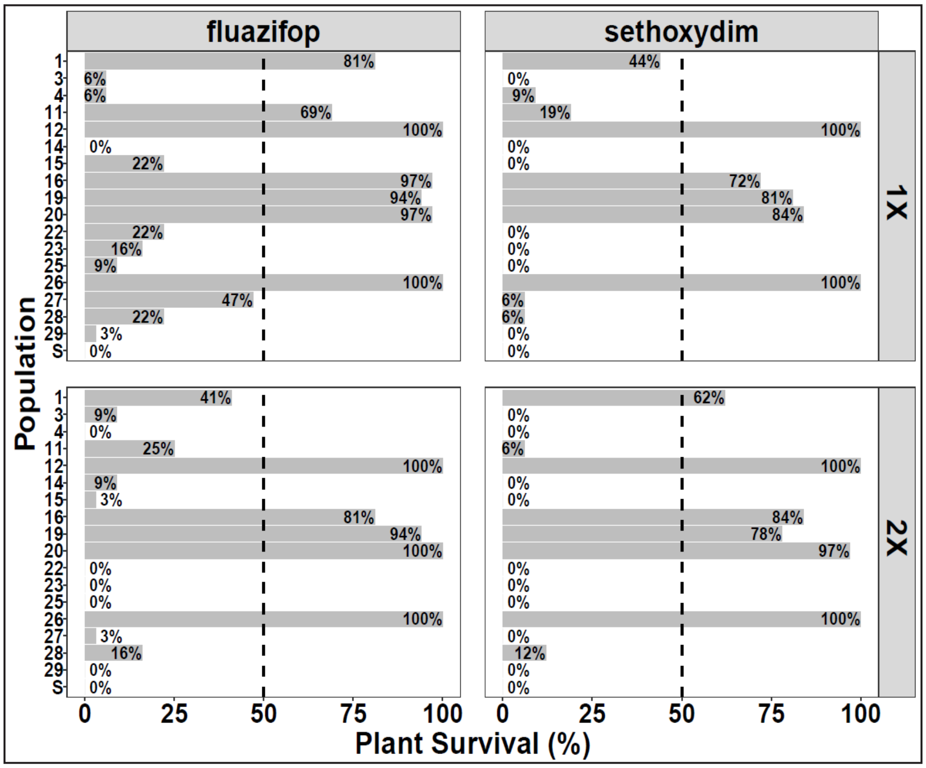

Figure 1. Downy brome survival to fluazifop and sethoxydim at the labeled rate (1X) and two times the labeled rate (2X) of each herbicide. Populations with ≥ 50% survival (represented by the dashed line) were classified as resistant.

oil concentrate at 1% v/v using a research sprayer delivering 20 GPA spray volume through a TP8003E nozzle to downy brome plants at the three- to four-leaf stage (6 inches tall).

Data collection

At 21 days after treatment, plant survival was evaluated visually as dead (no green tissue = 0) or alive (green tissue and evidence of regrowth = 1). Survival was expressed as the proportion of surviving plants relative to the total number of treated seedlings. Downy brome populations with ≥ 50% survival to the 1X rate of the herbicides tested were considered resistant.

Results and Discussion

Resistance screenings revealed that some downy brome populations were resistant to the ACCase inhibitors fluazifop and sethoxydim (Figure 1). Survival levels varied among populations for each herbicide, with some exhibiting cross-resistance.

Of the 17 populations screened, seven had greater than 50% survival when treated with the 1X rate of fluazifop (16 fl oz/A). Survival decreased slightly when treated with the 2X rate of fluazifop (32 fl oz/A), but five populations had more than 50% survival. Similarly, five populations had more than 50% survival when treated either with the 1X rate (2.5 pts/A) or the 2X rate (5 pts/A) of sethoxydim. Five populations were cross-resistant to fluazifop and sethoxydim, with greater than 50% survival when treated with the 1X rate or the 2X rate of both herbicides. Four downy brome populations were below the resistance threshold used in this study (≥ 50% survival to the 1X rate) but had greater than 20% survival indicating that resistant individuals were present.

Conclusion

In this study, we confirmed seven ACCase-resistant downy brome populations (based on ≥50% survival rate) of the 17 populations collected from fine fescue seed production fields in northeastern Oregon. These findings highlight the need for integrated weed management strategies to delay further resistance evolution and spread. In the absence of alternative herbicide modes of action for postemergence application, implementing cultural and mechanical control will be key to help reduce herbicide selection pressure and improve long-term downy brome management in fine fescue fields.

References

Ball, D. A., Frost, S. M., & Bennett, L. H. (2007). ACCase-inhibitor herbicide resistance in downy brome (*Bromus tectorum*) in Oregon. *Weed Science*, *55*(2), 91–94. https://doi.org/10.1614/WS-06-120.1

Ribeiro, V. H. V., Brunharo, C. A., Mallory-Smith, C., Walenta, D. L., & Barroso, J. (2023). First report of target-site resistance to ACCase-inhibiting herbicides in *Bromus tectorum* L. *Pest Management Science*, *79*(10), 4025-4033. https://doi.org/10.1002/ps.7607

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WEED MANAGEMENT NEEDS ASSESSMENT SURVEY FOR FIELD CROPS IN OREGON

Victor H. V. Ribeiro

Introduction

As a first step in building an effective statewide applied research and extension program, a weed management needs assessment survey was performed to evaluate current challenges and needs faced by Oregon growers and other agricultural stakeholders. Such surveys play a critical role in capturing perceptions, management strategies, and research needs that shape agronomic decisions (Sarangi et al., 2018). The findings from this survey are expected to guide future research and outreach efforts aimed at improving weed management strategies in Oregon's field crops.

Material and Methods

The survey targeted agricultural stakeholders involved with the diverse field crops grown in Oregon. It was made available online through the Qualtrics platform from October 2024 to February 2025. A survey link was distributed via email to the Oregon Grass Seed Commission, Oregon Clover Commission, Oregon Mint Commission and other industry groups. The survey was also shared on LinkedIn and Twitter, and a QR code linking to the survey was shared during the Oregon Society of Weed Science and winter extension meeting presentations. In addition, Extension agents assisted in distributing the survey around the state.

The survey consisted of eight questions divided into three sections: the first section gathered general information (respondent's occupation and location); the second focused on resource and support needs; and the third addressed current weed management challenges and economic impacts. Six questions allowed only one response, leading to cumulative totals of 100%, while two questions allowed multiple responses, resulting in totals exceeding 100%. The data were exported to a Microsoft Excel file, with responses to each question organized into separate columns, and were visualized using bar graphs in R statistical software (version 4.4.2; R Core Team, 2024).

Results and Discussion

<u>Respondent demographics</u>

A total of 184 respondents participated in the survey, with 47% identifying as growers, 28% as crop consultants, 8% as extension agents, and 17% as "other" (e.g., researchers, field representatives and educators). Seventy-four percent of the respondents were located in Western Oregon, while 26% were based in Eastern Oregon.

<u>Resource and support needs</u>

When respondents were asked about topics they would like more information or training on, 46% expressed interest in new herbicide technologies, 25% indicated herbicide resistance, 17% in nonchemical weed control methods, and 12% in weed biology and ecology (Figure

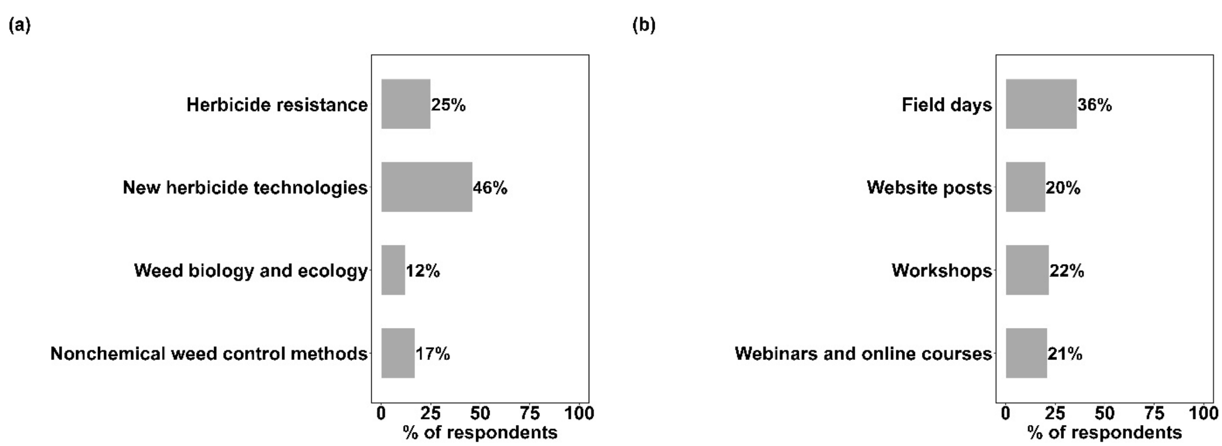

Figure 1. Summary of (a) topics respondents would like more information or training on and (b) their preferred methods for receiving weed management information.

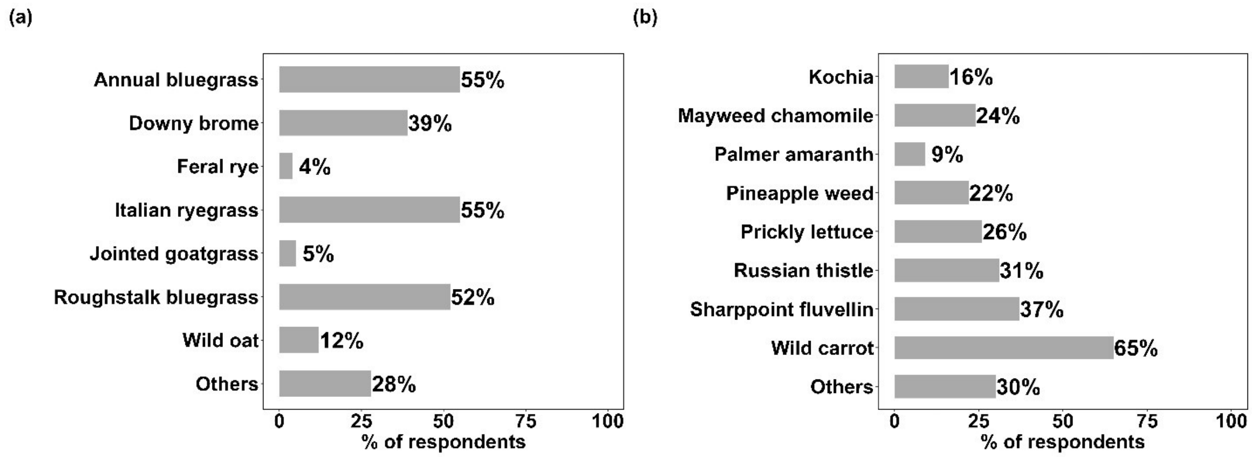

Figure 2. The most problematic (a) grass and (b) broadleaf weed species as identified in the survey.

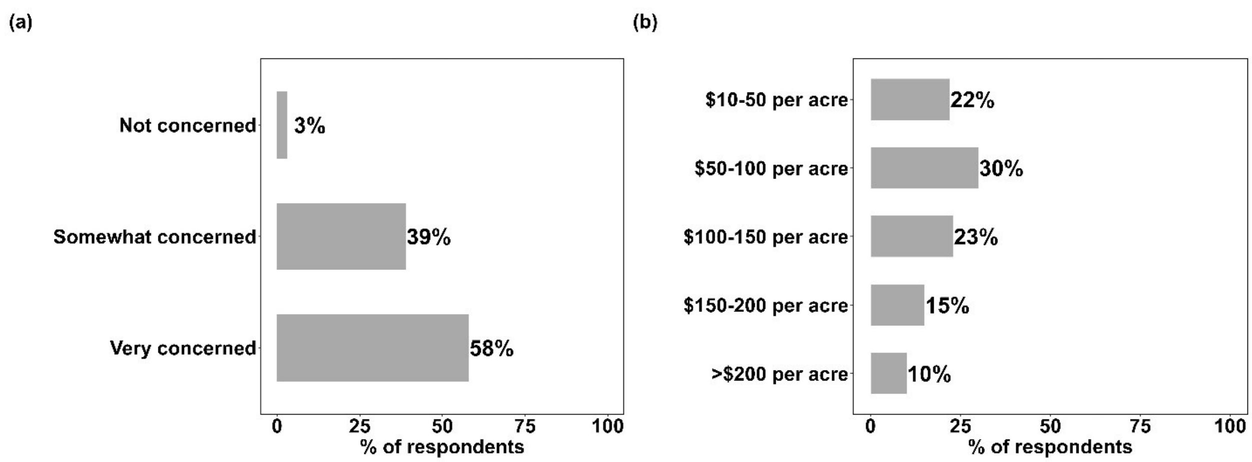

Figure 3. The (a) overall concern about herbicide-resistant weeds on respondents' farms based on survey responses and (b) the average cost per acre respondents report spending on weed control in field crops.

1a). In terms of preferred methods for receiving weed management information, 36% of respondents favored field days, 22% preferred workshops, 21% chose webinars and online courses, and 20% preferred website posts (Figure 1b).

Current weed management challenges and economic impacts

Respondents indicated several weed species as particularly troublesome in their fields (Figure 2). Among grass weeds, annual bluegrass (*Poa annua*), Italian ryegrass (*Lolium multiflorum*), and roughstalk bluegrass (*Poa trivialis*) were the most frequently reported, with at least 52% of respondents indicating them as major concerns, followed by downy brome (*Bromus tectorum*) at 39% (Figure 2a). Wild oat (*Avena fatua*), jointed goatgrass (*Aegilops cylindrica*), and feral rye (*Secale cereale*) were reported by 12%, 5%, and 4% of respondents, respectively. Additionally, 28% of respondents listed "other" grass weeds, including rattail fescue (*Vulpia myuros*), barnyardgrass (*Echinochloa crus-galli*), foxtail (*Setaria* spp.), and other bromegrasses (*Bromus* spp.).

For broadleaf weeds, wild carrot (*Daucus carota*) was by far the most problematic weed species, reported by 65% of respondents (Figure 2b). Sharppoint fluvellin (*Kickxia elatine*) and Russian thistle (*Salsola tragus*) followed, with 37% and 31%, respectively. Prickly lettuce (*Lactuca serriola*), mayweed chamomile (*Anthemis cotula*), pineapple weed (*Matricaria matricarioides*), kochia (*Bassia scoparia*), and Palmer amaranth (*Amaranthus palmeri*) were identified as concerns by 26%, 24%, 22%, 16%, 9% of respondents, respectively. Additionally, 30% of respondents listed "other" problematic broadleaf weeds, including common groundsel (*Senecio vulgaris*), horseweed (*Erigeon canadensis*), thistles (*Cirsium* spp.), and pigweeds (*Amaranthus* spp.).

In addition to current weed management challenges, respondents were also asked about their level of concern regarding herbicide-resistant weeds on their farms. Fifty-eight percent of respondents indicated being very concerned, 39% were somewhat concerned and only 3% were not concerned (Figure 3a).

To assess the economic impact of weed management in growers' fields, respondents were asked about the average cost of weed control per acre in their crops. Thirty percent of respondents reported an average weed control cost of $50 to $100 per acre, followed by 23% who estimated $100 to $150 per acre (Figure 3b). Other responses included 22% reporting costs of $10 to $50 per acre, 15% reporting $150 to $200 per acre, and 10% reporting spending more than $200 per acre.

Conclusion

The survey results will serve as a foundation for prioritizing research topics, fostering collaborations with key stakeholders, and designing applied research projects and extension programs that are directly aligned with the needs and concerns of Oregon's growers.

References

Sarangi D, Jhala AJ (2018) A statewide survey of stakeholders to assess the problem weeds and weed management practices in Nebraska. Weed Technology, 32:642-655

R Core Team (2024) R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

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I would like to thank everyone who participated in the survey. Your input is instrumental in guiding the direction of future research and outreach efforts within Oregon's agricultural community.

EVALUATING RODENTICIDES IN BAIT BOXES FOR VOLE CONTROL IN GRASS SEED CROPS – YEAR 2

K. Christy Tanner

Introduction

The gray-tailed vole (*Microtus canicaudus*) can cause substantial yield losses in Willamette Valley grass seed crops (Verhoeven and Anderson, 2021), and growers have few options for control. Historically, elevated vole populations caused yield losses throughout the region on a periodic basis. More recently, an extended period of elevated vole populations occurred in 2019 through early 2023 (Verhoeven and Anderson, 2021; Tanner and Mahoney, 2024). After only a short reprieve, reports of vole damage increased again beginning in late 2024. These recent outbreaks have highlighted the need for improved vole control options.

The only rodenticide active ingredient registered for use in grass seed is zinc phosphide, with several bait formulations available. Only 26% of growers reported being satisfied with the effectiveness of zinc phosphide baits in a 2021 survey (Verhoeven and Anderson, 2021). Tillage and crop rotation can reduce vole populations, but this option is a last resort in perennial grass seed crops (Steiner et al., 2007).

This study tested whether voles would enter bait boxes and feed on diphacinone and chlorophacinone rodenticide baits during the spring in tall fescue fields. The Oregon Department of Agriculture has indicated that a special local need (Section 24c) label for either of these rodenticides is possible. This study was designed to collect the data needed to support these labels. Data from the first year of this project (one field site) can be found in the *2023 Seed Production Research Report* (Tanner and Mahoney, 2024). This report presents data from studies conducted in the second year of the project at three field sites and some previously unpublished data from the first year of the project.

Materials and Methods

Overview:

The 2024 study was conducted in three established tall fescue fields in Linn and Benton counties, OR (Table 1). The 2023 study was conducted in a first-year field (planted spring 2022), using the materials and methods described here. The study design was a randomized complete block design with four replicates. Each experimental unit consisted of a bait box filled with the treatment bait and placed in the center of a single vole colony. Vole colonies were selected along four transects. When possible, bait boxes were placed at least 50 feet apart, but due to lower vole populations at the start of the trial, some bait boxes were spaced as close as 30 feet. In 2023, the transects were placed 100 feet apart. In 2024, the transects were placed in the areas between sprayer tracks (90–100 feet spacing) to avoid interference with the growers' field operations. Boxes were monitored for 8 to 14 weeks (Table 1).

Treatments

Five rodenticidal baits and a nonlethal check (pelleted Payback Egg Layer chicken feed, CHS) were evaluated. The bait treatments included Ramik Green (diphacinone, Neogen), Ramik Brown (diphacinone, Neogen), PCQ-Ag (diphacinone, Motomco), Rozol (chlorphacinone, Liphatech), and DoubleTap (chlorphacinone, Liphatech).

Bait box and vole activity measurements

Motomco Titan bait boxes with iQ trays were used for this trial. The iQ tray holds the bait inside the bait box and contains a capacitive sensor that detects and records animal activity inside the box. When the sensor is triggered, the device records the date and time as an "event," and begins a 30-minute waiting period when

Table 1. Field locations, study dates and lengths.

Field	Location	Study dates	Study length (weeks)
Field 1	Shedd, OR	March 8 – June 5, 2024	12
Field 2	Tangent, OR	March 19 – June 26, 2024	14
Field 3	Corvallis, OR	April 24 – July 1, 2024	9
2023	Tangent, OR	April 13 – June 8, 2023	8

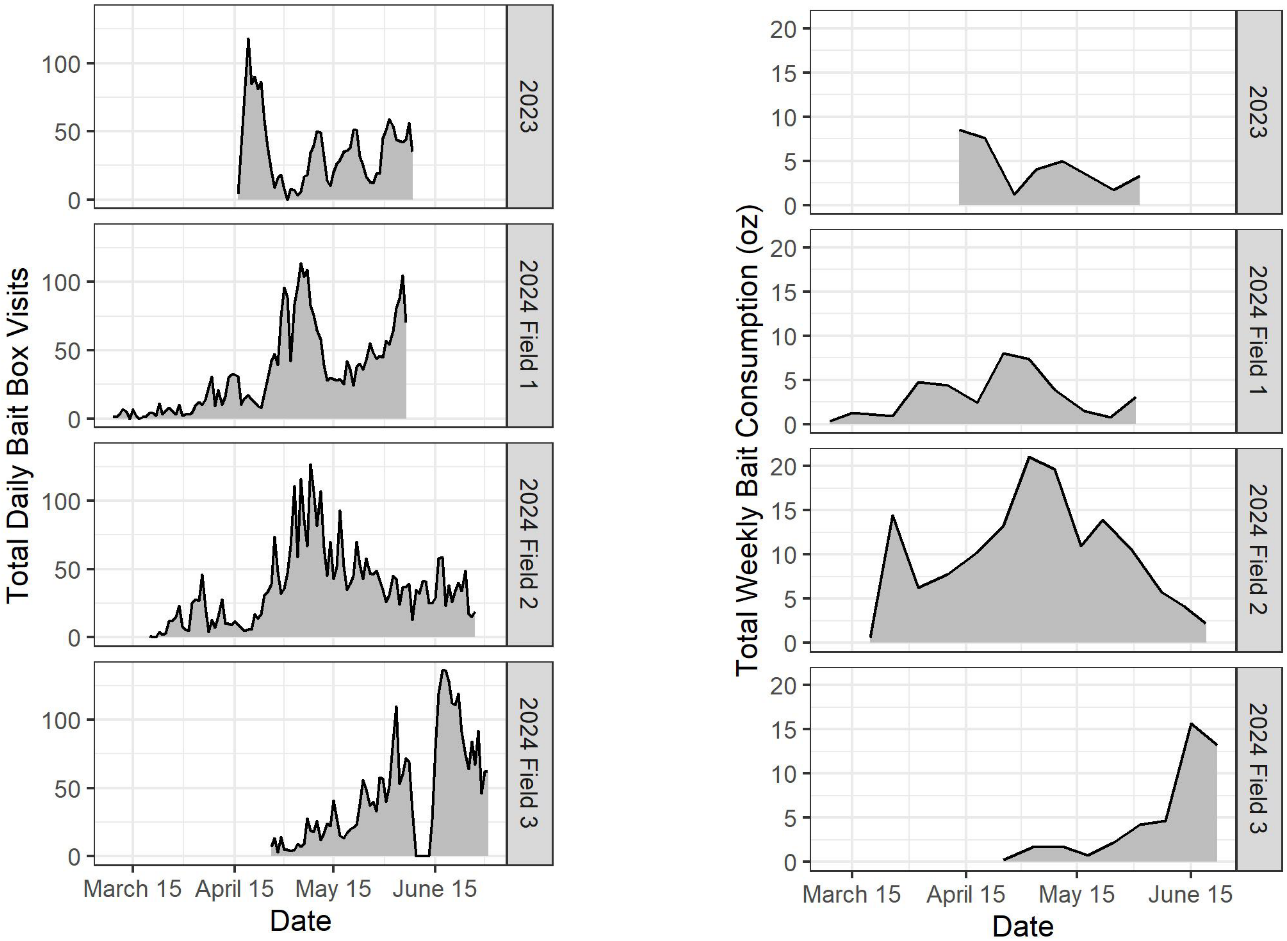

Figure 1. Overall daily bait box visits (left) and weekly bait consumption (right) for the three field sites studied in 2024, and data from the 2023 trial. These data show the total from all 24 bait boxes at each site.

no new events are recorded. A single animal feeding in the box is likely to trigger the sensor multiple times (e.g., entering the box, moving around, feeding and exiting the box) and was recorded as a single event. However, multiple animals interacting within the box in a 30-minute window are also recorded as a single event. Event data were 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 (3.5 oz per box). All plots were inspected for signs of vole activity and photographed each week.

Previous studies indicate that baits can gain or lose moisture from the environment, causing an increase or decrease in weight, without any bait consumption (Salisbury and Anderson, 2021a and 2021b). To control for these factors, moisture check bait boxes (one for each type of bait with screen placed over the entrances so voles could not enter) were placed at each field site. After collection, all bait samples were stored in a resealable plastic bag with a 0.71 oz desiccant packet until they achieved a constant weight. Weight loss from the experimental samples was adjusted by subtracting the average weight change observed in the moisture check samples for the corresponding field and bait type.

Game cameras

Game cameras were placed in Fields 2 and 3 (6 per field) to gather information about vole behavior. Cameras were placed near bait boxes (within the same vole colony) at heights of 0 to 12 inches. Camera placement was selected to capture images of vole burrows or the entrances of bait boxes.

Statistical analysis

Statistical tests were performed using R statistics software. The effects of bait treatment and field were analyzed using ANOVA, followed by a Tukey test to identify differences between groups. Statistical analysis included data from the field studied in 2023.

Table 2. Summary of bait box data showing the total number of visits recorded and total bait consumption during the study (n = 4 boxes per bait type per field). The percentage of times that boxes of each bait type had five or more visits, or at least 0.2 oz of bait consumption during weekly data collection (or "observation") is also shown.

Bait	Total visits (mean ± SE)	Total bait consumption (oz) (mean ± SE)	Observations with ≥ 5 visits (%)	Observations with ≥ 0.2 oz bait consumption (%)
Field 1 (48 observations per bait type)				
Chicken feed	116± 40	0.8 ± 0.4	60	8
Ramik Brown	115 ± 31	0.5 ± 0.6	52	2
Ramik Green	102 ± 37	1.4 ± 1.3	42	8
PCQ Ag	148 ± 89	2.2 ± 1.1	56	17
Rozol	107 ± 29	3.8 ± 1.7	52	29
DoubleTap	152 ± 71	0.7 ± 0.2	56	8
Field 2 (56 observations per bait type)				
Chicken feed	247 ± 130	23.5 ± 17.7	61	57
Ramik Brown	101 ± 65	2.3 ± 1.9	29	9
Ramik Green	160 ± 58	2.1 ± 3.2	50	16
PCQ Ag	124 ± 54	2.5 ± 2.7	39	13
Rozol	112 ± 29	3.0 ± 3.0	50	11
DoubleTap	161 ± 38	0.8 ± 0.6	57	7
Field 3 (36 observations per bait type)				
Chicken feed	92 ± 32	0.9 ± 1.4	50	8
Ramik Brown	119 ± 23	1.1 ± 0.8	61	25
Ramik Green	131 ± 65	1.7 ± 2.3	50	33
PCQ Ag	106 ± 39	2.7 ± 1.6	44	33
Rozol	91± 34	2.1 ± 0.8	53	28
DoubleTap	207 ± 61	1.8 ± 0.6	53	42

Results and Discussion

Field observations

Signs of vole activity such as droppings, clipped vegetation and fresh digging were present in all three fields throughout the study period. The majority of the animals captured in game camera recordings were identified as gray-tailed voles, but mice, shrews, weasels, and birds were also recorded. Damage at Field 2 and Field 3 was severe enough that both fields were removed from production after the 2024 harvest. These data indicate that voles were active during the study.

Corrections for bait moisture changes

The weight changes observed in moisture check samples ranged from an increase in weight of 0.02 oz to a decrease of 0.22 oz. Field, bait type, the interaction between field and bait type, and week all had statistically significant effects on the amount of weight change observed in the check samples. Standard deviations among samples from the same field and bait type ranged from 0.01 to 0.04 oz. This approach corrected for the average impact of bait moisture changes. However, the variability in weight loss among check samples demonstrates a source of random error in individual bait weight measurements. After applying the weight loss correction based on the check samples, 29% of samples had negative consumption values of up to -0.25 oz, i.e., they appeared to have gained weight. In addition, 61% of samples from boxes with no recorded events had consumption of up to 0.25 oz. An additional eight samples had bait consumption of more than 0.25 oz with no recorded events; however, these samples had clear evidence of vole activity such as droppings or evidence of nest building in the box. It is possible that residual vole activity in previous weeks interfered with the sensor.

Box visits and bait consumption

This study showed that voles will enter bait boxes and consume bait from mid-March through mid-June (Figure 1). Visits to bait boxes and bait consumption occurred throughout the study period. However, individual fields experienced periods of high and low activity. For example, in Field 3 there was a five-day period during which none of the bait boxes recorded visits. All three fields in 2024 had relatively few box visits for the first few weeks, while box visits peaked at the start of the 2023 trial. These data show that willingness of voles to enter bait boxes and consume bait can have wide fluctuations over a several week time scale. Studies covering shorter time scales have the potential to produce misleading results.

Total visits and bait consumption by field and bait type are shown in Table 2. On average, the boxes recorded between 102 and 247 total visits or 8.5 to 17.9 visits per week (Table 2). Some boxes recorded high numbers of visits, with 27 boxes recording ≥ 50 events in a week, while other boxes recorded no activity in a week. Average bait consumption per box by bait type was 0.5 to 3.8 oz total, or 0.04 to 0.31 oz per week, with the notable exception of chicken feed at Field 2 in 2024 (Table 2). The chicken feed was often completely consumed in three of the four Field 2 chicken feed boxes, resulting in an average consumption of nearly 24 oz total. Lethal doses of the rodenticidal baits tested in this study are expected to be around 0.14 to 0.39 oz per vole (Byers, 1978). Bait consumption of at least 0.2 oz in one week was observed 19% of the time. This means that for most boxes, there was not enough bait consumed in a week to kill a vole.

Statistical analysis revealed interactions between bait treatment and field for both box visits and bait consumption. Chicken feed consumption was greater than all other baits, but this result is heavily influenced by high chicken feed consumption at Field 2. When Field 2 was excluded from the analysis, the effect of field was not significant, the estimated mean consumption for chicken feed was the lowest numerically, and Rozol had higher bait consumption than chicken feed or Ramik Brown ($P < 0.05$). Analysis of visits to bait boxes suggests that Rozol resulted in fewer visits than DoubleTap ($P < 0.05$). This suggests that Rozol might be less likely than other baits to attract voles into the box, but they are more likely to consume Rozol once they are in the box. No other treatment differences were detected.

References

Byers, R.E. 1978. Performance of rodenticides for the control of pine voles in orchards. Journal of the American Society of Horticultural Science 103(1):65-69.

Salisbury, S. and N.P. Anderson. 2021a. Evaluation of gray-tailed vole feeding of diphacinone and chlorophacinone baits in bait boxes placed in grass seed production fields. Oregon Seed Council Research Report, PAR2122. 2020–21.

Salisbury, S. and N.P. Anderson. 2021b. Evaluation of vole activity in mobile bait boxes in a grass seed production field. Oregon Seed Council Research Report, PAR2118. 2020–21.

Steiner, J.J., W.E. Gavin, G.W. Mueller-Warrant, S.M. Griffith, G.W. Whittaker, and G.M. Banowetz. 2007. Conservation practices in Western Oregon perennial grass seed systems: III. Impacts on Gray-Tailed Vole Activity. Agron. J., 99: 537-542. https://doi.org/10.2134/agronj2006.0165.

Tanner, K.C. and S. Mahoney. 2024. Evaluating diphacinone and chlorophacinone rodenticides in bait boxes for vole control in grass seed crops. *In:* N. P. Anderson, C. Mallory-Smith, and D.L. Walenta, editors. *2022 Seed Production Research Report.* Oregon State University, Ext/CrS 170.

Verhoeven, E.C., and N.P. Anderson. 2021. An industry survey of current practices, problems and research priorities in Western Oregon grass and clover seed cropping systems. In N.P. Anderson, A.G. Hulting, D.L. Walenta, and C. Mallory-Smith (eds.). *2020 Seed Production Research Report.* Oregon State University, Ext/CrS 164.

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SURVEY OF CURRENT PRACTICES, PROBLEMS AND RESEARCH NEEDS IN WILLAMETTE VALLEY CROPPING SYSTEMS

Hana You, Collins Bugingo and K. Christy Tanner

Introduction

The annual seed and cereal crop production meetings were held at three locations across the Willamette Valley in the winter of 2025. During these meetings, stakeholders including growers, agronomists, and researchers participated in an industry survey to gather insights on current agronomic practices and challenges within the Willamette Valley's seed and cereal industry. The survey provides valuable insights into the seed and cereal cropping systems, helping OSU Extension and research faculty identify gaps and priorities where resources, services or support may be lacking. Additionally, the data offer guidance for planning and decision-making in Extension programs and research, focusing on the highest priorities.

Methods

The survey was conducted during three sessions of seed and cereal production meetings in Forest Grove, Salem, and Albany in January 2025. Using electronic polling tools (Vevox), a 13-question survey was administered at the end of each meeting. The questions were designed to gather insights from growers and industry partners on current practices and challenges in the seed and cereal cropping systems across the Willamette Valley, including Linn, Lane, Benton, Marion, Polk, Yamhill, Washington, and Clackamas counties. Survey questions and responses were grouped into four categories: respondent demographics, pest issues, soil and agronomic practices, and education and/or research needs.

The survey received responses from 121 individuals, with 29 from Forest Grove, 51 from Salem and 41 from Albany. The number of respondents varied for each survey question and among locations, and the applicable respondent count (*n*) for each question is indicated in the tables. The survey questions were multiple-choice style, except for question 13. Depending on the question, respondents were allowed to select their top choice, their top three or make any number of choices. The number of choices allowed for each question is shown in the tables. Question 13 was a written response question, and the answers were tallied and converted into percentages (Table 3). Data are shown for each location and all locations combined. The results are presented as the percentage of respondents selecting each answer. The total of the responses may be more than 100% if more than one response was allowed.

Results and Discussion

The primary participants in the survey were growers (52% of respondents) followed by agricultural retail/seed company agronomists (35%) and researchers (8%) (Table 1). The survey respondents reported working in Linn (49%), Marion (48%), Polk (31%), Benton (28%), Yamhill (26%), Washington (26%), Lane (21%) and Clackamas (12%) counties (Table 1). Out of 53 growers, 42 farm in a single county, while 11 farm in multiple counties. All but one consult in multiple counties. Data are reported for all respondents unless regional or role differences are specified.

Current practices

- Tall fescue (86%) was the most widely grown crop across all regions, with other grasses and rotational crops showing regional variation. In Forest Grove, red and crimson clover followed tall fescue, while in Albany perennial ryegrass was the second most-grown crop (Table 1).
- Results indicated the importance of small acreage crops in regional cropping systems. Of the 20 crop options, 15 were selected by at least one-third of the respondents in at least one location.
- The majority of respondents (83%) indicated that they use both dry farming and irrigation, while 27% and 19% of respondents from all the locations selected dry farming and irrigation, respectively (Table 1).

Pest issues

- Over half of the respondents (57%) reported that voles and gophers were their top pest problem, followed by slugs and snails (44%) and roughstalk bluegrass (35%) (Table 2).
- The need to identify effective vole and slug control remains one of the key research priorities, which was previously documented (Verhoeven and Anderson, 2021).
- Roughstalk bluegrass (58%) was more problematic in the south Willamette Valley than in the mid and north Willamette Valley. Italian ryegrass, annual bluegrass and wild carrot were also identified as problematic weed species.
- Most respondents identified herbicide resistance (81%) as

their biggest challenge in weed control.

- Fifty-eight percent of respondents reported rotating insecticides with different modes of action to manage insecticide resistance.
- Respondents expressed a strong interest in receiving more information on herbicide resistance (82%) and new herbicide technologies (78%).

Soil and agronomic practices

- The top research priorities in soil health and fertility management included: pH (69%); N, P and K (66%); and micronutrients (50%) (Table 3).
- Agronomic research priorities included plant growth regulators (63%) and residue management (54%).

Education and/or research needs

- The majority (64%) of respondents want Extension faculty to focus on pest management over soil health and fertility (17%) or agronomic practices (17%) (Table 4).
- The preferred delivery methods for Extension educational outreach were field days and Extension publications.
- When participants were asked what rotational crop (text entry) they are interested in, 29% of respondents expressed interest in canola, while 5% indicated interest in radish and flax.

References

Verhoeven, E.C., and N.P. Anderson 2021. An industry survey of current practices, problems, and research priorities in western Oregon grass and clover seed cropping system. 2020 Seed Production Research at Oregon State University Ext/CrS 164, pp 3–7.

Acknowledgments

The authors would like to express their appreciation to the growers, agronomists and other stakeholders who participated in these surveys.

Table 1. : Respondent demographics

What is your role? (%, choose one)

Roles	Albany (n=41)	Salem (n=51)	Forest Grove (n=29)	Combined (n=121)
Farmer	34	55	72	52
Agronomist (ag retailer)	42	29	10	30
Agronomist (seed company)	7	6	8	6
Researcher	7	6	7	6
Other	10	4	3	6

What counties do you farm or work in? (%, choose multiple)

County	Albany (n=44)	Salem (n=43)	Forest Grove (n=23)	Combined (n=110)
Linn	84	21	13	45
Lane	34	7	13	19
Benton	43	14	13	25
Clackamas	5	21	4	11
Marion	32	72	13	44
Washington	5	14	78	24
Yamhill	2	35	43	24
Polk	16	47	17	28

What type of farming do you practice? (%, choose multiple)

Farming types	Albany (n=48)	Salem (n=45)	Forest Grove (n=26)	Combined (n=119)
Dry land	27	18	23	23
Irrigated	15	16	19	16
Both	77	69	58	70
Does not apply	4	4	12	6

What crop do you grow/consult on? (%, choose multiple)

Crops	Albany (n= 42)	Salem (n=47)	Forest Grove (n=27)	Combined (n=116)
Annual ryegrass	76 (60)	40 (29)	19 (7)	48 (32)
Perennial ryegrass	81 (67)	66 (43)	37 (14)	65 (42)
Tall fescue	88 (87)	85 (75)	85 (93)	86 (82)
Fine fescue	21 (7)	36 (29)	3 (0)	23 (16)
Orchardgrass	40 (13)	21 (0)	11 (7)	26 (5)
Bentgrass	29 (13)	23 (7)	7 (0)	22 (7)
White cover	69 (53)	21 (7)	15 (0)	37 (18)
Red clover	38 (20)	57 (32)	78 (86)	55 (42)
Crimson clover	52 (33)	47 (21)	67 (86)	53 (40)
Other clover	31 (20)	15 (4)	7 (7)	19 (9)
Wheat	69 (80)	68 (64)	63 (71)	67 (70)
Other cereals	26 (7)	34 (36)	14 (21)	27 (25)
Meadowfoam	52 (27)	36 (25)	0 (0)	34 (19)
Mint	14 (7)	13 (4)	0 (0)	10 (4)
Hops	5 (7)	9 (0)	0 (0)	5 (2)
Canola/other oilseeds	14 (0)	21 (21)	0 (0)	14 (11)
Radish seed	50 (27)	49 (29)	19 (14)	42 (25)
Turnip seed	48 (20)	43 (36)	0 (0)	34 (23)
Other specialty seeds	43 (33)	49 (39)	15 (21)	39 (33)
Other	21 (20)	38 (39)	22 (21)	28 (30)

Note that the numbers in parentheses show the percentage of crops grown by growers only.

Table 2. Pest issues

What are your top three pest problems? (%, choose three)

Pests	Albany (n=41)	Salem (n=42)	Forest Grove (n=26)	Combined (n=109)
Billbugs	10	10	15	11
Worms	7	21	15	15
Symphylans	7	17	11	12
Aphids	5	2	8	5
Slugs and snails	51	31	54	44
Voles and gophers	54	55	69	58
Annual bluegrass	29	40	31	34
Roughstalk bluegrass	59	29	12	36
Italian ryegrass	20	43	31	31
Rattail fescue	7	19	0	10
Wild carrot	20	21	30	23
Stem/ leaf rust	5	2	0	3
Fusarium wilt/root rot	2	0	0	1
Pythium	0	2	0	1
Yellow dwarf viruses	5	0	0	2
Seed gall nematodes	5	0	4	3
Other	5	5	4	5

What measures do you currently take to manage insecticide resistance in your crops? (%, choose multiple)

Measurements	Albany (n=42)	Salem (n=43)	Forest Grove (n=27)	Combined (n=112)
Rotating insecticides with different modes of action	36	84	52	58
Implementing integrated pest management (IPM) strategies	19	60	19	35
Monitoring pest populations regularly and applying pesticides only when necessary	24	74	26	44
Using resistant crop varieties	7	26	0	13
I do not currently have a specific strategy	12	9	4	9
Other	2	0	0	1

What are your biggest challenges in weed control? (%, choose multiple)

Challenges	Albany (n=36)	Salem (n=40)	Forest Grove (n=27)	Combined (n=103)
Herbicide resistance	67	98	78	82
Limited herbicide options	33	68	63	54
Cost of weed management	22	58	30	38
Environmental restrictions	17	60	11	32
Labor shortages	17	18	11	16
Herbicide timing	25	45	19	31

What weed science topics would you like more information or training on? (%, choose multiple)

Topics	Albany (n=33)	Salem (n=40)	Forest Grove (n=18)	Combined (n=91)
Herbicide resistance	76	83	94	82
New herbicide technologies	79	80	72	78
Culture weed control methods	15	38	28	27
Biological weed control methods	36	23	22	27
Timing of herbicide application based on PHI	21	38	17	27

Table 3. Soil and agronomic practices

What soil health and fertility aspects would like more research and education on? (%, n=100, choose multiple)

Practices	Albany (n=34)	Salem (n=42)	Forest Grove (n=24)	Combined (n=100)
pH management	65	69	75	69
N, P and K management	68	62	71	66
Micronutrients	47	57	42	50
Macronutrient	29	38	33	34
Micronutrient deficiency	38	36	38	37
Soil organic matter management	47	38	29	39
Soil structure and compaction	35	38	13	31
Biostimulant, Biofertilizer	38	52	13	38
Soil erosion and conservation	21	26	21	23

What other agronomic practices would you like to see more research/extension work on? (%, choose multiple)

Practices	Albany (n=38)	Salem (n=42)	Forest Grove (n=26)	Combined (n=106)
Plant growth regulators	53	67	73	63
Irrigation	58	48	46	51
Drainage	50	33	50	43
Residue management	58	62	38	55
Till or no-till practices	53	52	35	48

Table 4. Education and research needs

What topic area would you like extension faculty to focus on? (%, choose one)

Topics	Albany (n=43)	Salem (n=46)	Forest Grove (n=26)	Combined (n=115)
Soil health and fertility	14	15	23	17
Pest management	63	63	73	64
Agronomic practices	21	20	4	17
Other	2	2	0	2

How do you prefer to receive information? (%, choose multiple)

Event types	Albany (n=33)	Salem (n=39)	Forest Grove (n=19)	Combined (n=91)
Field days	73	74	79	75
Website posts	21	31	32	27
Social media posts	9	28	11	18
In-person Workshops	67	59	37	57
Virtual Workshops	15	13	21	15
Webinars/ online courses	21	18	37	23
Extension publication	48	56	42	51
Fact sheets	42	36	16	34
Other	0	3	5	2

Which crop would you be interested in as a potential rotational crop? (%, written responses)

Crops	Albany (n=21)	Salem (n=39)	Forest Grove (n=17)	Combined (n=77)
Canola	38	14	24	29
Radish	8	5	0	5
Flax	8	5	0	5
Other	46	76	76	61

HOW RELIABLE ARE THE FLUORESCENCE AND GROW-OUT TESTS IN DETECTING ANNUAL RYEGRASS IN PERENNIAL SAMPLES?

Sabry G. Elias, Yeaching Wu, and Adriel E. Garay

Introduction

Oregon is the largest producer of ryegrass in the U.S. and ranks second in the world. One of the foremost problems facing perennial ryegrass (PRG, *Lolium perenne*) growers is the presence of annual ryegrass (ARG, *Lolium multiflorum*) in PRG lots. Presence of ARG lowers the quality of the turf as it spoils its aesthetics. It is difficult even for experienced seed analysts to distinguish between ARG and PRG seeds because of the similarities in morphological characteristics including size, shape, and color. Therefore, other traits such as fluorescence and growth habits are used to differentiate between the two types. At present, there are two main tests used to identify and quantify the presence of ARG in PRG samples: 1) the fluorescence test (FLT), and 2) the grow-out test (GOT).

Gentner (1929) developed the FLT to distinguish between ARG and PRG. The ARG roots secrete a naturally occurring substance, annulene, that fluoresces under ultraviolet light. PRG does not contain this chemical; hence, their roots do not fluoresce. The fluorescence test has been widely used in seed testing laboratories to distinguish between ARG and PRG. However, some researchers have reported that the fluorescence trait was not always associated with the annual type and can exist in PRG (Nyquist, 1963). Floyd and Barker (2002) suggested that fluorescence could be affected by the environment. However, the magnitude of this effect, whether from the environment or other sources, has never been reported.

As with many seed quality tests, the fluorescence test has positive and negative aspects. It is simple, fast and economical. Yet, in some cases it overestimates the ARG presence in perennial samples. In addition, non-fluorescent ARG and fluorescent PRG have been reported, which affects the accuracy of the test. However, the magnitude of the effect has never been reported.

Several scientists recommended a GOT as a more accurate tool to differentiate ARG and PRG. There are a number of morphological characteristics that are useful in distinguishing ARG and PRG plants (Rampton, 1938). Nittler and Kenny (1972) showed that 74% of ARG formed heads after a five-week GOT. Most of the annual plants that did not head could be identified on the basis of vegetative characteristics such as stem elongation. They also reported that continuous light could further accelerate flowering.

The GOT was developed as an optional test to supplement the FLT and can be utilized when the FLT appears to overestimate ARG contamination in PRG seed lots, or when the FLT result exceeds the varietal fluorescent level (VFL) of the variety in question. The VFL is the percentage of seedlings that are expected to fluoresce in a perennial variety as determined by the plant breeder of each variety. Such VFL values are recognized by the National Grass Variety Review Board. The GOT provides realistic results because it is based on the morphological appearance of the plants. However, the main disadvantage is that it takes a long time. According to the AOSA Cultivar Purity Testing Handbook, plants should be evaluated when at least 80% of the annual control sample has headed, which is usually 35–42 days after transplanting the fluorescent seedlings. The transplanting happens after two weeks of germination test + one-week prechill for new crops, for a total of eight to nine weeks.

Both the FLT and GOT tests are accepted by the Association of Official Seed Analysts, the Association of American Seed Control Officials, the Association of Official Seed Certifying Agencies and the grass seed industry. However, there are no published reports related to the accuracy of the FLT for distinguishing between annual and perennial types or to the extent of overestimation of the annual type in perennial samples. Therefore, the objective of this study was to investigate the accuracy of the FLT test in determining the level of ARG contamination in perennial samples and compare the FLT and GOT test results with the respective VFL values of each variety.

Material and Methods

1. The fluorescence study: Data from the fluorescence tests of 8,231 certified PRG samples were compiled from the Oregon State University Seed Laboratory (OSUSL) database over a three-year period (2007–2009) representing 224 varieties. Fluorescence tests were conducted according to the AOSA Rules for

Testing Seed. The number of fluoresced seedlings was evaluated by exposing normal seedlings to ultraviolet light. The results were recorded and compared to the respective VFL values of each variety. Varieties that did not have a VFL description were exempted. The FLT value was calculated according to the following formula:

$$\% \, Fluorescence = \frac{No. \, of \, normal \, fluorescent \, seedlings}{Total \, normal \, seedlings} \, x \, 100$$

The % of ARG in a PRG sample was calculated as follows:

% annual ryegrass = (% FLT - %VFL_P)/100 x % pure ryegrass (ARG and PRG excluding impurities) where VFL_P is the varietal fluorescent level for the perennial variety, and the TFL is fluorescence test result.

% perennial ryegrass = % Total pure ryegrass in the sample (annual and perennial) – % ARG

2. The grow-out study: Data from the grow-out test of 104 certified PRG samples were collected from the OSUSL database over a three-year period (2007–2009) representing 26 varieties. The GOT was conducted according to the method described in the AOSA Cultivar Purity Testing Handbook. Percentages of ARG and PRG were calculated as follows:

$$Survival \, factor = \frac{Total \, no. \, of \, fluoresent \, seedlings \, that \, died \, during \, growout \, test}{Total \, no. \, fluorescent \, seedlings}$$

$$\%ARG = \frac{No. \, fluorescent \, plants \, headed \, or \, resemble \, annual \, control}{Total \, no. \, normal \, seedlings \, x \, survival \, factor} \, x\% \, Total \, pure \, ryegrass$$

% PRG = % total pure ryegrass in the sample (annual and perennial) - % ARG

For certified PRG lots, the Oregon Seed Certification program allows 3% ARG seeds in PRG samples above the VFL value of the tested variety, with consideration of the mechanical purity of each sample (i.e., excluding inert matter, other crop and weed seeds). However, in the Foundation class only 0.32% ARG is allowed, and in the Registered class 1.00% ARG is allowed. Therefore, in this study samples within +/- 3% of the VFL of each variety passed the certification standard.

Results and Discussion

1. Fluorescence (FLT) study: In 2007, 39% of the PRG samples tested by the FLT had less than or equal to their respective VFL values, and 54% were within 3% of their respective VFL values (Figure 2). Therefore, 93% of the 3,452 PRG samples representing 224 varieties passed the OSU certification requirement based on the FLT and only 7% needed a GOT to determine whether the FLT overestimated the contamination of ARG in perennial samples. These results confirmed that the FLT is a valid option to measure the percentage of contamination of annual type in PRG samples.

In 2008, 51% of the 3,372 PRG samples representing 187 varieties tested by the FLT had less than or equal to their respective VFL values, and 46% were within 3% of their respective VFL values (Figure 2). Therefore, 97% of 3,372 PRG samples passed the OSU certification requirement based on the FLT.

In 2009, 50% of the 1,407 PRG samples representing 148 varieties tested by the FLT had less than or equal to their respective VGL values, and 43% were within 3% of their respective VFL values (Figure 2). Therefore, 93% of the samples met Oregon certification standard, i.e., were within 3% of their respective VFL values.

Samples that exceeded the 3% tolerance VFL, were only 3%–7% of the total number of samples tested over the three-year period. The results confirmed that the FLT is a reliable test to distinguish between ARG and PRG, with a 93%-97% success rate.

Considering that this test is simple, fast and economical, with a success rate of over 90%, it should continue to be a valid option for ryegrass growers to use to estimate the annual contamination in perennial samples.

2. Grow-out (GOT) study: This study was conducted to determine whether the seedlings that fluoresce in the FLT were true annual type or if they would grow out to be similar in appearance to the perennial type. When a grower received an FLT result of a PRG sample that exceeded the 3% ARG tolerance of its respective VFL value he/she may ask for a subsequent GOT of the seedlings that fluoresced at the end of the germination test. Thus, the purpose of the GOT is to confirm whether all the fluorescent seedlings would form heads at the end of the six-week grow-out period or if some of them will have fine leaves, shorter stems and darker green color that are typical of PRG.

A total of 104 PRG samples were tested by the GOT in 2007, 2008 and 2009 because they did not pass the certification requirement when they were tested by the FLT. The results of the GOT in 2007 and 2008 showed

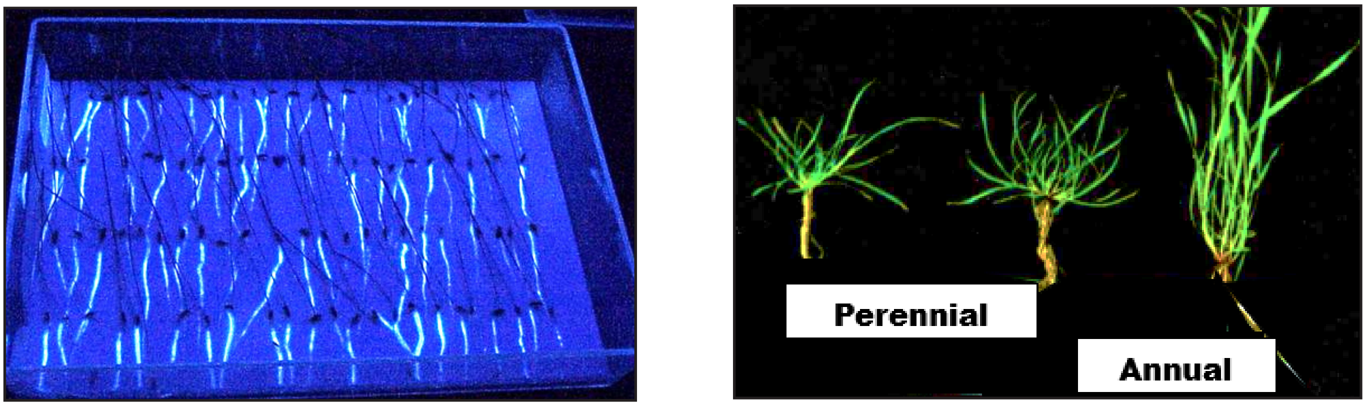


Figure 1. Left: Fluorescence test to distinguish between annual (roots fluoresce), and perennial ryegrass (roots do not fluoresce) (Photo by Sabry Elias). Right: Six-week-old grow-out test, (left) perennial (fine leaves, shorter growing and darker green), compared to the (right) annual ryegrass (larger, lighter seedlings (Photo by Reed Funk).

that 90% of these samples passed the certification requirement as they were within 3% of their respective VFL values. In 2009, 100% of the samples tested by the GOT were within 3% of their respective VFL values. In other words, 90%–100% of the samples that did not pass the Oregon certification standard by the FLT were within 3% of their respective VFL values when tested by the GOT. The FLT of the samples that were tested by the GOT ranged between 3.59% and 17.34%. These results agree with Nyquist (1963), who reported that not all fluorescing seedlings are true annual and that the fluorescence trait is not always associated with the annual type and can exist in PRG. The results also confirmed the usefulness of using morphological characteristics to distinguish between ARG and PRG plants (Rampton, 1938).

FLT and GOT test results (2008) for 30 PRG samples, representing seven varieties, were compared to their respective VFL values (Figure 3). Out of the 30 samples that were tested by the GOT, only three samples (1, 14, and 26) exceeded their respective VFL values by more than 3% (shown by arrows in Figure 3). These results suggest that the GOT gives a realistic assessment of ARG contamination in PRG samples by evaluating morphological appearances and growth habits of seedlings. It also depicts the extent of actual contamination regardless of the fluorescence level. In the GOT, phenotypical expression of the genetic makeup of seeds was clearly exhibited. As such, it can serve as a good reference point for further DNA tests.

In conclusion, the results confirmed that the FLT is a reliable test to detect and quantify annual ryegrass in perennial samples in over 90% of 8,231 samples tested over a three-year period. They passed the Oregon Seed Certification standard with the allowable 3% tolerance over their respective VFL values. In cases where the fluorescence test overestimates the annual type presence in perennial samples, which is between 3% and 7% (Figure 2) of the cases, depending on the year and the environmental conditions, the GOT provided a realistic determination of ARG contamination in PRG samples by evaluating morphological traits such as stem lengths, leaves width and color regardless of the fluorescence level.

References

Floyd, D.J. and R. Barker. 2002. Change in ryegrass seedling root fluorescence expression during three generations of seed increase. Crop Sci. 42: 905-911.

Gentner, G. 1929. Uber die verwendbarkeit von ultravioletten strahlenbei der samenpriifung. praktische blatter pflanzenbau und pflanzenschutz. 6: 166-172.

Nittler, L.W., and T.J. Kenny. 1972. Distinguishing annual from perennial ryegrass. Agron. J. 64: 767-768.

Nyquist, W.E. 1963. Fluorescence perennial ryegrass. Crop Sci. 3: 223-226.

Rampton, H.H. 1938. The use of morphological characters as compared with fluorescence tests with ultraviolet light in classifying ryegrass (Lolium spp.) of Western Oregon. J. Amer. Soc. Agron. 30: 915-922.

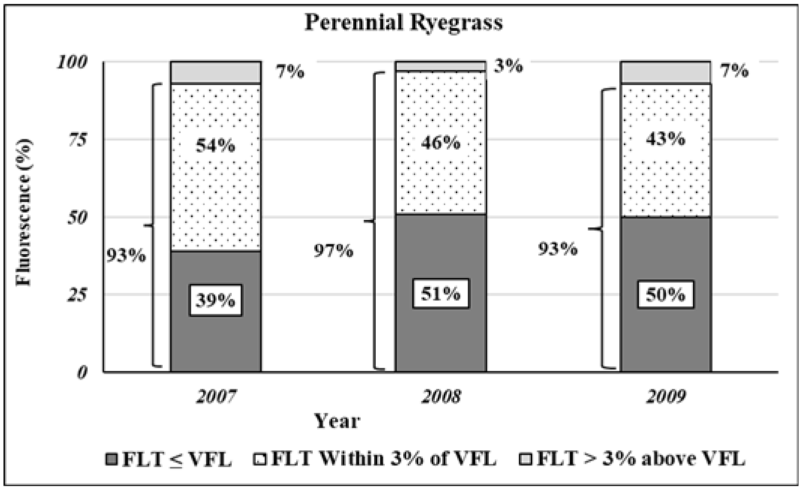


Figure 2. Fluorescence test (FLT) results of 8,231 certified perennial ryegrass samples over a three-year period (2007–2009) compared to their respective varietal fluorescence level (VFL) values. Of the samples, 93%–97% were ≤ or within 3% of their respective VFL values.

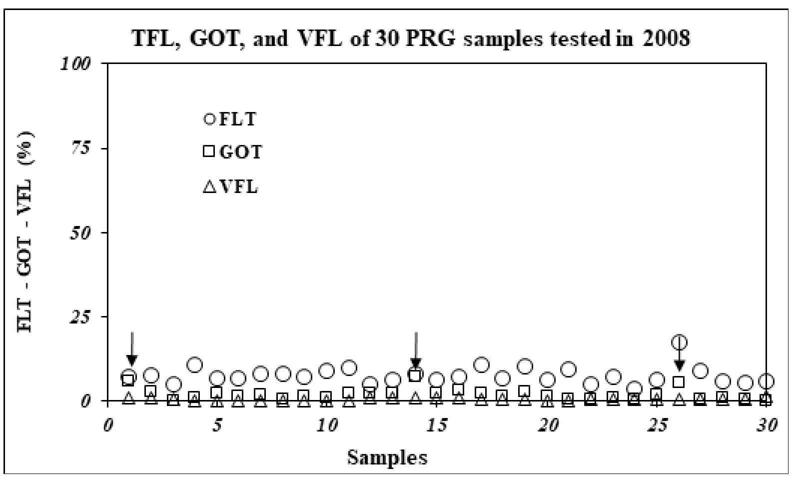


Figure 3. Thirty perennial ryegrass (PRG) samples exceeded their respective varietal fluorescence level (VFL) values by more than 3% when tested by the fluorescence test (FLT). When tested by the grow-out test (GOT), only three samples (indicated by the arrows) exceeded their respective VFL values by more than 3%.

SHORT GROW-OUT METHOD TO DIFFERENTIATE BETWEEN ANNUAL AND PERENNIAL RYEGRASS BY USING MORPHOLOGICAL TRAITS OF SEEDLINGS

Elisa Lemes, Carolina Borges, Yeaching Wu, Gizele Gadotti and Sabry Elias

Introduction

Oregon is one of the world's leading producers of cool-season forage and turf grass seeds, including annual and perennial ryegrass. The contamination of annual ryegrass (ARG, *Lolium multiflorum*) in perennial (PRG, *Lolium perenne*) seed lots has been one of the major challenges facing the growers in Oregon, the largest producer of annual and perennial ryegrass in the U.S. The presence of ARG in a PRG seed lot lowers the quality of the turf due to the unattractive look of big, light-colored annual plants in perennial turf. Seeds of ARG and PRG are indistinguishable because of the similarities in physical characteristics such as size, shape and color.

Currently, there are two main tests used to detect and quantify the presence of ARG in PRG samples — the fluorescence test (FLT) and the grow-out test (GOT). In addition to these two tests, a DNA test was developed in 2014 to differentiate between the two types. However, it encountered some issues, among which are:

- It is based on the FLT and the fluorescence trait is not always associated with the annual type and can exist in PRG (Nyquist, 1963; Okora et al., 1999).
- It takes a long time (14 days + prechilling treatment + FLT) before running the PCR.
- The sample size is small (only the fluorescent seedlings).
- No data are available on its reproducibility within varieties and among labs or results with the grow-out test.

The root FLT has been used since the 1930s to distinguish between ARG and PRG. The roots of ARG seedlings fluoresce under ultraviolet light because of the presence of a naturally occurring chemical in the roots (annulene, a monocyclic hydrocarbon compound with a fluorescence property), which typically is not present in PRG. This test is simple, economical, relatively fast and fairly accurate (> 90% pass certification requirement based on the FLT, data not shown). However, the development of new PRG varieties involves crossing ARG with PRG germplasm; therefore, the fluorescent trait may or may not express in the new progeny. As a result, the FLT sometimes overestimates the presence of ARG in PRG samples. To address this issue, the grow-out test was developed and used when FLT overestimates ARG contamination or when the TFL result exceeds the varietal fluorescence level (VFL) of the variety in question, which is described by the plant breeder of each variety. The VFL is the seedlings (i.e., seedling roots) that fluoresce in each sample but did not vary morphologically from the nonfluorescent check plants.

There are two methods available to conduct a grow-out test: 1) direct planting of 400 seeds in a greenhouse; or 2) transplanting the fluorescent seedlings at the end of the germination test. Typically, direct planting is used for forage perennials because of the high fluorescence level of this type, and transplanting fluorescent seedlings is used for turf perennial types. In the current GOT procedures, head formation of the annual type is the evaluation criterion to distinguish between ARG and PRG types. Although the GOT provides accurate results, the process involves up to eight weeks to complete (two weeks for seed germination and the FLT plus six weeks in the greenhouse to develop spikes).

In the rapidly changing market landscape, the time needed to conduct a GOT presents a major concern for seed producers in situations where results are needed more quickly. The objective of this study was to determine if seedling morphological characteristics such as seedling height (SH), leaf width (LW) and leaf color (LC) could be used to detect ARG seedlings in PRG grow-out tests in less than eight weeks. Three studies were conducted to evaluate the feasibility of using these morphological characteristics to differentiate between annual and perennial seedlings in less than eight weeks.

Abbreviations: ARG, annual ryegrass; FLT, fluorescence test; GOT, grow-out test; LC, leaf color; LW, leaf width; PRG, perennial ryegrass; SH, seedling height; SGT, standard germination test; VFL, varietal fluorescence level.

Materials and Methods

Study 1. Determine the accuracy of detecting ARG in PRG samples using seedling morphological characteristics.

A total of five seed treatments were included in the study. Three seed subsamples of PRG variety 'Silver Dollar' (VFL, 0.8%) were artificially contaminated with seed of ARG variety 'Gulf' (VFL, 99.02%) using the following PRG:ARG ratios (by seed count): 90:10, 80:20, and 60:40. Control treatments for comparison included 100% pure samples each of PRG variety 'Silver Dollar' and ARG variety 'Gulf.'

For the GOT, 400 seeds from each of the seed ratio treatments were planted in 50-cell greenhouse trays. A control sample was included. A "Professional Growing Mix," not combined with soil (Sun Gro Horticulture, Agawam, MA; www.sungro.com), was used as the planting medium. Seeds were chilled at 10°C (50°F) for seven days to break dormancy. The trays were then moved to a greenhouse at 25°C, with continuous light of about 232 µmol m-2s-1. The seedlings were irrigated each week with water mixed with All-purpose Miracle-Gro (24-8-16; 1 teaspoon:1 gal of water) (Scotts Miracle-Gro Co., Marysville, OH) for optimum growth conditions. The number of ARG type was recorded for 10 seedlings randomly selected from each tray every other day, starting one week after planting until the end of the GOT (six weeks), using the seedling morphological criteria of SH, LW and LC.

Study 2: Evaluate the effectiveness of detecting ARG in PRG samples with different VFL levels using seedling morphological traits.

Four commercial turf-type PRG varieties (identified as a, b, c, and d) with VFL values of (a) 1.38, (b) 3.40, (c) 5.54, and (d) 12.73% were included in the study. Four replications of 100 seeds each variety were placed on top of white blotter papers moistened with 0.2% KNO_3 solution. Seeds were chilled at 10°C for seven days before moving to a germinator at 15-25°C (15°C for 16 h and 25°C for 8h) for 14 days (AOSA Seed Testing Handbook, 2017). At the end of the standard germination test (SGT), the seedlings' roots were exposed to ultraviolet light to determine the number of seedlings that fluoresced.

At the end of SGT, the fluorescent seedlings were transplanted to greenhouse trays. The number of seedlings transplanted was 5, 13, 20 and 47 for PRG varieties a, b, c and d, respectively. Control treatments of nonfluorescent seedlings of each variety were also included e, in addition to 'Silver Dollar' PRG and 'Gulf' ARG.

Seedlings were evaluated at weekly intervals for six weeks immediately after fluorescent seedlings were transplanted. They were classified as PRG when heading was not observed and had similar morphology to the nonfluorescent seedlings; or ARG when seedlings formed heads and morphologically did not resemble the nonfluorescent control seedlings. Seedlings without heads but that had wider blades, lighter color and elongated stems (off types or intermediate ryegrass) were classified as annual type because these seedlings are deemed undesirable turf by the seed-industry standard.

Study 3: Assess the efficacy of seedling morphology criteria in detecting ARG in forage PRG samples with high VFL levels.

Three forage type PRG (1, 2 and 3) with VFL of 39.5%, 84.6% and 85.6% were used. 'Silver Dollar' PRG and 'Gulf' ARG were used as controls. Procedures of planting and sampling used in Study 1 were followed for the GOT in Study 3**.** However, since seedling physical appearance of both types is similar, the only criterion used for the GOT to differentiate forage PRG from ARG was head formation in ARG within six weeks.

Statistical analysis

Mean standard deviation and standard errors were used to measure the magnitude of differences among treatments including stem length and leaf width. The Munsell color chart was used to score leaf color.

Results and Discussion

Study 1

Results indicated that SH, LW and LC measurements can be used to differentiate between ARG and PRG as early as three weeks after planting (Figures 1, 2). All ARG in PRG samples in PRG:ARG ratios of 90:10%, 80:20%, and 60:40% were successfully detected and separated. Differences in SH, LW and LC were reliable features to distinguish between the two types. At week three, the average ARG seedlings of the samples were taller than PRG by 10.9 cm (±1.96) (Figure 1). Similarly, the average LW of ARG was 2.27 mm (± 0.32) more than PRG (Figure 2). For LC, both PRG and ARG were dark green [7.5GY(5/8 and 4/6)] at week one and two. However, at week three, the color of ARG leaves started to turn lighter green [7.5GY(6/8-6/10)] whereas LC of the PRG remained dark green. Rampton (1938) observed similar results regarding the physical characteristics between ARG and PRG plants. These results suggested that SH, LW and LC were suitable morphological traits for distinguishing between ARG

Table 1. Number of fluorescent seedlings at the end of the germination test and number of seedlings with annual morphological traits at the end of growout tests of four turf perennial ryegrass varieties with different varietal fluorescence levels (VFL).

Variety	VFL (%)	Number of fluorescent PRG seedlings at the end of the germination test[1]	Seedlings with annual morphological traits at the end of GOT[2]	Difference between ARG and non-fluorescent PRG seedlings, 4 weeks after transplanting[3]	
				SH (cm)	LW (mm)
a	1.38	5	0	All perennial seedlings	
b	3.40	13	0	All perennial seedlings	
c	5.54	20	8	8.3	1.0
d	12.74	47	33	5.9	0.3

[1] Fluorescent test (FLT) was conducted at the end of the germination test (14 days) according to the Association of Official Seed Analysts (AOSA) Rules for Testing Seeds.
[2] Seedlings with annual morphological traits was separated from non-fluorescent seedlings at the end of grow-out test (GOT), 6 weeks after transplanting.
[3] Differences in seedling height (SH) and leaf width (LW) between annual type (ARG) and non-fluorescent seedlings (PRG) 4 weeks after transplanting.

and PRG starting three weeks after planting.

Study 2
Four turf PRG samples (a, b, c and d) with different VFL values of 1.38%, 3.40%, 5.54% and 12.73%, respectively, were used to determine the efficacy of using seedling morphological traits in separating ARG and PRG. Table 1 summarizes the findings of Study 2.

At the end of the SGT (14 days), fluorescent tests were conducted. A total of 5, 13, 20 and 47 seedling roots fluoresced from samples a, b, c and d, respectively (Table 1), and were transplanted into the greenhouse for GOT.

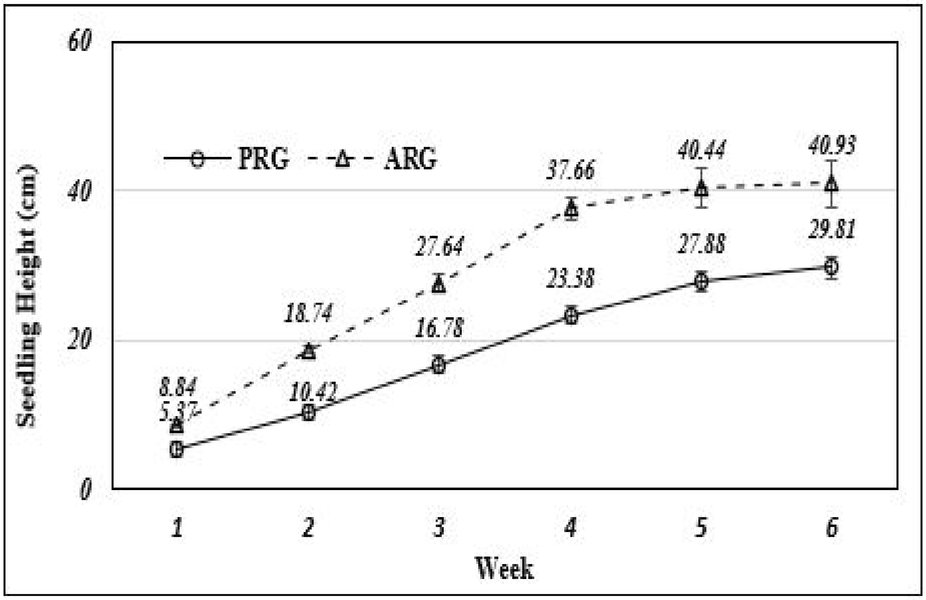
At the end of the GOT (six weeks), all seedlings from samples a and b resembled the nonfluorescent seedlings controls of the respective varieties and did not form heads, which is expected for PRG that need vernalization to flower and form heads.

In samples c and d, the number of the fluorescent seedlings that did not resemble the non-fluorescent controls was 8 and 33, respectively (Table 1), and 80% of them formed heads by week six. In weeks three and four, the average difference between ARG SH and the nonfluorescent PRG controls was 5.9-8.3 cm, and in LW was 0.3-1 mm (Table 1). The LC of the annual type was lighter than the nonfluorescent controls.

These results suggested that SH, LW and LC were reliable criteria to differentiate between ARG and the turf type of PRG by the third or fourth week. In addition, seedlings of PRG might fluoresce like ARG, but they might not form heads or look like annual type by the end of the six-week GOT period (Nyquist, 1963; Okora et al., 1999). If a seed analyst has any doubt about whether a seedling is annual or perennial, the test can be extended up to six weeks.

Study 3
Differences in SH, LW and LC of three forage PRG varieties with high VFL values (39.5, 84.6 and 85.6%) were compared against ARG and PRG controls. The morphological traits of the forage PRG seedlings were similar to the ARG control regardless of the VFL value; however, none of them formed heads at the end of GOT (six weeks). This is because the forage PRG need vernalization to flower and form heads unlike ARG, which forms heads by the end of the six-week period without vernalization. Since both forage PRG and ARG share similar SH, LW, and LC, the only characteristic that can differentiate between them is head formation at the end of the grow-out test period. Therefore, the test period for forage PRG cannot be shortened and has to be evaluated after six weeks using the heading criterion.

Conclusions
Plant height, leaf width and leaf color provided reliable tools to distinguish between ARG and turf types of PRG using the GOT within three to four weeks compared to six to eight weeks when the current heading criterion



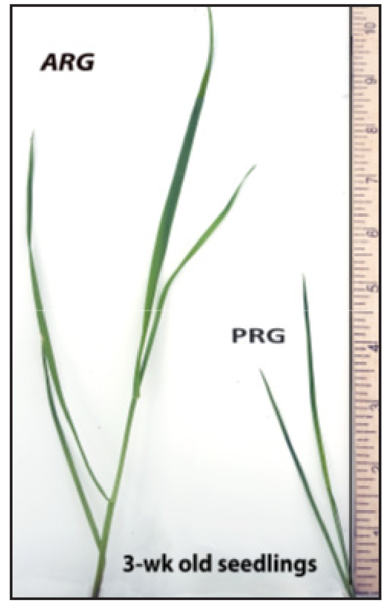


Figure 1. Left: Differences in mean seedling height between annual (ARG) and perennial (PRG) ryegrass grown for six weeks in a greenhouse. Means with error bars that are not overlapping are significantly different from each other. Right: Difference in ARG and PRG seedling height in three-week-old seedlings.

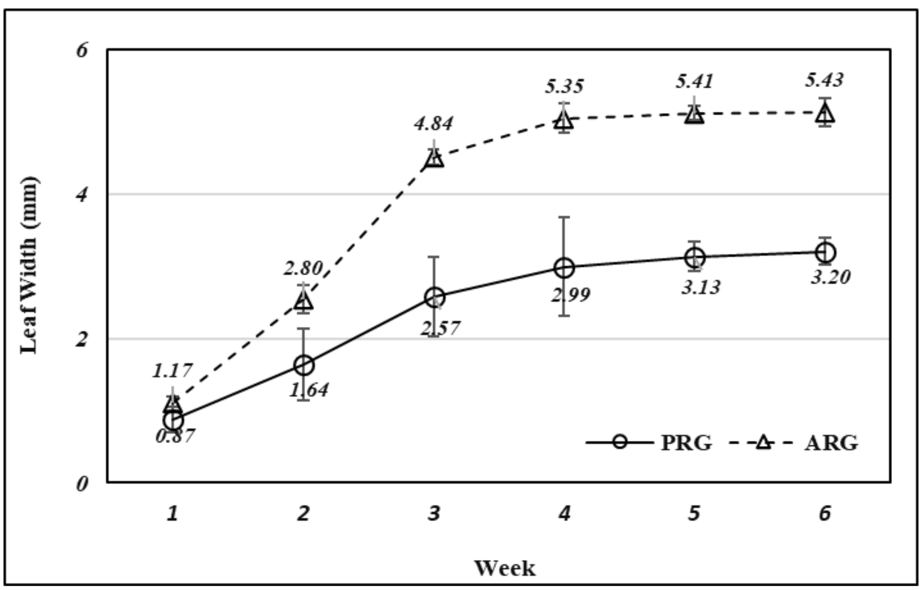


Figure 2. Differences in mean leaf width between annual (ARG) and perennial (PRG) ryegrass grown for six weeks in a greenhouse. Means with error bars that are not overlapping are significantly different from each other.

was used. The shortened GOT method allows growers to receive results three to four weeks earlier than the current heading evaluation method, enabling them to make faster marketing decisions in today's competitive market.

The grow-out test can be conducted using two methods: 1) sequentially, by transplanting the fluorescent seedling following the standard germination test; and 2) direct planting in the greenhouse and evaluating in week three or four using morphological traits instead of heading criterion. In both methods, evaluations based on seedling morphology instead of heading can save two to three weeks in the GOT.

Head formation should remain the criterion for detecting

ARG in forage PRG type with high levels of VFL. Direct planting of seeds in the greenhouse, instead of transplanting seedlings, should be used.

References

AOSA. 2017. Rules for Testing Seeds. Vol. 1. Assoc. Off. Seed Anal. Washington, D.C.

Floyd, D.J.; Baker, R.E. 2002. Change of ryegrass seedling root fluorescence expression during three generations of seed increase. Crop Sci. 42: 905-911.

Nyquist, W.E. 1963. Fluorescent perennial ryegrass. Crop Sci. 3: 223–226.

Okora, J.O., C.E. Watson, L.M. Gourley, B.C. Keith, and C.E. Vaughn. 1999. Comparison of botanical characters and seedling root fluorescence for distinguishing Italian and perennial ryegrass. Seed Sci. & Technol. 27:72 1 730.

Rampton, H. H. 1938. The use of morphological characters as compared with fluorescence tests with ultraviolet light in classifying the ryegrasses (Lolium spp.) of western Oregon. J. of Am. Society of Agronomy. 30: 915-922.

SYMPHYLAN CONTROL IN CARBON PLANTED PERENNIAL RYEGRASS SEED CROPS — 2024

A.R. Willette, P. A. Berry, A.C. Branka, N.P. Anderson, and N. Kaur

Introduction
The garden symphylan (*Scutigerella immaculata* Newport) is a root-feeding soil arthropod pest. Garden symphylan are quick-moving, centipede-like and white, with six to 12 legs. The garden symphylan overwinters deep in the soil and has two peak egg-laying periods (spring and early fall). As temperatures become favorable (between 42° and 70°F) and soil moisture improves, adults move to the upper 6 inches of the soil to lay eggs. Both egg-laying and hatch timing align with planting seed crops, which results in reduced yield and survival of several high-value crops in Western Oregon (Umble and Fisher, 2003).

Recent research efforts evaluated various insecticide products that represented diverse modes of action and were applied in the spring and fall for garden symphylan management in tall fescue [*Schedonorus phoenix* (Scop.) Holub] and perennial ryegrass (*Lolium perenne* L.) seed crops (Willette et al., 2024; Willette et al., 2023; Bateman et al., 2023). In this study, our objective was to assess insecticide efficacy for garden symphylan control during carbon-banded seeding of perennial ryegrass. Activated carbon is commonly sprayed over grass seed rows during planting to protect emerging grass seedlings from herbicide damage. Carbon can adsorb several different active ingredients that prevent the herbicide from reaching the soil. Thus, the goal of this study was to determine if carbon-seeding influenced insecticide efficacy for garden symphylan control.

Materials and Methods
On September 12, 2024, perennial ryegrass (var. ‘Black Pearl’) was established in a symphylan-infested field at the Hyslop Research Farm Laboratory near Corvallis, OR. The trial design included five insecticidal treatments (Table 1) and an untreated control arranged in a randomized complete block with four replications. Perennial ryegrass was seeded into plots 16.25-by-30 feet at a rate of 12 lb/acre on 10-inch row spacing to a depth of 0.35 in (approx.).

At planting, activated carbon (OXPURETM 325A-9) mixed with each insecticide treatment was applied in a 1- to 1.5-inch band directly over the seed row using a Nifty Tank fitted with an agitator sprayer unit. The carbon application rate was 30 lbs activated carbon/acre. Immediately after planting, Direx 4L herbicide at 2 qt/acre was applied using an ATV-mounted boom sprayer using a spray volume of 15 gallons/acre. Irrigation water (1.5 inches) was applied 24 hours after insecticide application to incorporate the insecticide. Nitrogen was applied at 40 lbs/acre and Zidua SC herbicide was applied at 3 oz/acre at timings similar to industry standards in Western Oregon.

Data collected from the trial included symphylan population abundance and percent perennial ryegrass cover. Symphylan abundance was determined using the potato bait method by deploying six bait stations per plot and counting symphylans per bait station 24 to 48 hours after deployment 15 and 29 days after treatment (DAT) (Willette et al., 2023). Percent perennial ryegrass cover data were collected at 84 DAT, determined by photographing four 1-by-4 ft areas/plot and quantifying the amount of green cover in each photograph using the Canopeo application. Data were analyzed using a general linear model, and means were separated using Fisher comparison ($P \leq 0.05$) (SAS Institute Inc., 2023).

Results and Discussion
Symphylan counts in potato bait stations 15 DAT indicated that Capture LFR and AzaGuard had lower garden symphylan abundance than the untreated control (Table 1). In contrast, treatment means for F4092-3, Elevest, and Endigo were not different than the nontreated control. Capture LFR had 52% less garden symphylan abundance than the nontreated control at 29 DAT and was consistent with 15 DAT results. AzaGuard, F4092-3, Elevest and Endigo treatments were not significantly different than the nontreated control at 29 DAT (Table 1). Significant differences in percent perennial ryegrass cover were not observed at 84 DAT.

In conclusion, Capture LFR was determined to be the most effective treatment for symphylan suppression compared to other insecticides in the study when applied at planting with carbon-banding during grass seed establishment.

References
Bateman, C., Willette, A. R., Kaur, N., Dorman, S. J.,

Table 1. Trade name (active ingredient), rate, Insecticide Resistance Action Committee (IRAC) class, mean symphylan counts, and mean percent perennial ryegrass cover in an insecticide efficacy trial conducted in a fall-planted perennial ryegrass field in Corvallis, OR 2024

Trade name (active ingredient)	Rate	IRAC class	Symphylan counts[1]		Perennial ryegrass % cover[2]
			LS mean[3]		
	(fl oz/a)		15 DAT [4]	29 DAT	84 DAT
Control	—	—	8.7 a	9.9 ab	14.3 a
AzaGuard (azadirachtin)	16	—	4.5 bc	7.0 bc	14.8 a
Capture LFR (bifenthrin)	8.5	3A	3.6 c	4.8 c	14.4 a
Elevest (bifenthrin and chlorantraniprole)	9.6	3A+28	8.3 ab	10.9 ab	10.3 a
Endigo (lambda-cyhalothrin, thiamethoxam)	4.5	3A/4A	9.95 a	12.9 ab	13.8 a
F4092-3	8.5	3A+4A	7.1 abc	7.7 bc	11.3 a
P-value	—	—	0.0187	<0.0001	0.1651

[1]Mean symphylan counts collected from six potato baits per plot in each treatment.

[2] Mean percent cover is the mean from four photographs of 1-by-4-foot area analyzed using Canopeo App.

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

[4] Days after treatment (DAT)

Buckland, K., & Anderson, N. P. 2023. Symphylan control in grass grown for seed, 2022. *Arthropod Manag. Tests.* Oxford University Press.

SAS Institute Inc. 2023. The SAS system for Windows (Release 9.4). SAS Institute, Inc.

Umble, J.R. and J.R. Fisher. 2003. Sampling considerations for garden symphylans (Order: Cephalostigmata) in western Oregon. J. of Econ. Entom. 96:969–974.

Willette, A.R., N.P. Anderson, S. J. Dorman, and N. Kaur. 2024. Comparative Efficacy of Pyrethroid Insecticides Against Symphylans in Tall Fescue Seed Crops. In N.P. Anderson, C.A. Mallory-Smith, and D.L. Walenta, (eds.). *2023 Seed Production Research Report.* Oregon State University, Ext/CrS 170.

Willette, A.R., N. Kaur, N.P. Anderson, and S.J. Dorman. 2023. Do newer pesticide chemistries provide enough symphylan control in grass seed crops? (year 1). In N.P. Anderson, C.A. Mallory-Smith, D.L. Walenta, and J.F. Spring (eds.). *2022 Seed Production Research Report.* Oregon State University, Ext/CrS 168.

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BREAD DOUGH OPTIMIZATION TO ATTRACTTHE PESTIFEROUS GRAY FIELD SLUG *(DEROCERAS RETICULATUM)*

Casey H. Richart, Aeurkan Supavarasuwat and Rory J. Mc Donnell

Introduction

Terrestrial slugs cost the Willamette Valley grass seed industry an estimated $60 million annually. These costs include estimates of damage, replanting and control, which alone is estimated at $11 million annually (Salisbury 2015). Eradication of invasive slugs is not feasible. Thus, we employ the strategy of improving management methods and decreasing the costs of control. One such approach is to use inexpensive attractants for attract-and-kill methods or as food adjuvants so that the amount of expensive (and often less environmentally friendly) molluscicides can be greatly reduced without sacrificing treatment effectiveness. Our research has shown that fermenting bread dough is a low-cost and strong attractant of a wide diversity of pestiferous slugs and snails, presenting a unique opportunity for developing more effective, sustainable and environmentally friendly approaches to slug management (Veasey et al. 2021).

Probably the most damaging species of slug in the world is the gray field slug (*Deroceras reticulatum*). This species is certainly the most damaging species to the grass seed industry in the Willamette Valley. Thus, we focus here on the optimization of bread dough as an attract-and-kill approach to the gray field slug. We conducted laboratory choice-test assays to assess if some types of flour, yeast or flour-yeast combinations were more attractive to the gray field slug than others. The most attractive flour-yeast combinations determined from laboratory assays were then used in perennial ryegrass (*Lolium perenne*) and tall fescue (*Lolium arundinaceum*) to assess their relative attractiveness in commercial field settings.

Material and Methods

All bread dough recipes in this study followed Veasey et al. (2021) by dissolving 0.5 oz of yeast into 2.1 cups of water, then thoroughly mixing with 1.1 lbs. of flour; laboratory choice assays used half these quantities. We prepared dough 24 hours before deploying in laboratory and field research trials.

For laboratory choice assays, 10 flour-yeast combinations were made using five types of flour and two types of yeast (Table 1). Choice assay arenas were plastic "shoebox" containers (14-by-8-by-5 inches), the bottoms of which were lined with a damp paper towel. We weighed 0.18 oz of two different doughs into 0.5 oz plastic portion containers and placed them at opposite ends of the arena. Ten gray field slugs that had been withheld food for 24 hours were then placed at the center of the arena within a 5.9 inch impression on the paper towel (made using a petri dish). Assays were observed for one hour, recording slugs contacting a dough portion container as choosing that dough and removing them from the experiment. Slugs not contacting a portion container within an hour were recorded as nonresponders. All flour-yeast combinations were tested against one another (45 pairwise comparisons) for three replicates (135 total assays). We assessed the preferential attractiveness of different doughs with chi-square tests, incorporating Yates's correction for continuity.

We used the three highest-performing bread dough recipes from laboratory choice assays to test their relative attractiveness in field trials. These were: 1) all-purpose flour + active dry yeast; 2) all-purpose flour + instant yeast; and 3) bread flour + active dry yeast.

Table 1. Flour types, yeast types and abbreviations. Abbreviations used in the manuscript and subsequent tables.

Product	Abbreviation
King Arthur Unbleached Bread Flour	Bread
Kroger All Purpose Bleached Enriched Flour	All-purpose
Bob's Red Mill Dark Rye Flour	Rye
Kroger Whole Wheat Traditional Flour	Wheat
Fleischmann's Instant Yeast	Instant
Fleischmann's Active Dry Yeast	Active

Table 2. Chi-square tests for laboratory assays. The five (of 45 total) laboratory choice assays with significant differences between bread doughs (α of 0.05 = X^2 of 3.841) to attract *Deroceras reticulatum* are presented here.

Dough A	Dough B	# Slugs Dough A	# Slugs Dough B	# Slugs No Choice	X^2
Bread + instant	Rye + instant	19	6	5	5.76
All-Purpose + active	Rye + active	16	5	9	4.76
Bread + instant	Wheat + instant	14	4	12	4.50
All-Purpose + instant	Rye + instant	17	6	7	4.35
Bread + active	Rye + instant	17	6	7	4.35

The four treatments included 2.1 oz of each dough and ¼ cup of water in 0.5 oz portion containers. Field trials included 10 replicates of each treatment using both Snailer traps (Rincon Vitova) and 1.6 ft square quadrats. Thus, each field experiment had 80 total traps. For the Snailer traps, treatments were placed at the center of the trap, with 5 oz of a liquid metaldehyde (OrCal Slug-Fest) and water solution in the bottom of the traps to increase the likelihood that slugs entering traps did not subsequently leave them. The 19.7-inch quadrats were sprayed with liquid metaldehyde at the label rate for grass seed crops, the treatments were placed at the center of the quadrats. There were 9.8 ft between treatments within a replicate and 49.2 ft between replications. The studies were conducted in both a perennial ryegrass field (Tangent, OR) set up on 28 October 2024, and in a tall fescue field (Shedd, OR) set up on 19 November 2024. Each experiment was run for three days, checking and removing dead slugs from Snailer traps or from 19.7-inch plots daily; 19.7-inch plots were searched until no new dead slugs were seen for 30 consecutive seconds. ANOVA analyses was used to determine significant differences (α = 0.05) between treatments, we calculated the Tukey-Kramer *q* statistic pairwise comparison for each treatment and used a studentized range *q* table to assess support for rejecting the null hypothesis of no difference between groups.

Results and Discussion

Laboratory choice assays suggested differences in the attractiveness of doughs made from different flour-yeast combinations, with five (of 45) pairwise combinations testing different from one another (Table 2). There were no differences between yeast types. Instead, flour type appeared to drive choice preferences, with all-purpose bleached enriched flour and unbleached bread flour found to be more attractive than dark rye flour and whole wheat traditional flour (Table 2). Gluten flour was not different from any other types of flour. We found the poor performance of the high-gluten flour surprising, given our personal observations of protein being an attractant to the gray field slug in the field and in the lab. Further research on the types of protein and perhaps the seasonality of protein as an attractant (e.g., in preparation for egg-laying) could be of interest.

The three highest performing bread dough recipes for laboratory assays were all-purpose bleached enriched flour with active dry yeast, all-purpose bleached enriched flour with instant yeast, and unbleached bread flour with active dry yeast. These bread dough recipes were advanced to the field trials.

For field trials in tall fescue, ANOVA and Tukey-Kramer tests found all bread dough types were different from the water negative control (Table 3), but the three recipes were not different from one another (data not shown). The results were not as strong for trials in perennial ryegrass, with only all-purpose enriched flour found to be more attractive than water (Table 3). The different response of slugs in tall fescue compared to perennial ryegrass could be due to several reasons. First, negative control captures were very high in Snailer traps in the perennial ryegrass fields relative to the tall fescue fields (Table 4). Second, there was high variation in rainfall during the two field trials, with 1.00 inch over the course of the perennial ryegrass experiment compared to the 2.17 inches in the tall fescue field (NOAA Online Weather Data, https://www.weather.gov), and slugs could have been responding to this variation. Third, slug numbers were relatively low in perennial ryegrass quadrats compared to tall fescue quadrats (Table 4), and it could be that slugs were easier to manually find in tall fescue than in perennial ryegrass.

We view the tall fescue field trial results of strong significance (at α = 0.01 in 5 of 6 comparisons and at α = 0.05 in the other) between doughs and water,

Table 3. ANOVA and Tukey-Kramer test results for field trials. Chi-square values significant at α = 0.05 are emboldened and values significant at α = 0.01 are emboldened and italicized.

Grass field	Trap type	Group 1	Group 2	ANOVA p-value	Tukey-Kramer X^2
Tall fescue	Snailer	All-purpose + active	Water	0.0000087	***6.906***
		All-purpose + instant	Water		***5.536***
		Bread + active	Water		***5.974***
	Plot	All-purpose + active	Water	0.0000056	***7.294***
		All-purpose + instant	Water		**4.119**
		Bread + active	Water		***6.004***
Perennial ryegrass	Snailer	All-purpose + active	Water	0.111	0.499
		All-purpose + instant	Water		0.107
		Bread + active	Water		3.033
	Plot	All-purpose + active	Water	0.028	**4.235**
		All-purpose + instant	Water		2.420
		Bread + active	Water		1.556

Table 4. Number of slug captures in field trials.

	Number of slug captures				
	Tall fescue		**Perennial ryegrass**		
Treatment	**Snailer**	**Plot**	**Snailer**	**Plot**	**Total**
All-purpose + active	160	176	131	80	547
All-purpose + instant	135	112	120	59	426
Bread + active	143	150	202	49	544
Water (-control)	34	29	117	31	211

but no differences detected between dough types very positively, for all-purpose bleached enriched flour, unbleached bread flour, and active and instant yeast are all relatively inexpensive and readily available worldwide, and all would likely perform well in bait-and-kill management strategies.

Our standard bread dough recipe in previous research used all-purpose bleached enriched flour and active dry yeast (e.g., Veasey et al. 2021) and this flour-yeast combination resulted in the most frequent and strongest significant differences (Table 3). This recipe also resulted in the highest number of attracted slugs captured in the field trials reported here (Table 4). Although not statistically significant, it suggests that our standard research bread dough recipe is highly attractive to slugs in agricultural settings.

Field trial analyses and the results reported here combine all slug species captured. However, multiple species were captured at both field sites. In the perennial ryegrass field, 834 total slugs were captured, of which 96.9% (n = 808) were gray field slugs, 0.5% (n = 1) were dusky slugs (*Arion (Mesarion)*), and 2.6% (n = 22) were the reticulate taildropper (*Prophysaon andersonii*). In the tall fescue field, we captured 930 total slugs, of which 83% (n = 769) were gray field slugs, 17% (n = 160) were meadow slugs (*Deroceras laeve*), and 0.001% (n = 1) were brown-banded slugs (*Arion circumscriptus*).

We will repeat the perennial ryegrass and tall fescue field trials in the spring of 2025.

References

Salisbury, S. 2015. The Cost of Slugs to the Grass Seed Industry in the Willamette Valley. Oregon House Committee of Agriculture and Natural Resources, Salem, OR.

Veasey, R., M. Cordoba, A. Colton, L. Fujimoto, C. Dodge, I. Foley, G. Adams, T. Anderson, R. Merenz, A. Hara, A. Roda, J. Millar, and R. Mc Donnell. 2021. Fermenting Bread Dough as a Cheap, Effective, Nontoxic, and Generic Attractant for Pest Snails and Slugs. Insects, 12(4), Article 4. https://doi.org/10.3390/insects12040328

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