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The Central Oregon Agricultural Research and Extension Center (COAREC) faculty and staff are pleased to present this summary of 2022 research activities for your review. The reports included in this publication represent a snapshot of the research focus in our region by faculty stationed in central Oregon.

Our research center is part of a network of Oregon State University research locations across the state (OAES) which operate under the umbrella of the Statewide Public Service Programs. These programs include OSU Extension, OAES and the Forest Research Laboratory. Currently, we have two faculty researchers working in Plant Pathology and Soil Science at COAREC who collaborate with Extension in Deschutes, Crook and Jefferson County at the local level and with other counties statewide to ensure we are addressing the most pressing and important needs today and far into the future. In addition to our research programs, we have active Extension programs in Agriculture Education, Honey Bee and Pollinator Health as well as access to a multitude of other programs and information through the OSU Extension system.

Today, our Plant Pathology program is working toward improved and sustainable management of plant diseases in central Oregon specialty crops. This includes understanding pathogen biology and disease epidemiology, developing tools for disease detection and pathogen identification, disease modeling and forecasting, and developing integrated disease management strategies.

In the future, we look forward to strong, active research programs moving COAREC to the forefront of innovative research and finding solutions to existing and emerging problems in our area such as abiotic stress, plant diseases, insects, and weeds, and finding ways to support honeybees and pollinators.

If you have not had the opportunity to visit COAREC in the past or to talk with one of our researchers about their work, we invite you to attend an event or visit our location. Your ideas and involvement are a key component to our success. It is the local community that allows us to continue to provide important research and educational opportunities for central Oregon that are vital to the agricultural community and local economy.

If you have questions or thoughts, you would like to share with me feel free to call (541-475-7107), email me (Jeremiah.Dung@oregonstate.edu) or visit COAREC in person. Your feedback and comments are appreciated and are helpful as we plan for the upcoming year.

Thank you,

Jeremiah Dung, Interim Director
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Phenology of Insect Pests in Kentucky Bluegrass in Central Oregon

Seth Dorman, Navneet Kaur, and John Spring

Introduction

Several insect pests can damage Kentucky bluegrass stands and potentially reduce seed yields in central Oregon, including cutworms, armyworms, and billbugs. While acute losses to these pests are not particularly common in grass seed production in the area, economic losses are possible, and many fields receive regular preventative insecticide applications. A better understanding of pest phenology could be useful to improve control of these pests by supporting targeted insecticide use rather than preventative – particularly in light of the recent loss of the broad-spectrum insecticide chlorpyrifos – while also potentially lowering input costs and reducing the risk of insecticide resistance development. Thorough understanding of pest population dynamics is also essential for development of improved integrated management strategies.

As a component of extensive statewide efforts to better describe the phenology of key insect pests of grass seed production across Oregon, adults of the noctuid species true armyworm (*Mythimna unipuncta*), glassy cutworm (*Protagrotis obscura*), black cutworm (*Agrostis ipsilonone*), and sod webworm (*Chrysoteuchia topiaria*), and adults and larvae of billbug (*Sphenophorus* spp.) were monitored in 3 Kentucky bluegrass fields in Jefferson County over the 2022 growing season.

Materials and Methods

Three fields were monitored over the 2022 growing season. Field 1 was a 3rd year stand of ‘Merit’, which had a Group 1 insecticide applied each fall, and a group 3 insecticide applied in spring of 2021, but not 2022. Field 2 was a 2nd year stand of ‘Diva’, which had a Group 3 insecticide applied in fall of 2021 and 2022, and no spring insecticides. Field 3 was a 3rd year stand of ‘Rockstar’ which did not have any insecticide applied in 2021 or 2022.

In each field, billbugs were monitored by pitfall traps and sod samples. Linear pitfall traps with a 1m trapping slot were buried to grade perpendicular to row direction at two locations in each field, approximately 325 yd apart. Pitfall traps were placed 4/11/22 to 7/5/22, removed for harvest, and replaced 9/12/22 to 10/31/22. Sod samples were taken on two dates approximately 2 weeks apart from each field in mid-spring (late April and early May), and again in the fall (late September and early October). At each sampling date, 12 samples of 1 ft diameter and 6 in depth were taken at even intervals between the pitfall traps. Samples were dried in Berlese funnels for 4 days to collect mobile insects, followed by manual dissection to detect any insects remaining in the sod.

Noctuid species were monitored by pheromone-baited bucket traps (UniTraps) placed at 4 ft height on t-posts at 110 yd spacing along the upwind side of the field. Traps were placed 5/17/22 and monitored weekly through 10/31/22, although results for the full trap period are not available for all species at the time of writing.

Results and Discussion

Data collected in central Oregon (Figure 1) are a small component of the overall Oregon Pest Monitoring Network, a recently initiated collaboration between entomologists and others at USDA-ARS and OSU. The network provides statewide monitoring and reporting on common insect pests of seed crops across Oregon, management recommendations, and more, and can be viewed at: (https://storymaps.arcgis.com/stories/304d0f3725bf4e49a3daf6dce1ddd3bc). A real-time mapping feature allows flexible viewing of current or historical monitoring data via an online, mobile-friendly interface. The mapper also has functionality allowing growers and agronomists to contribute their own monitoring data to the network in a geographically anonymized manner.

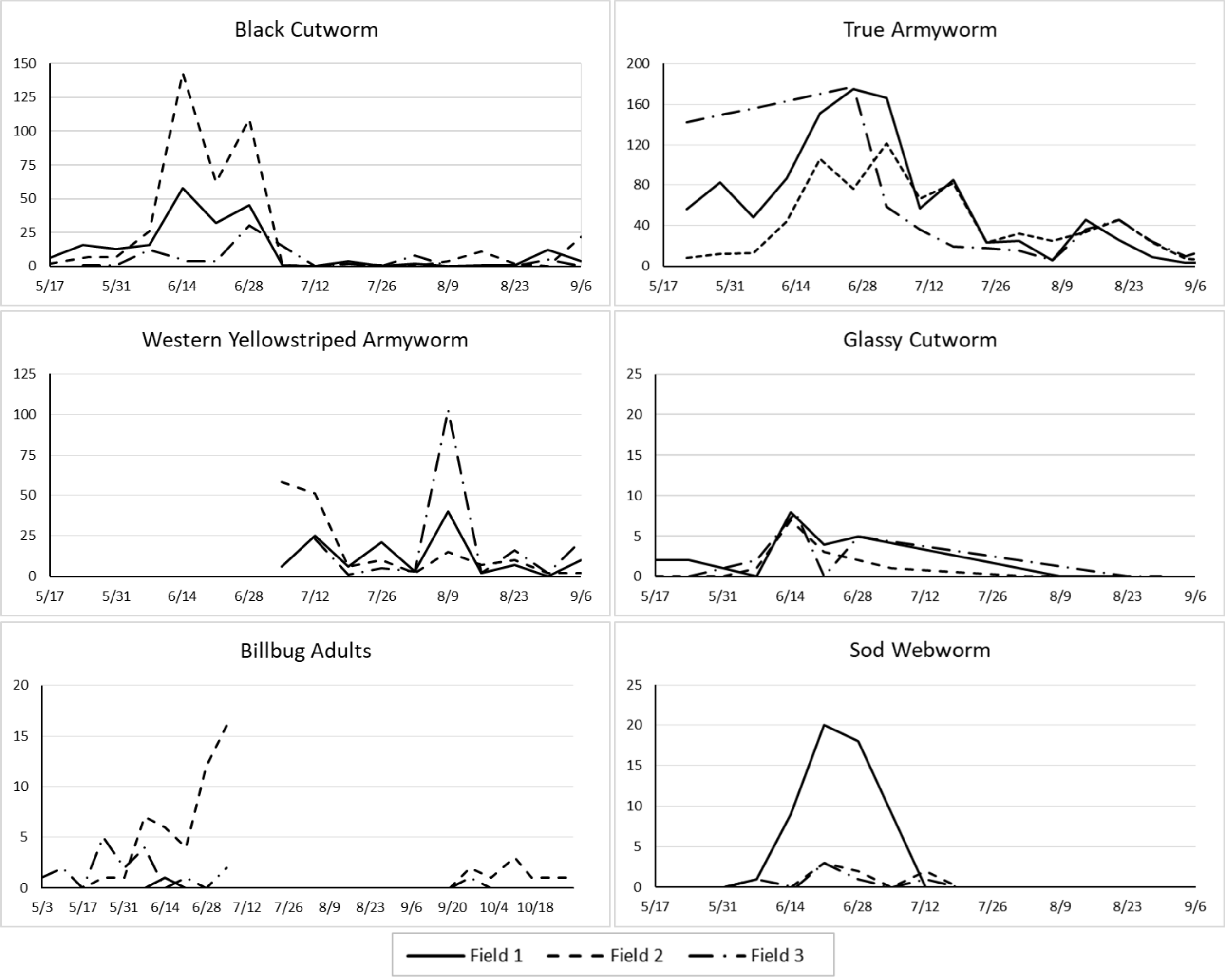
Most noctuid species had a relatively large primary flight in June, and lower numbers for the remainder of the season. Black cutworm had a peak in numbers trapped in June, followed by low, steady presence for the rest of the monitoring period. An non-target species, western yellowstriped armyworm (*Spodoptera praefica*), was also captured in considerable numbers in black cutworm pheromone traps. It was not positively identified until early July, so dynamics of May/June flights are unknown, but it appeared in low, steady numbers in most fields for the rest of the season, with a notable short increase in numbers in early August. True armyworm was trapped at the highest numbers of all target species, with a peak flight in late June, followed by declining numbers in mid-summer and a smaller secondary flight in later August. Glassy cutworm captures were relatively low in comparison to other species, with a maximum in early to mid-June followed by a slow decline to zero in August. Sod webworm was detected only before harvest, and in low numbers in 2 of 3 fields.

The large majority of billbug adults captured appear to be Denver billbug (*Sphenophorus cicatristriatus*) on the basis of preliminary observations. Numbers varied between fields, but adults were present in relatively higher numbers before harvest than after in all fields. Adults present in the spring complete their lifecycle and die after harvest, and are replaced in the fall by newly emerging adults of the next generation, which will then overwinter in the field. In each field, sod samples were taken twice, a week apart, in both fall and spring. Sod samples contained larvae, and often additional adults beyond pitfall trap catch shown in Figure 1. In Field 1, no billbugs were detected at spring sampling, and 2 adults and 1 larva found in the 24 ft^2 sampled area in the fall. In Field 2, spring sod samples contained 2 adults and 2 mature larvae, while fall samples (following a Group 1 insecticide application) contained only 1 adult. Field 3 had no billbugs in spring sod samples, but a total of 7 adults and 5 larvae in the fall.

Acknowledgements

For central Oregon components of the project, the authors would like to thank Willow Tree Farms, Klann Farms, and Roff Farms for hosting trial sites and Keelie Sullens for technical support. Financial support from the Eastern Oregon Kentucky Bluegrass Work, Oregon Seed Council, and Oregon Tall Fescue Commission is gratefully acknowledged.

Figure 1. Population counts of monitored insect pests in three Kentucky bluegrass fields in central Oregon over the 2022 growing season.



Indaziflam in Kentucky Bluegrass Stand Establishment for Long-Duration Grass Weed Control in Central and Eastern Oregon, Year 2

John Spring, Darrin Walenta

Introduction

Grass weed control is a consistent challenge in Kentucky bluegrass (KBG) seed production, and herbicides currently available for this use are limited. Indaziflam (as Alion from Bayer Crop Science in crop uses, and as Rejuvra from Envu in rangelands) is a uniquely long-lasting soil residual herbicide with strong activity on cheatgrass and other winter annual grass weeds important in KBG. Residual control of grassy weeds for 2 to 3 years after a single application is common in rangeland uses, along with excellent safety on established perennial grasses. Alion is currently labelled for use in established stands of several grass species grown for seed, but not in KBG. Initial testing of post-harvest applications to established bluegrass demonstrated acceptable crop safety in the Grande Ronde Valley in northeast Oregon (Walenta 2016). However, the typical after-harvest application window has several challenges. Ash and crop residue remaining after burning or flaming can tie up pre-emergence herbicides (and is a known concern with indaziflam) and reduce activity. Herbicides also require properly timed and adequate irrigation and/or precipitation for activation prior to weed emergence, and to maintain activity during extended windows of weed germination and emergence. If adequate moisture is not available during this time frame, weed control with pre-emergent herbicides is greatly complicated. Additionally, the long residual activity of indaziflam may pose carryover concerns to rotational crops if used later in the life of an established stand.

Application of indaziflam in seedling stands has potential to substantially improve grass weed control in both fall and spring planted KBG. Application conditions are generally more favorable at this time than in established stands, both for uniform coverage and for herbicide activation and prolonged activity. The long residual activity of indaziflam means that a single application has potential to provide durable pre-emergence grass weed control during the sensitive seedling stage and into following years of the stand, but with minimal carryover risk as stands rotate to other crops after 3 to 4 years of production. In 2021, field trials were conducted to test the crop safety of indaziflam applied to seedling KBG in central and northeastern Oregon (Spring and Walenta 2021) with encouraging results. Field trials were conducted at two locations over the 2022 crop year to generate further data on this use pattern.

Materials and Methods

Field trials were located in two commercial stands of KBG, a spring-seeded stand in Union County near La Grande OR, and a fall-seeded stand in Wheeler County near Clarno OR. In La Grande the trial was located in a stand of ‘Gaelic’ seeded in April of 2021 under center pivot irrigation. The Clarno site was in a stand of ‘Rockstar’ seeded in August 2021 under wheel line irrigation. Trials were established in a randomized complete block design with 4 replicates and an individual plot size of 8’x25’ (La Grande) or 10’x30’ (Clarno). Indaziflam was applied as Alion at 1, 2, and 3 oz/ac at each of 3 growth stages of KBG using CO_2 powered backpack sprayers delivering 21 or 15 gallons per acre. Growth stages were 3-5 leaf, 3-5 tiller, and 10+

tiller size. Applications were made in La Grande 5/26/21, 6/25/21, or 9/1/21 and in Clarno 10/5/21, 11/16/21, or 3/25/22. Sites were chosen to be weed-free. Trials received all production inputs alike with the rest of the field. Crop injury was rated shortly after the onset of rapid stem elongation following 2nd node emergence on a percent scale from 0 to 100 (with no effect at 0 and complete plant death at 100) on 5/4/22 in La Grande and 5/13/22 in Clarno. At crop maturity, a 6’ wide swath in the center of each plot was windrowed with plot swather, and allowed to dry in the field prior to threshing with a plot combine. Seed was then re-threshed with a stationary thresher, and cleaned with small air-screen cleaner to a final weight of 19-20lb/bu and approximately 98% purity for calculation of clean-seed yield.

Results and Discussion

At the La Grande location, visually apparent crop injury was minor (<10-15%) at the earlier application timings, and increased slightly with increasing Alion rate (Figure 1). No crop injury was observed in 10+ tiller treatments. Seed yield was equivalent to the nontreated check at 1 oz/ac Alion applied to 3-5 leaf KBG, but showed a moderate reduction (estimated 200 to 300 lb/ac loss) at 2 oz/ac. The 3 oz/ac rate was not tested at this application timing in this trial. For 3-5 tiller applications, yield was equivalent to the check at 1 oz/ac Alion, equivalent or slightly less at 2 oz/ac, and considerably reduced at 3 oz/ac. For all Alion rates applied to 10+ tiller KBG, yields appear equivalent to the nontreated check at the level of precision the somewhat variable data from this site can support. Overall results from this spring-seeded stand are consistent with those seen in two fall-seeded stands in 2021 (Spring and Walenta 2021).

At the Clarno location, no crop injury was visually apparent for any rate of Alion applied at the 3-5 leaf stage (Figure 1). At the 3-5 tiller stage, minor crop injury (<10%) was visually apparent, and appeared to increase slightly with increasing Alion rate. Applications made to 10+ KBG in the spring caused the highest levels of injury observed in the trial at 2 and 3 oz/ac rates (Figure 1). Injury was quite high at the 3 oz/ac rate, including substantial stunting of top growth and major reductions in fertile tiller number. Although visible crop injury at earlier application timings was minor (3-5 tiller treatments) or non-existent (3-5 leaf treatments), all Alion rates applied at these timings appear to have decreased seed yield relative to the non-treated check by a slight to moderate amount. Rate did not influence injury level for treatments applied at the 3-5 leaf stage, but there appears to be a pattern of slightly increasing injury with increased rate at 3-5 tiller applications. Considerable variability is evident in the data which prevents precise estimation of this yield reduction with confidence, but losses appear to be approximately 200 to 400lbs/ac clean seed in this trial. (This level of yield loss is similar to that observed in 2021, although with slightly higher variability at this site particularly.) Yield reductions were similar or slightly higher than this at 1 and 2 oz/ac rates applied at the 10+ tiller stage, and very high at the 3 oz/ac rate, where little seed was produced.

This pattern of crop safety (i.e. good safety and relatively minor yield reduction from applications made to early growth stages, and much higher injury observed from the last application timing made to well-established seedlings) is nearly the reverse of that observed at the La Grande trial in 2022 and of the two trials conducted in 2021. In all of these trials, applications made to small plants were most injurious and safety generally increased with KBG size at application. We suspect that differing soil water dynamics between trials may be the cause of this difference. Alion is known to require adequate binding time to dry soil (48 hours is a reasonable rule of thumb) in order to ‘fix’ to the upper profile and be resistant to downward leaching by water, which can otherwise result in crop root damage. In this trial, early applications were made to a dry soil surface and at least 3 days prior to the next irrigation, and good safety was observed. At the 10+ tiller application timing, however, consistent rains and slow soil drying in cool spring conditions meant that an application window with dry surface soil was not obtainable. Applications were made to a not-entirely-dry soil surface with good moisture in the profile below, and we presume that subsurface recharge prevented the upper profile from drying entirely for a long enough period for Alion to bind and resist leaching on the first irrigation for the season at ~5 days after application. In contrast, very dry spring conditions in 2021 allowed for adequate binding time on dry soil at this application timing, and relatively minor injury was observed in 2021.

The unexpected ‘inversion’ of crop safety versus KBG size at application observed at the Clarno trial is potentially quite important. It suggests that micro-environmental conditions at application exert a critical influence on crop safety, which, under certain conditions at least, may be more important than the more general pattern of increasing crop safety on larger, more established seedlings that was observed at the other three trial locations to date. We presume that soil moisture conditions are the controlling factor here, although this requires considerable further investigation before this can be concluded with any certainty. If this effect is repeatable, however, and can be quantified precisely enough to lead to management guidelines, it may allow applications to be made to very small seedlings with adequate crop safety, or at least to avoid conditions in which severe injury is more likely regardless of crop size.

Considering combined observations of crop safety across the 4 trial locations we have conducted to date, Alion still appears to hold strong potential for early post-emergence use in seedling Kentucky bluegrass. The unexpected pattern of crop injury observed at the Clarno location in 2022, however, indicates that considerable further work remains to confidently describe the conditions under which safe use is likely, and those under which injury potential is unacceptably high. Trials are being repeated again for the 2023 crop year at two locations in central and northeastern Oregon.

Note: Indaziflam is not currently registered for use in Kentucky bluegrass seed production and is being evaluated on an experimental basis only. Mention of indaziflam in the context of this trial is not to be considered a recommendation for commercial use or non-permitted testing .

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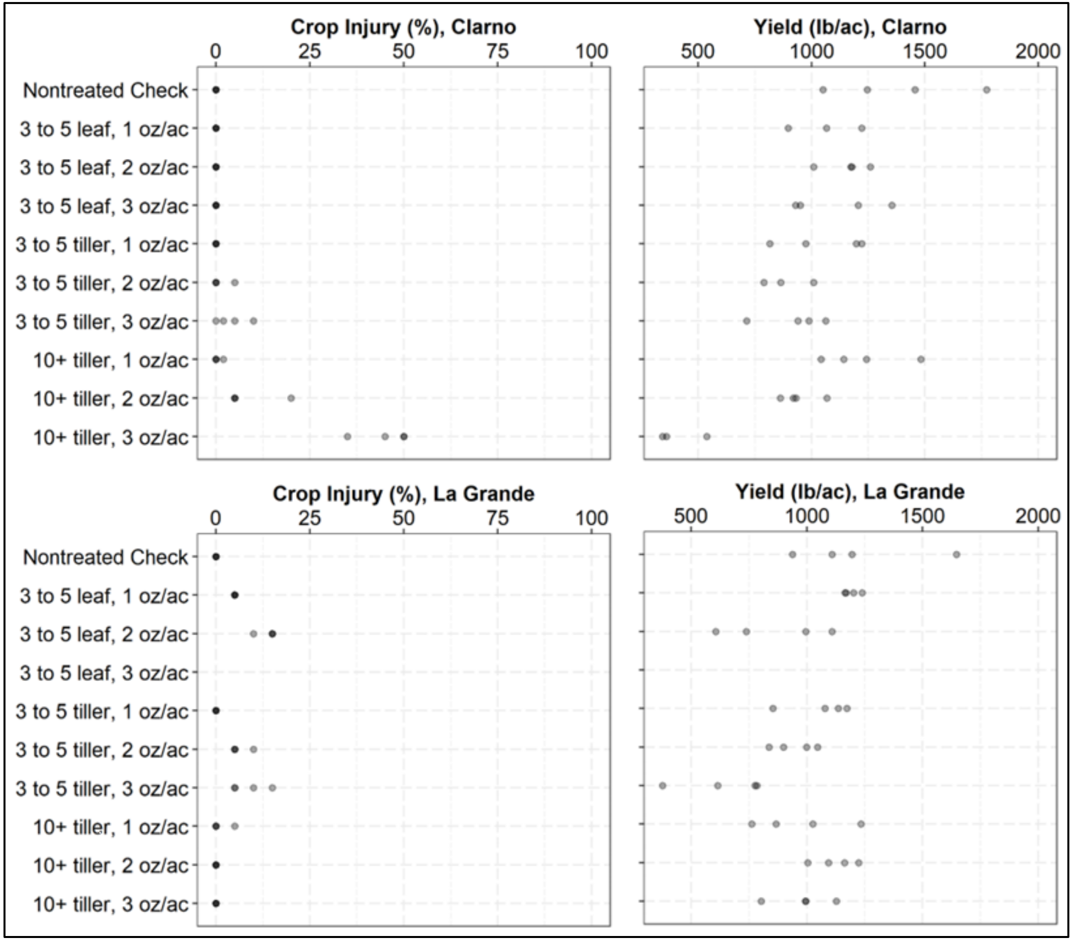
Figure 1. Crop injury shortly after 2nd node emergence in the spring and clean seed yield following treatment of seedling Kentucky bluegrass stands with experimental applications of indaziflam (Alion herbicide).



Early Post-Emergence Pyroxasulfone in Perennial Ryegrass in the Columbia Basin

John Spring

Introduction

Pyroxasulfone is a Group 15 (VLCFA synthesis inhibitor) herbicide registered for some uses in cool season grass seed production in Oregon, including in perennial ryegrass. It is a soil-active seedling growth inhibitor with efficacy on a broad spectrum of weeds – including many problematic grassy weeds – and generally good safety on established plants due to minimal foliar uptake. Pyroxasulfone has good pre-emergence activity on rattail fescue, and can provide control or suppression of other problematic weeds such as downy brome, annual bluegrass, and volunteer Kentucky or roughstalk bluegrass, among others.

As Zidua SC (BASF), pyroxasulfone is currently labelled for use in established stands of tall fescue and perennial ryegrass in Oregon and Washington west of the Cascades only. This geographic restriction resulted from an initial lack of data from eastern Oregon/Washington environments. Subsequent work (Salisbury 2020-22, ongoing) has demonstrated acceptable safety in established stands east of the Cascades, and label expansion is expected in the near future. As Fierce (a premix with flumioxazin, Valent), pyroxasulfone is labeled across Oregon, Washington, and Idaho in perennial ryegrass, tall fescue, fine fescue, and orchardgrass. Allowable uses include fall applications to new carbon seedings, established stands, and to spring-seeded stands that have at least 8 tillers by the time of fall application. Development work for this label was also conducted primarily in western Oregon.

For both formulations, currently labelled uses are largely incompatible with typical single-harvest (annual) production practices for perennial ryegrass in the Columbia Basin. In 2021, the most recent year for which data are available, approximately 32% of Oregon perennial ryegrass seed was grown in the Columbia Basin (Anderson et al. 2022). The vast majority of perennial ryegrass in the Columbia Basin is seeded in late summer or early fall and provides a single seed harvest the following summer before being rotated to another crop. Particularly poor stand longevity in the region prevents perennial production. Rattail fescue is a priority weed in the area, and pyroxasulfone is known to have good activity on the species. Thus, if new use patterns can be developed for single-year production systems in the Columbia Basin, pyroxasulfone could represent a valuable new tool for control of rattail fescue particularly, and for a range of other weeds as well.

While perennial ryegrass is not currently grown in central Oregon on any appreciable acreage, it has characteristics that could be advantageous under the current drought scenario. Modern varieties can be successfully planted late in the fall (typical timing is late September to early October in the Columbia Basin), and seedling growth is rapid and vigorous relative to Kentucky bluegrass. This would allow more efficient use of limited irrigation water for stand establishment in the fall, and stands could probably be established on considerably less water than Kentucky bluegrass. Late planting also allows perennial ryegrass to follow potatoes, wheat, or other late-harvested crops. Should perennial ryegrass emerge as a viable crop for central Oregon, it is likely that production challenges and practices would have many similarities to those in the Columbia

Basin.

The objective of this study was to evaluate the crop safety of the pyroxasulfone-containing herbicides Zidua SC and Fierce EZ when applied to early growth stages of fall-seeded irrigated perennial ryegrass grown in the Columbia Basin.

Materials and Methods

Field trials were conducted at 2 locations near Hermiston Oregon over the 2021-22 crop year. Site 1 was on a Quincy fine sand planted to 'Frontier' perennial ryegrass, and Site 2 on a Shano very fine sandy loam planted to 'Align 2' perennial ryegrass, both under center pivot irrigation. Trials were arranged in a randomized complete block design with 4 replicates and individual plot size of 10 x 30 feet. Herbicides were applied by $C0_2$-powered hand boom, delivering 15 gpa in a coarse droplet size and with no adjuvants. Natural precipitation and/or irrigation of at least 0.25 inch was received ≤ 5 days after all applications. All field inputs were applied across the trial sites alike with the field by the grower. Experimental herbicide treatments were applied at several seedling growth stages (Table 1). Applications were made on 10/11/21 (3-5 leaf growth stage), 11/3/21 (3-5 tiller), or 3/17/22 (8-tiller). Crop injury was evaluated at intervals throughout the growing season on a 0 to 100% scale, with no injury at 0% and complete plant death at 100%. Injury data were analyzed using a generalized linear model with beta regression and logit link to confirm main effects of treatment and block, followed by multiple comparison using Tukey's method. Site 2 was lost early in the spring growing season to heavy infestation with annual ryegrass, and only limited crop safety evaluations were possible. Site 1 generated good evaluation data through crop heading as intended.

Results and Discussion

Zidua SC rates tested correspond to the current label rate for use in established perennial ryegrass (3 oz/A, 0.098lb ai) and 2X that rate (6 oz/ac, 0.20 lb ai). Current labelled rates for Fierce EZ in perennial ryegrass are between 3 and 6 oz/A (0.04 to 0.08 lb pyroxasulfone/ac). Unfortunately, an error during treatment list calculations gave rates of 2 and 4 oz/ac Fierce EZ, so tested rates do not correspond exactly to labelled rate range in established perennial ryegrass. The Fierce rates tested contain 0.027 or 0.053 lb ai/ac pyroxasulfone, considerably lower than the loading of Zidua SC rates tested. This was fortunate in the sense that it allowed observation of crop response to a wider range of pyroxasulfone rates. Not surprisingly, crop injury appears to follow pyroxasulfone rate rather directly, with higher injury levels consistently observed at higher rates.

Applications made at the 3-5 leaf stage (early October 2021) did not provide adequate safety at either Zidua rate, with severe crop damage and stand loss persisting across the growing season. With both rates of Fierce (and the lower pyroxasulfone rates they contained), heavy crop damage was observed in fall and early spring, but plots were able to recover surprisingly well, and showed minimal injury by crop heading. Nonetheless, this growth stage is almost certainly too early to obtain adequate safety margins on coarse soils with realistic use rates of pyroxasulfone.

For applications made at the 3-5 tiller stage (early November 2021, around the end of the active fall growth), injury in Fierce treatments was minimal by crop heading. Crop injury from Zidua was concerningly high, but not unambiguously unacceptable, particularly at the 3 oz rate. At the final evaluation of crop safety in early June, numerical ratings reflect a combination of actual plant damage and delayed growth stage relative to the non-treated check. In other words, a good portion of the crop ‘injury’ at the June rating reflects delayed heading/pollination/seed fill rather than irreversible plant damage. (For example, at the June rating check plots were noted entering dough stages of seed fill while many plants in severely 'injured’ plots were in late boot or early pollination stages, but otherwise healthy and vigorous.) In a whole field setting, this would of course necessitate several weeks of additional irrigation and delay harvest, but with an extended growing season these delayed plants would be likely to complete their development normally and recover most of the yield potential decrease reflected in early June. Unfortunately, the field was swathed according to development of non-treated checks, so continued observation of development in delayed treatments was not possible.

Crop injury from Zidua applied to 8-tiller seedlings (at early green-up, in mid-March 2022) was somewhat higher than 3-5 tiller applications through May and June. Again, crop injury from both timings manifested primarily as delayed growth, and it is speculated that plants in the earlier applications simply began metabolizing herbicides and recovering from growth delays earlier than plants in the later applications, and thus had less injury at any given point later in the season. Similar to injury from 3-5 tiller applications, these injury levels are concerningly high, but are not unambiguously unacceptable for the same reasons. Injury from both Fierce rates was within acceptable levels by crop heading.

Atrazine was very safe at the 0.5lb ai/A rate at both 3-5 tiller and 8 tiller application timings. At 1 lb/A, early spring injury levels approached 30% when applied to 3-5 tiller seedlings, but were minimal by crop heading. Crop safety of the higher rate was consistently good when applied to 8 tiller seedlings. On sandy soils, a use rate of 1 lb ai/A atrazine is fairly high, and good efficacy could be reasonably expected even at the 0.5lb ai rate on most target weeds, including rattail fescue. Unfortunately, while atrazine appears to offer excellent agronomic potential for Columbia Basin perennial ryegrass production, the EPA has a permanent, no-exceptions prohibition on registration (or re-registration) of any additional use sites for atrazine, and the regulatory outlook for continuing availability of the chemical in any crop is increasingly dim.

Overall, results from this initial trial suggest that pyroxasulfone may have a possible fit when applied to seedling perennial ryegrass in the Columbia Basin. Further trials including yield evaluations appear warranted to further investigate this possibility, and have been initiated for the 2023 season.

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Thank you to Mike and Alex Hawman for hosting trial sites. Financial support for the project from the Oregon Seed Council is gratefully acknowledged.

Figure 1. Crop injury across the growing season from pyroxasulfone-containing herbicides applied to seedling perennial ryegrass in the Columbia Basin. Crop injury on a 0-100% scale, with no injury at 0 and complete crop death at 100%. Values are a mean across 4 replicates at each site. Within a column, means followed by the same letter are not significantly different by Tukey's multiple comparison test (α=0.05).

Herbicide, Rate	Growth Stage	Crop Injury (%)									
		3-Dec-20		*16-Feb-21*		*14-Apr-21*		*13-May-21*		*13-Jun-21*	
		Site 1	*Site 2*	*Site 1*	*Site 2*	*Site 1*	*Site 2*	*Site 1*	*Site 2*	*Site 1*	*Site 2*
Nontreated Check	-	*0*	*0*	*0*	*0*	*0 a*	-	*0 a*	-	*0 a*	-
Zidua SC, 3 oz / A	3-5 leaf	71	66	85	85	74 *g*	-	60 *fg*	-	43 *bc*	-
	3-5 tiller	4	0	6	10	10 *abcd*	-	26 *de*	-	18 *ab*	-
	8 tiller	-	-	-	-	11 *bcd*	-	36 *def*	-	38 *b*	-
Zidua SC, 6 oz/ A	3-5 leaf	71	75	89	94	86 *g*	-	70 *g*	-	73 *c*	-
	3-5 tiller	4	9	10	29	38 *f*	-	48 *efg*	-	31 *b*	-
	8 tiller	-	-	-	-	19 *cdef*	-	58 *fg*	-	46 *bc*	-
Fierce EZ, 2 oz/ A	3-5 leaf	31	20	38	30	16 *bcde*	-	12 *abc*	-	6 *a*	-
	3-5 tiller	4	1	4	1	6 *abc*	-	1 *a*	-	5 *a*	-
	8 tiller	-	-	-	-	11 *bcd*	-	14 *bcd*	-	10 *a*	-
Fierce EZ, 4 oz/ A	3-5 leaf	64	64	66	59	33 *ef*	-	25 *de*	-	3 *a*	-
	3-5 tiller	6	11	5	8	10 *abcd*	-	8 *abc*	-	4 *a*	-
	8 tiller	-	-	-	-	10 *abcd*	-	19 *cd*	-	13 *a*	-
Atrazine, 0.5 lb ai/ A	3-5 tiller	0	0	1	1	6 *ab*	-	3 *ab*	-	4 *a*	-
	8 tiller	-	-	1	0	13 *bcde*	-	0 *a*	-	0 *a*	-
Atrazine, 1 lb ai/ A	3-5 tiller	1	4	6	3	26 *def*	-	28 *de*	-	3 *a*	-
	8 tiller	-	-	3	0	8 *abcd*	-	5 *abc*	-	0 *a*	-

**Note – Crop injury at the June rating date (approaching physiological maturity of non-treated plants) incorporates both crop damage and growth stage delay, which was considerable in many treatments - up to an estimated 2-3 week delay in progression of heading, pollination, and seed development. It is assumed that yield reductions for many treatments would likely be considerably lower on a field scale than implied by numerical plot ratings if swathed at physiological maturity. As field was swathed according to developmental stage of non-treated plants, evaluation of actual crop damage to plots with delayed growth stage at maturity was not possible.*

Evaluating Nutrient Uptake and Partitioning for Hybrid Carrot Seed Production in Central Oregon, 2017-2018

Amber Moore, Tracy Wilson, Ekaterina Jeliazkova, and John Spring

Introduction

This study was conducted to address questions from agronomists and growers interested in better understanding nutrient requirements of hybrid carrot varieties grown for seed in Central Oregon. Seed yields of hybrid carrot varieties are lower by 1.5 to 2.5 times and less consistent than open-pollinated varieties. In order to manage soil fertility for optimal seed yield, growers need to understand hybrid carrots nutrients needs, and align nutrient application with the period of greatest nutrient uptake. A better understanding of the nutrient requirements of hybrid carrot seed varieties may help to increase seed yields and reduce seed yield variability.

Current information related to fertility management in carrot seed production systems is on seed yield response to N, P, and K application rates. A number of these studies were conducted with tropical carrot seed varieties under a production season of 3 to 5 months duration, and only one evaluated seed yield response of a hybrid Nantes variety. In Central Oregon the production of carrot crop for seed extends up to 13 months in duration. Assessment of in-season plant nutrient uptake dynamics under local field conditions is important for understanding how much of a nutrient is needed by the plant, when the plant has the greatest need for each nutrient, and how much of a specific nutrient is taken up during different growth stages.

In-season N, P, K, S, Ca, Mg, B, Mn, Cu, and Zn uptake in above-ground biomass was evaluated in Madras, OR, from 2000 to 2002 on hybrid Nantes type 49-1 (Butler et al., 2002; Hart and Butler, 2003). The information generated from these studies provided insights on nutrient uptake by hybrid carrot grown for seed to growers in Central Oregon. However, because these studies were conducted approximately 2 decades ago, there was interest in understanding nutrient uptake patterns under current field management practices and for other hybrid Nantes types.

Plant nutrient uptake by aboveground biomass provides the bases for total fertilizer requirements estimates, but does not provide insight on how the nutrients support seed growth or on amount of recycled from crop residue nutrients returned back to the field. Prior to this research, published information on nutrient partitioning in carrot seed crops was limited to a single paper detailing results from a study in the UK.

Materials and Methods

This study was conducted in two commercial hybrid carrot seed production fields near Madras, Oregon. The soil properties and nutrient levels at 0-6 inches soil depth were similar for both fields, specifically soil pH at 5.9 or 6.2, organic matter 1.9 or 2.0%, NO_3-N 114 or 187 ppm, Olsen P 30 or 55 ppm, and Olsen K 228 or 239 ppm for fields 1 and 2, respectively. From 2014 through 2016 both fields were in irrigated Kentucky bluegrass seed production and rain-fed following harvest in July 2016 until carrot planting. Bluegrass sod was terminated and the ground prepared for carrot planting with conventional tillage. In July 2017 custom blended dry fertilizer was broadcasted, then incorporated. Field 1 received 48 lb N ac^{-1}, 48 lb P ac^{-1}, and 48 lb K ac^{-1}. Field 2 received 2000 lb ac^{-1} lime, plus 15 lb N ac^{-1}, 41 lb P ac^{-1}, 45 lb K ac^{-1}, 34 lb S ac^{-1}, and 1.8 lb B ac^{-1}. Both fields were planted to Hybrid 'Nantes' type 969 carrot seed on August 9, 2017 in Field 1 and August 7, 2017 in Field 2, at 30-inch row spacing, 0.2-inch depth, and 12 live seed ft^{-1} of row. Field 1 was planted with alternating 4-row sets of the female line (male-sterile, seed parent) and 2-row sets of the male line (male-fertile, pollen parent). In Field 2, male sets of 2-row and 4-row widths alternated with 4-row female sets. From May to August 2018, both fields were irrigated to full crop demand, Field 1 with furrow and Field 2 with subsurface drip irrigation.

Weather conditions from August 2017 to end of September 2018 were as follow: total precipitation of 8 inches, and average, average high, and average low temperatures for that same period were 49.5 °F, 65.8 °F, and 32.9 °F, respectively (Western Regional Climate Center, 2019).

In each field, sixteen plots divided among four blocks were established for a different study, with only one of the 4 plots per block selected at random for evaluating in-season nutrient uptake. Plot size varied slightly among plots based on field size and areas excluded on the basis of poor stand establishment, for Field 1 plot length ranged from 1290 to 1590 ft and plot width was 3 sets (8 female rows total), and for Field 2 plot length ranged from 1158 to 1247 ft and plot width was 5 sets (12 female rows).

From mid-October 2017 to early August 2018, excluding January and February when plant growth was minimal, whole plant samples of roots and tops included, were destructively hand collected from female rows only, for a total of 7 sampling events per field. At each sampling event three randomly selected areas of 3 x 2.5ft (one-row width) were sampled and composited per plot. Whole plant samples were partitioned into roots, tops, and umbels (flowers) with garden clippers and combined into a single composite sample per plot. During the summer months when biomass increased substantially, only a subset of plants from each sub-sample were included in the final composite sample. Samples were dried at 140° F, then ground to pass a 2 mm sieve.

For both fields, carrot seeds were harvested from eight rows of female plants per plot with commercial combines, on September 20-21, 2018 for Field 1 and on September 25, 2018 for Field 2. Of the harvested seed per plot, 4 subsamples were collected and composited. Seed subsamples were cleaned on small scale lab equipment, dried, and ground to pass 1 mm sieve. All biomass samples, including seed were analyzed for total N via combustion, and P, K, S, Ca, Mg, Zn, Fe, Mn, Cu, and B via ICP-OES of nitric acid digests.

Average values were calculated across fields for biomass accumulation and tissue nutrient uptake by plant part (roots, tops, umbels, and seed) at crop maturity. Harvest index was calculated by dividing clean seed yield at harvest by aboveground biomass at crop maturity (tops combined with umbels); nutrient index was calculated by dividing seed nutrient uptake at harvest by aboveground nutrient uptake at crop maturity (tops combined with umbels). Daily accumulation rate values were obtained by dividing the difference between nutrient uptake at end date and start date for sampling period by the number of days in the sampling period.

Results and Discussion

Total dry matter accumulation and nutrient uptake

Averaged whole plant biomass (dry weight basis) was 7645 lb ac^{-1}, ranged between 5,240 and 12,950 lb ac^{-1} for individual plots (Table 1, Figure 1). Roots, tops, and umbel portions represented 7, 65, and 28% of total biomass accumulation at crop maturity, respectively. Averaged whole plant uptake for N, P_2O_5, K_2O, S, Ca, Mg, and Na was 123, 31, 204, 14, 94, 34, and 23 lb ac^{-1}, respectively. Mean whole plant Zn, Fe, Mn, Cu, and B uptake was 0.14, 1.79, 0.37, 0.03, and 0.27 lb ac^{-1}, respectively. At crop maturity, nutrient removal or total umbel nutrient uptake, followed the order: N > K_2O > Ca > P_2O_5 > Mg > S > Na > Fe > Mn > B > Zn > Cu. Nutrient uptake by roots and tops, or nutrient carryover in crop residue, was as follows: K_2O > N > Ca > Mg > Na > P_2O_5 > S > Fe > Mn > B > Zn > Cu. Potassium carryover was considerable at an average of 150 lb ac^{-1} K_2O, which would be available for uptake by the following crop. Nitrogen carryover was noticeably lower compared to K, with an average of 63 lb ac^{-1} N remaining in the roots and tops tissue after harvest.

Seed yield and nutrient uptake

Seed biomass weight (dry weight basis) at harvest represented only 3% of the total aboveground biomass (tops + umbels) (Tables 1, 2). Mean seed yield (dry weight basis) was 222 lb ac^{-1} ranging between 151 and 324 lb ac^{-1} over the eight individual plots of the two fields (Table 2). The highest mean seed nutrient uptake was for N (7 lb ac^{-1}), followed by Ca (6 lb ac^{-1}) and K (4 lb K_2O ac^{-1}). Averaged seed nutrient concentration was 3.0, 0.5, and 1.6% for N, P, and K, respectively. Approximately 8-9% of P and Zn in the plant were concentrated in the seed at harvest in comparison to 1-7% for other nutrients, indicating that maintaining sufficient levels of P and Zn in the soil may be important for seed development.

Whole plant nutrient uptake by season

In-season nutrient accumulation was divided into three growth stages (Table 3): 1) Initial establishment and winter/early spring dormancy stage (October to April); 2) Vegetative stage (April to late May); 3) Flowering and seed production stage (late May to August). During these growth stages plants accumulated biomass and nutrients as follows:

Initial establishment and winter/early spring dormancy. Plants accumulated only 5% of total biomass (Tables 1, 3). Plants took up 3 to 7% of plant nutrients during this period, with the notable exception of Cu where 15% of total uptake occurred during this period.

Vegetative stage. Plants accumulated approximately 11% of total biomass and took up 10 to 23% of the total nutrients during this stage (Tables 1, 3). The uptake of N, K, Zn, and Fe was the greatest with a range of 17-21% of total uptake, while only 11-16% of total P, S, Ca, Mg, Na, Mn, Cu, and B uptake occurred during this period.

Flowering and seed production - the period of greatest biomass production and nutrient uptake. Plants accumulated approximately 84% of biomass produced (Tables 1 and 3). Total uptake of 72 to 84% for all nutrients occurred during this stage. Uptake of P, S, Mg, Ca, and B at the high end, ranged from 80 to 84%. Peak nutrient uptake rate (lb nutrient^{-1} ac^{-1} day^{-1}) occurred around June 10 for all nutrients except for Fe, where peak uptake occurred on July 13 (Table 4).

Partitioned nutrient uptake by season
Patterns of nutrient uptake for K, Ca, and Mg in the root, tops, and umbels similar to patterns observed for in-season biomass accumulation (Figures 1, 2).

In contrast, in-season Na, Fe, and Cu uptake patterns differed dramatically from dry matter accumulation during specific growth periods (Figures 1, 3). Root uptake of Na and Fe during the growth period of 23 Apr. 2018 to 26 June 2018, increased 9.3-fold and 5.1-fold, respectively, compared to the previous growth period of 20 Oct. 2017 to 23 Apr. 2018. During the same time period, root uptake for all other nutrients only increased by 2.5-fold to 3.5-fold. The reason for increased root uptake of Na and Fe during the vegetative growth period in May and June is not understood. Copper accumulations differed from other nutrients, with 22% of total Cu taken up by the plant at the initial 20 Oct. 2017 sampling event, and 77% of the Cu concentrated in the tops portion of the plant. In comparison, plants had accumulated only 3% of total biomass by that time. Based on these findings, Cu appears to be important for initial vegetative growth and development.

Conclusion

These data may be used to inform and refine fertilizer rates and fertility practices in Nantes-type hybrid carrot seed production in Central Oregon, and in similar temperate irrigated production regions.
For extended report, see: *Moore, A.D., Spring, J.F., Jeliazkova, E.A., Wilson, T.L. Seasonal nutrient partitioning and uptake in hybrid carrot seed production. Agronomy Journal. 2021; 113: 1934– 1944.* https://doi.org/10.1002/agj2.20503.

Seasonal nutrient partitioning and uptake in hybrid carrot seed production | Agronomy Journal

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Western Regional Climate Center. (2019). Madras Oregon (355139). Western Regional Climate Center. Retrieved from https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?or5139

Table 1. Biomass accumulation and nutrient uptake in Nantes-type hybrid carrot at crop maturity in Madras, Oregon, averaged across two fields and four replications per field.

Plant Parameter	Root	Tops	Umbel	Whole Plant
	------ lb ac^{-1} ------			
Biomass	568	4970	2107	7645
N	4.4	58.8	59.6	122.7
P_2O_5	2.2	15.2	13.7	31.2
K_2O	11.5	140.4	52.4	204.3
S	0.5	6.6	7.1	14.1
Mg	2.1	20.1	11.6	33.9
Ca	2.9	55.3	35.9	94.1
Na	3.9	16.6	2.2	22.7
Zn	0.01	0.05	0.08	0.14
Fe	0.4	0.92	0.47	1.79
Mn	0.02	0.19	0.16	0.37
Cu	0.002	0.02	0.01	0.03
B	0.01	0.13	0.14	0.27

Note: Tissue nutrient concentration percent can be calculated by dividing nutrient uptake (lb ac^{-1}) by biomass accumulation (lb ac^{-1}) and multiplying by 100.

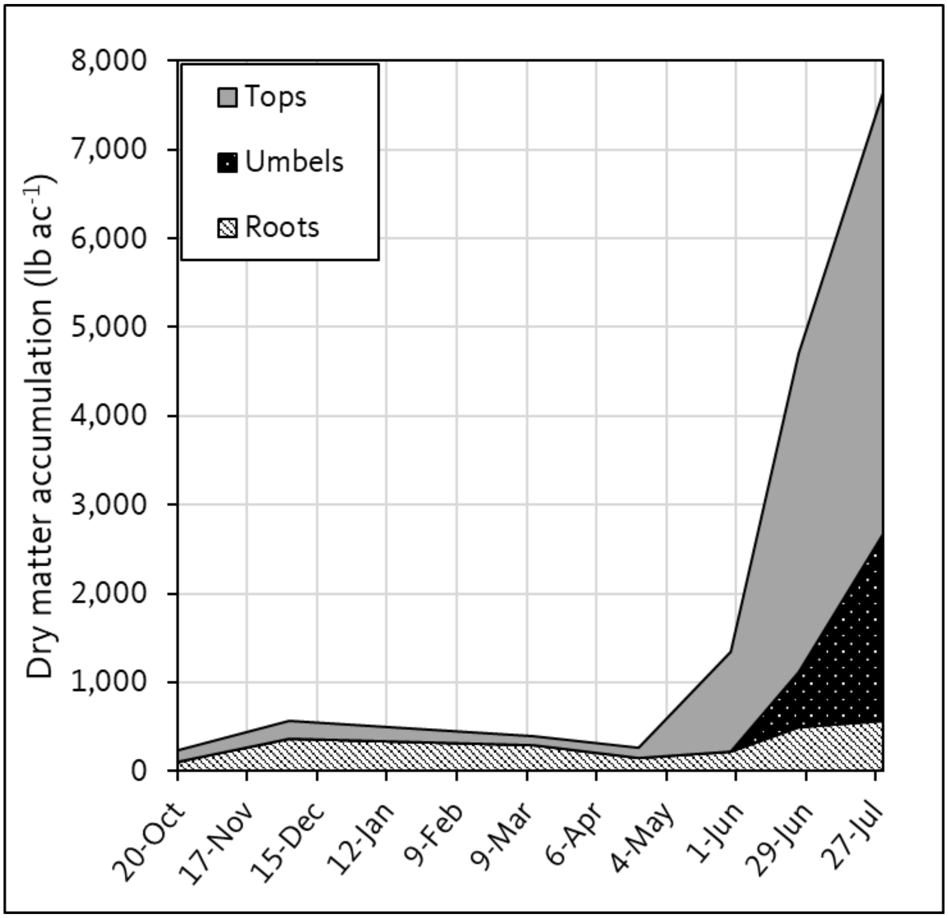

Figure 1. In-season dry matter accumulations in Nantes-type hybrid carrot produced for seed in Madras, Oregon. Data collected from four replicated plots within two commercial carrot production fields on Madras silt loam over the 2017-2018 production cycle.

Table 2. Clean seed biomass accumulation and nutrient uptake for Nantes-type hybrid carrot in Madras, Oregon, averaged across two fields and four replications per field. Biomass values and seed nutrient uptake listed on a dry weight basis.

Plant Parameter	Seed Nutrient Concentration	Clean Seed Uptake	Harvest & Nutrient Index
	------- % -------	------- lb ac^{-1} -------	
Biomass	NA*	222	0.03
N	3.1	7.0	0.05
P_2O_5	0.5	2.5	0.08
K_2O	1.6	4.3	0.02
S	0.4	0.9	0.06
Ca	2.7	6.2	0.06
Mg	0.8	2.1	0.06
Na	0.08	0.2	0.01
	------- mg kg^{-1} -------	------- lb ac^{-1} -------	
Zn	46	0.010	0.00010
Fe	210	0.050	0.00003
Mn	95	0.020	0.00010
Cu	8	0.002	0.00010
B	57	0.010	0.00004

*NA = Not applicable

Table 3. Mean biomass accumulation and nutrient uptake in Nantes-type hybrid carrots in Madras, Oregon over three growth stages.

Plant Parameter	Winter Dormancy (Oct. – Apr.)	Vegetative (Apr. – May)	Flowering and Seed Set (June – Aug.)
	--------------------------- lb ac^{-1} -------------------------		
Biomass	398	809	6,177
N	8.0	24.1	112.1
P_2O_5	1.9	4.4	25.4
K_2O	12.6	40.2	178.1
S	0.6	2.3	12.6
Ca	2.8	12.1	75.1
Mg	1.3	5.2	27.7
Na	0.7	3.8	20.2
	--------------------------- lb ac^{-1} -------------------------		
Zn	0.009	0.029	0.120
Fe	0.130	0.423	1.436
Mn	0.015	0.062	0.301
Cu	0.006	0.006	0.030
B	0.009	0.029	0.214

Table 4. Maximum daily biomass accumulation and whole plant nutrient uptake rates in Nantes-type hybrid carrot type in Madras, Oregon. Range represents the highest and the lowest value for individual plots during the period of maximum accumulation.

Plant Parameter	Day and Month	Maximum Accumulation Rate	
		Mean	Range
		------------- lb ac^{-1} day^{-1} -------------	
Biomass	10 June	117	44-203
N	10 June	2.1	0.6-4.0
P_2O_5	10 June	0.4	0.2-0.7
K_2O	10 June	2.9	1.0-6.1
S	10 June	0.2	0.1-0.5
Ca	10 June	1.2	0.5-2.1
Mg	10 June	0.4	0.2-0.7
Na	10 June	0.4	0.2-0.6
Zn	10 June	0.002	0.0010-0.004
Fe	13 July	0.020	0.0080-0.030
Mn	10 June	0.004	0.0040-0.005
B	10 June	0.004	0.0010-0.006
Cu	10 June	0.001	0.0001-0.002

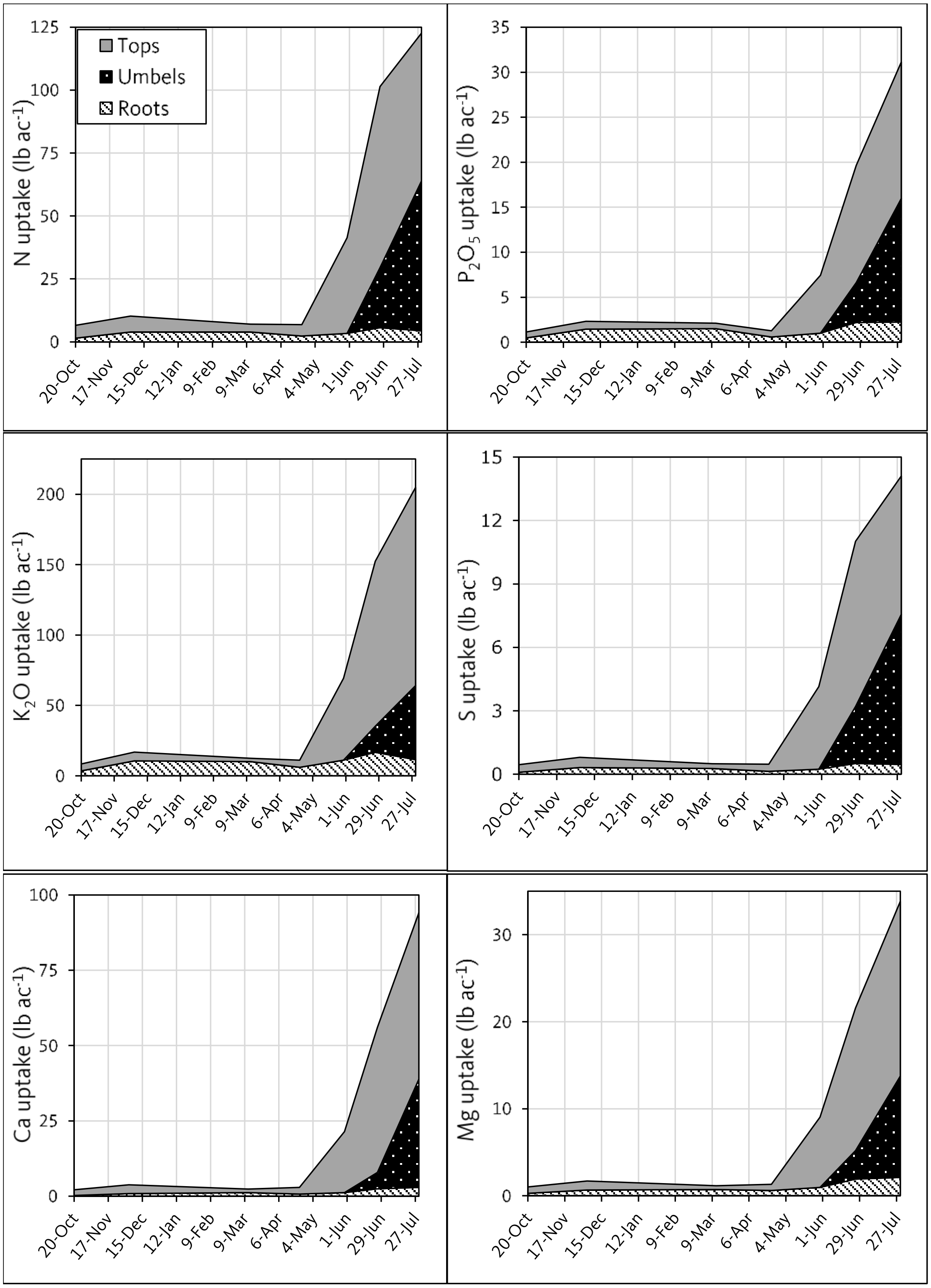

Figure 2. In-season N, P, K, S, Ca, and Mg uptake in Nantes-type hybrid carrot produced for seed in Madras, Oregon. Data collected from four replicated plots within two commercial carrot production fields on Madras silt loam over the 2017-2018 production cycle.

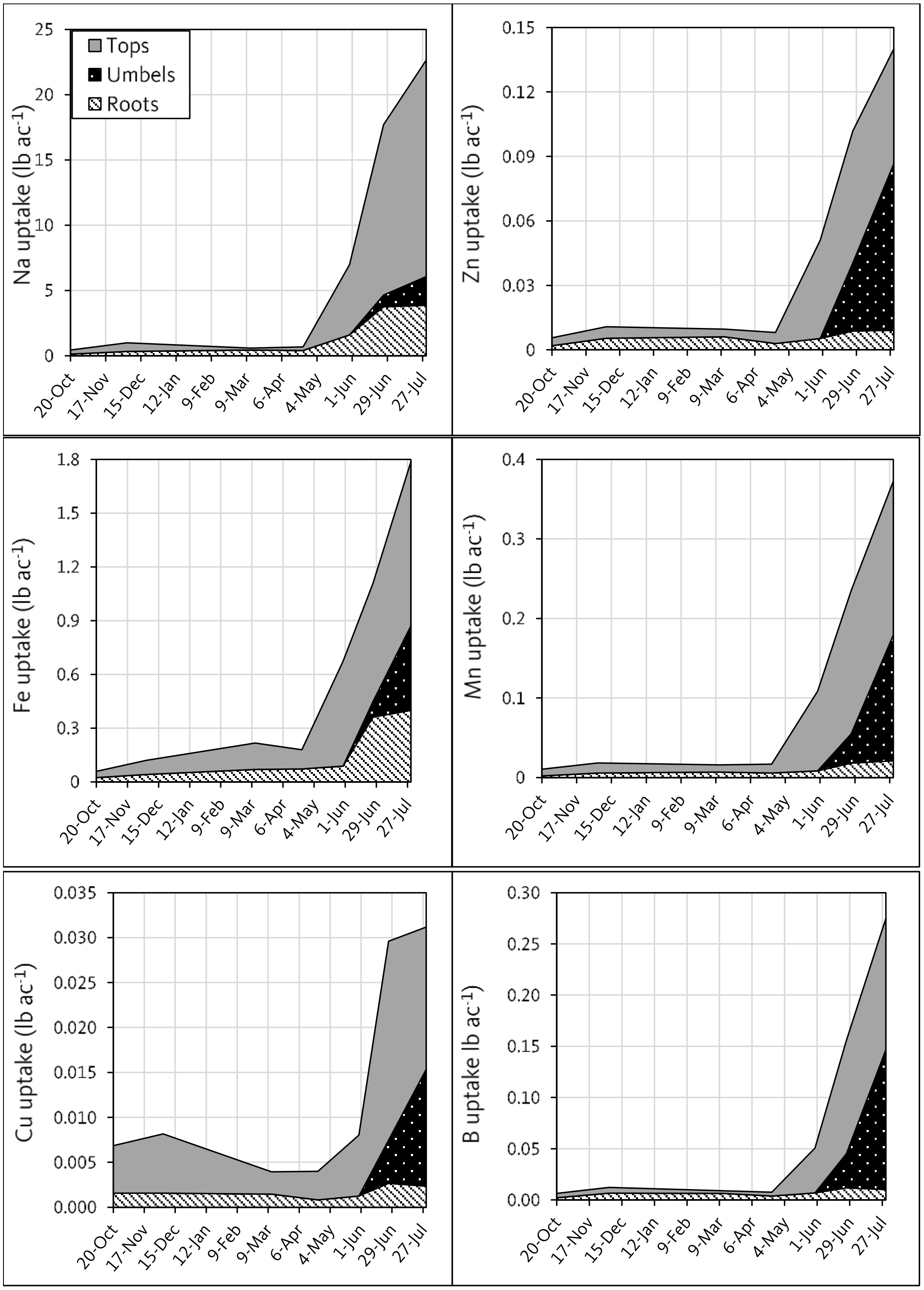

Figure 3. In-season Na, Zn, Fe, Mn, Cu, and B uptake in Nantes-type hybrid carrot produced for seed in Madras, Oregon. Data collected from four replicated plots within two commercial carrot production fields on Madras silt loam over the 2017-2018 production cycle.

Control of Volunteer Kentucky Bluegrass in Winter Wheat

John Spring

Introduction

With limited irrigation water in central Oregon, late-fall planting of winter wheat without fall irrigation has been a common practice, relying on fall precipitation to germinate the wheat. In fields rotating out of Kentucky bluegrass, the inability to pre-irrigate prior to tillage for residue preparation or before wheat planting for weed control – both fairly common practices until recently – has increased the potential amount of volunteer Kentucky bluegrass (as well as cheatgrass, rattail fescue, and other winter annual weeds) that must be controlled in the wheat crop. While efficacy of common herbicides used in wheat for control of grassy weeds is well known for cheatgrass and rattail fescue, very little information is available on the performance of these options for control of volunteer Kentucky bluegrass.

Additional complications arise from the very late emergence of winter wheat in this planting pattern in most years, and from the use of wheat as a risk-reduction strategy against future water uncertainty. Many grass-active herbicides for use in wheat have a fairly narrow window of application relative to crop development (often no later than jointing), and before weeds get too large (with control of most species declining rapidly when they exceed a few leaves in size). In early fall-planted wheat, this window occurs in mid-fall, and the decision to use or not use an herbicide is made in then. In late-emerging wheat, however, the early part of this crop-stage application window often occurs at the very end of the growing season in the fall, followed by a winter pause, and the later end of the window allows applications to be made again in early spring the following year. For cheatgrass control, it has been well documented that fall applications generally outperform spring applications, but this has not been tested for volunteer Kentucky bluegrass. Additionally, the versatility of wheat allows for many acres to be planted at relatively low cost, and only committed to a final end-use the following spring, when better information is available regarding water allotments and precipitation patterns. In years with low water allotments and poor natural precipitation, the wheat can be used as a cover crop to provide soil protection and weed suppression in dry fallow with no further inputs. In years with low water allotments but adequate spring precipitation (such as 2022), harvest of limited-input grain hay may be profitable. In the scenario of larger-than-expected water allotments and favorable prices, some of these already established wheat acres could be dedicated to fully irrigated hay or grain production. In two of these three scenarios, fall application of grass active herbicides would likely be unnecessary, and represent poor return on investment. Thus, from a risk perspective, spring applications are more attractive, provided they are agronomically effective on target weeds.

The objective of this trial was to compare the efficacy of Powerflex HL, Olympus, Osprey, Varro, and Axial XL applied in late fall or early spring, and Zidua SC applied in the fall for control of volunteer Kentucky bluegrass in rainfed, late-planted winter wheat following Kentucky bluegrass in central Oregon conditions.

Materials and Methods

Field trials were conducted in two fields over the 2021-22 growing season (one near Madras on Agency Plains, Field 1, and one near Culver, Field 2). Both fields were in irrigated Kentucky bluegrass production for the 2019-21 crop years. Fields received their last irrigation for the season in June 2021 prior to bluegrass harvest. Straw was baled, and residue prepared for wheat planting with conventional tillage of dry soil in summer/fall. Winter wheat was drilled in early November in both fields, and volunteer bluegrass and wheat emerged together by mid-November. Both fields received irrigation in the spring, with Field 1 harvested as grain hay, and Field 2 harvested for grain. Trials were arranged in a randomized complete block design with 4 replicates and individual plot size of 10x30 feet. Herbicide applications were made by C02 powered hand boom in 15 gpa in coarse droplets. Fall herbicide applications were made with wheat at 3 leaf stage and KBG at 2-3 lf stage on 11/30/21. Spring applications were made 3/23/22 with wheat at Feekes 4.0 (tillered, at onset of active growth in spring), and KBG with 2 to 3 tillers. Kentucky bluegrass control was evaluated visually at several times over the growing season on a percent scale from 0 to 100%, (with no injury at 0 and complete plant death at 100). Kentucky bluegrass aboveground biomass was harvested from two 2.7ft^2 quadrats per plot during the summer. Field 1 biomass was harvested 5/27/22 prior to field swathing, and Field 2 biomass harvested 7/1/22, just prior to the onset of crop drying towards maturity.

Results and Discussion

Several of the products tested provided acceptable – if not complete – control of volunteer Kentucky bluegrass (KBG). Effect of application timing (fall vs spring) was variable by product in these trials, with some providing better activity when applied in the fall, and others in spring. Combinations of treatments (one fall and one spring, or one pre-emergence and one early postemergence) would likely improve control dramatically if warranted by intended use of the crop and a need to completely control volunteer KBG, but were not tested in this trial. <u>It is important to note that many of these products have lengthy rotational restrictions, which should be fully understood and considered carefully prior to use to avoid damage to high-value rotational crops, and/or potential label violations.</u>

Zidua (pyroxasulfone, also found in Anthem Flex for use in wheat) did not completely kill volunteer KBG (as reflected in moderate % control ratings), however, it did heavily suppress the growth of plants that did survive, and KBG biomass at harvest was greatly reduced at harvest at both sites. It is primarily a soil active, pre-emergence herbicide, and labelling is restricted to pre-plant or early post-emergent applications only, so it was not tested in the spring. Zidua differs from the rest of the products tested in having good activity on rattail fescue, although it is usually marginal for control of downy brome. If the weed spectrum in a field is expected to include rattail fescue as well as volunteer KBG, and odds of keeping the field through harvest are high, a Zidua application is worth considering. Zidua can also be applied post-plant-pre-emergence to the wheat crop, which is essential for good activity when targeting rattail fescue, and will likely improve KBG control as well. Rotational restrictions vary considerably depending on the following crop, but intervals are workable for many crops.

Powerflex (pyroxsulam) was much more effective when applied in the fall than in spring, as is usually true for downy brome control as well. Fall applications provided moderate control to visual evaluation, but KBG biomass was meaningfully reduced relative to the nontreated check at both sites. Spring applications provided suppression only, and cannot be recommended. Of the products tested, Powerflex is considered by many as the best option in terms of efficacy on downy brome. Rotational intervals are generally 10 to 12 months depending on crop, which may be problematic in many fields in central Oregon.

When applied in the fall, Olympus (propoxycarbazone) was the most effective product evaluated for control of volunteer KBG, reflected in high control values for visual evaluation in late spring, and in almost complete reduction of KBG biomass production at both sites. Spring applications provided suppression only. Crop rotation considerations may preclude use of Olympus in most central Oregon systems, however. Intervals for the few specified crops on the Olympus label are quite lengthy (most 12-22 months), and for most crops grown in central Oregon label language requires a field bioassay be completed before planting.

At Site 1, fall application of Osprey (mesosulfuron) provided suppression only. Performance in the spring was much better, where it provided moderate levels of KBG control and biomass reduction. At Site 2, spring applications provided a negligible gain in activity over fall, but neither did more than suppress volunteer KBG. Rotation intervals with Osprey are 10 months to most central Oregon crops.

Varro is a product intended primarily for control of green foxtail and wild oat in the central and northern Plains wheat markets. The active ingredient of Varro (thiencarbazone) is premixed with mesosulfuron (Osprey) in Osprey Xtra, however, which is available in the PNW, and was included to provide a separate test of each component of Osprey Xtra in these trials. (Active ingredient rates used in this trial are identical between Osprey and Osprey Xtra, and for the rate of Varro tested and that in Osprey Xtra.) Fall applications of Varro were more effective than spring, with spring applications resulting in suppression at Site 1, and very little effect at Site 2. Fall applications provided good suppression of KBG at Site 1, and moderate to good suppression at Site 2. Thus, if used in the fall, Osprey Xtra is presumed likely to provided somewhat better suppression of volunteer KBG than Osprey, although this was not directly tested. Osprey Xtra labelling does require a bioassay before rotation to crops not listed (included KBG and vegetable seed), so consider crop sequences carefully prior to use.

Performance of Axial XL (pinoxaden) varied by site, but appeared to offer a workable option for KBG control. At Site 1, spring applications provided better control than fall applications to visual evaluation, but levels of KBG biomass reduction were equivalent between treatments, and generally good. At Site 2, fall applications provided slightly better control and higher suppression of KBG biomass than spring applications. Axial is not active on downy brome or rattail fescue, but does provide good activity on wild oats, green foxtail, and several other grassy weeds with a more spring-oriented emergence pattern. As Axial is allowable for application to wheat as late as flag leaf (much later than other products tested in this trial), and has negligible rotational restriction, it may be best positioned as a spring application, either as a follow-up to a fall application, or as a stand-alone option in crops in which the decision to keep until harvest is made later in the spring.

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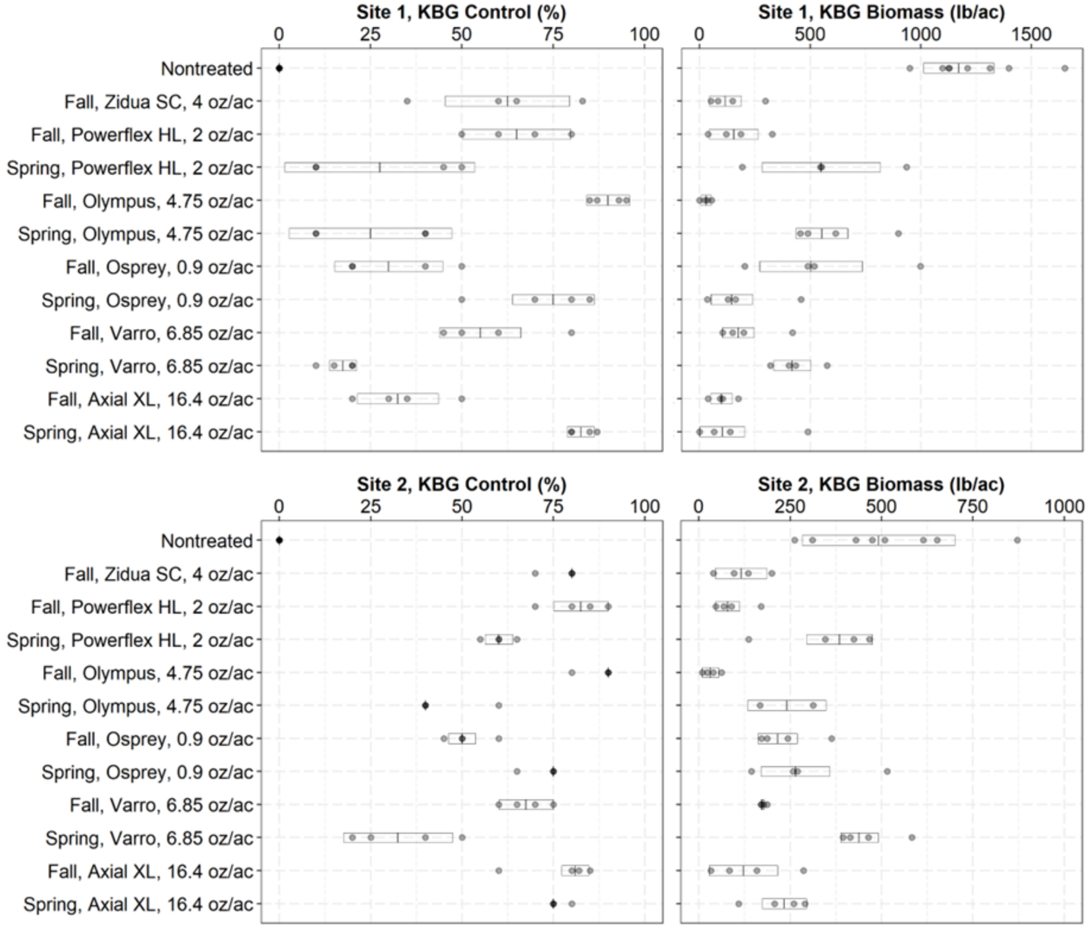
Figure 1. Control of volunteer Kentucky bluegrass in late-planted, irrigated winter wheat at the end of May (9 weeks after spring applications), and Kentucky bluegrass biomass immediately prior to grain hay harvest (Site 1, 5/27/21) or just prior to beginning of crop dry-down (Site 2, 7/1/21). Control estimated visually on a percent scale from 0 to 100 (with no injury at 0 and complete plant death at 100). Points represent individual plots, bars show raw median average deviation of the mean, with middle line indicating treatment median value.



Glyphosate Rate and Timing Effect on First Cut Roundup Ready Alfalfa

Mylen Bohle, Jennifer MacAdam, Steve Orloff, Mike Knepp, Hoyt Downing, and Steve Fransen

Introduction

During crop year 2016, at least sixteen Roundup Ready alfalfa fields in Crook, Deschutes, Jefferson, and Lake counties in Oregon, had symptoms on first cutting that were surmised to be from the application of glyphosate. There were signs of stunting, chlorosis and/or the "shepherd's crook" of the top portion of the alfalfa plant. Steve Orloff, Farm Advisor with University of California Cooperative Extension at Yreka, CA, early on noticed fields in northern California which showed similar symptoms after spring glyphosate applications. He also documented yield losses in previous years, and subsequently in other states. It was hypothesized that following frost events after glyphosate application were thought to have a negative effect on alfalfa. A field trial was established in the Christmas Valley, Oregon area to document the effect of glyphosate on alfalfa at two different rates at two different timings for phenotypic symptoms and changes in yield and quality.

Materials and Methods

The alfalfa field was planted to Integra 8444R cultivar at 26 lb/ac in late summer 2014 at the James Warkentin Farm, about 5 miles north and east of Christmas Valley. Field elevation is approximately 4330 feet. The field is irrigated by a mid-elevation sprinkler application pivot. The field has been sprayed, annually, with glyphosate since establishment. Soil samples (0-12-inch) were taken on November 3, 2011, and analysis was performed by Soiltest Farm Consultants, Moses Lake, WA. Soil test results are in Table 1. Fertilizer applied in the Spring of 2016 included an application of 200 lb/ac of 12-40-0-10, 35 lb/ac of 0-0-62, and 35 lb/ac elemental sulfur. The trial was laid out as a randomized complete block design with 4 replications, which straddled the second to last outside pivot tower. One set of pivot wheel tracks went through all the plots in the third replication, equally. The plots were 10 ft x 20 ft.

Herbicide treatments included an untreated check, glyphosate at 22 oz./ac, and glyphosate at 44 oz./ac acid equivalents (a.e), with two different timings, applied on April 28 (4-inch plant height) and May 9 (8-inch plant height); 5 oz/ac a.e. Raptor (a labeled herbicide for post-emergence control / suppression of broadleaved, grassy and sedge weeds in alfalfa) was applied on May 9. Application was made with 20 gal/ac city of Prineville water with a garden backpack sprayer. April 28 application was made between 1:00 – 2:00 pm with a very light breeze, on a cloudy day (target height was 3-6 inches) and temperature was 57 degrees F when finished. May 9 application was made between 8:30 to 9:30 a.m. with a very light breeze, on a sunny day (target height was 6-12 inches) and temperature ranged from 42 degrees F to 55 degrees F, from start to finish of application. Alfalfa plant heights were measured at time of herbicide application and the weeds present in the check plots identified and are presented in Table 2. Daily low air temperatures (degrees F), from the Christmas Valley Agrimet weather station, prior to and after herbicide application dates, are in Table 3. Cumulative growing degree days (GDD's) from January 1 on various dates until the day of harvest are in Table 4.

Alfalfa plant heights (inches) were measured on June 9. Harvest was on June 21, 2016 with a sickle bar forage harvester. Harvest area was 52.5 square feet (3.5 feet width x 15 feet) with every plot length measured. The ½-1-pound fresh weight sub-samples were weighed in the field with a portable Scout scale. The samples were transported to the COAREC, and oven dried at 149 degrees F till no change in weight and weighed. Dry matter and moisture percentage were calculated to determine dry matter yields which are presented on an oven dry matter basis. Forage quality was determined in 2022 by NIRS at Utah State University, Logan. Genstat 21.1 version was used for statistical analysis. Significant differences are based on PLSD 0.10, although PLSD 0.05 is also presented.

Table 1. Soil test results from November 3, 2011, based on Varis soil testing program at the James Warkentin Farm, Christmas Valley, Oregon.

Soil Depth (inches)	CEC Meq/100g)	Ca (ppm)	SS (mmhos cm $^{-1}$)	P (ppm)	pH	Na (ppm)	Mg (ppm)	K (ppm)	EC (dS/m)
0-9	11.0	1962	0.88	4	8.0	424	264	334	0.34

Table 2. Integra 8444R Roundup Ready alfalfa cultivar plant height (inches) of the check plots on the two dates of application of Glyphosate and Raptor at the James Warkentin Farm, Christmas Valley, Oregon, in 2016.

Herbicide Application Date	R I		Rep II		Rep III		Rep IV		Mean		Grand Mean
	Sub Plot Measurements										
	1	2	1	2	1	2	1	2	1	2	
	Plant Height (inches)										
April 28	6.5	5.25	5.0	6.5	4.75	4.0	3.75	7.5	5.0	5.8	5.4
May 9	9.0	6.0	7.5	9.25	8.0	8.25	8.5	8.0	8.3	7.9	8.2
Very Minor Weeds present in plots	Cheatgrass		Jagged Chickweed		None Detected		Tansy Mustard				

Table 3. Daily low temperature (degrees F) at the Agrimet Weather Station at Christmas Valley, Oregon, prior to and after application of herbicide treatments on April 8 and May 9 on Integra 8444R Roundup Ready alfalfa cultivar at the James Warkentin Farm, Christmas Valley, Orgon in 2016.

	April															
Date	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
Temp F	*21*	*25*	*26*	*31*	*20*	*22*	*28*	*31*	*36*	*35*	*29*	*42*	*30*	*30*	*25*	
Date	16	17	18	19	20	21	22	23	24	25	26	27	**28**	29	30	
Temp F	*19*	*23*	*25*	*28*	*30*	*30*	*37*	*29*	*32*	*26*	*14*	*33*	***30***	*30*	*29*	
	May															
Date	1	2	3	4	5	6	7	8	**9**	10	11	12	13	14	15	
Temp F	*24*	*26*	*35*	*46*	*42*	*43*	*52*	*38*	***33***	*23*	*23*	*31*	*30*	*29*	*39*	
Date	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Temp F	*36*	*30*	*36*	*36*	*33*	*32*	*32*	*32*	*32*	*38*	*31*	*30*	*26*	*35*	*29*	*32*

Temperature (Fahrenheit) were rounded to the nearest whole number.

Table 4. Cumulative growing degree days (GDD's) from January 1, 2016, based on 41-degree F base temperature from the Agrimet Weather Station located at Christmas Valley, Oregon (4360 feet Elevation).

	March 31	April 28	May 9	June 2	June 21
GDD's	63	229	337	565	835

Results and Discussion

Glyphosate rate and timing effect on Roundup Ready alfalfa yield, dry matter and moisture content, plant height on June 2, and chlorosis score are in Table 5. Selected analyte quality and nutrient results are presented in Table 6.

The damage caused by glyphosate is very similar to bacterial stem blight disease. It is believed that there may be a negative association between frost, RR alfalfa taller than 6-inches when glyphosate is applied, and alfalfa is infected with bacterial stem blight. The temperature dropped below 32 degrees F for 4 out of 5 days prior to and four consecutive days after the April 28 application date at the Warkentin farm. The temperature did not drop below 32 degrees F for 6 days prior to the May 9 application. While it is not known how many days after the application for sure, we surmise that the temperatures did drop below freezing for 5 days after application, based on the Agrimet weather station at Fort Rock, some 20 + miles away at similar elevation (see Table 3).

There was a significant yield decrease (0.3 t/ac) for the glyphosate rate of 44 oz/ac (high rate) applied on May 9, Table 5, compared to the other treatments.

It is also interesting that a significant difference in dry matter and moisture percentage for the high rate applied on May 9. The DM and moisture were lower than the check and the 22 oz/ac rate applied on May 9.

The 44 oz/ac rate applied on both dates had significantly higher chlorosis scores than the check and 22 oz/ac rates. Raptor, with a similar score as the 44 oz/ac rates, also had a significantly higher chlorosis score than the check and 22 oz rates at both height applications.

The soil pH of 8.0 might have been another contributing factor to the yield reduction since it is one unit above 7.0. Soil phosphorus was 4 ppm in 2014, annual fertilizer applied may or may not have taken care of the P deficiency (alfalfa needs a soil P test of 20 ppm for optimal production).

The Roundup Ready cultivar could play a role in the injury depending upon how resistant it was to bacterial stem blight. An initial screening of alfalfa cultivars with Fall Dormancy (FD) 2-4 were determined to have better resistance to bacterial stem blight than other FD's in general. Integra 8444R is a FD 4, but still suffered some injury and yield reduction from the high rate of glyphosate application at a height of 8-9 inches.

Table 5. Glyphosate rate and timing effect on Integra 8444R Roundup Ready alfalfa cultivar yield, dry matter, moisture, plant height (June2), and chlorosis score at the James Warkentin farm, Christmas Valley, Oregon in 2016.

Treatment Herbicide/ Rate / Plant Height*	Application Date	Yield (t/ac)	DM (%)	Moisture (%)	June 2 Plant Height[1] (in)	Chlorosis Score (1-10)[2]
Check	--	2.36	24.1	75.9	14.8	1.50
Glyphosate 22 oz. 4-inch	Apr. 28	2.28	23.7	76.3	14.8	2.00
Glyphosate 44 oz. 4-inch	Apr. 28	2.34	23.8	76.2	14.1	3.50
Glyphosate 22 oz. 8-inch	May 9	2.23	24.4	75.6	15.7	2.25
Glyphosate 44 oz. 8-inch	May 9	2.06	22.8	77.2	15.8	3.75
Raptor 5 oz. 8-inch	May 9	2.31	23.4	76.6	15.1	3.50
Mean		2.26	23.7	76.3	15.0	2.75
Prob. > F		0.032	0.096	0.096	0.116	0.059
PLSD 0.10		0.15	0.9	0.9	NS	1.4
PLSD 0.05		0.185	NS	NS	NS	NS
CV%		5.4	3.0	0.9	5.8	41.6

*Plant Height goal. [1] Mean of 4 measurements per plot. [2] Chlorosis score 1 = none, 10 = 100%.

There were no differences between treatments for most of the forage quality analytes (Table 6.). Most key forage quality analytes crude protein, ADF, aNDF, RFV, and RFQ, were not statistical different among treatments. However, at the 22 oz/ac rate of glyphosate and 8-inch height application, alfalfa had the lowest IVT DMD48 result, but not the 44 oz/ac at 8-inch application, which yielded less than all other treatments. There were no statistical differences between these two treatments. The 22 oz/ac rate at 8-inch height IVT DMD48 was significantly lower than the 22 and 44 oz/ac at 4-inch height application.

For potassium concentration, the check was significantly higher than all other treatments except for the 22 oz/ac glyphosate rate at 4-inch height application . *Note: This is NIRS K%, so it may or may not be a real difference; since there were no traditional lab tests to confirm for nutrient concentration.*

For starch, the check has the highest concentration was significantly higher than the 22 oz/ac and 44 oz/ac glyphosate rate at 4-inch height and Raptor treatment at 8-inch height. The 22 oz and 44 oz/ac rate at 8-inch height was significantly higher than the 22 and 44 oz/ac rate applied at 4-inch height and 5 oz/ac Raptor at 8-inch height. This result is important because alfalfa stores and uses starch for regrowth and winter survival.

For protein yield, the check, 22 and 44 oz/ac rate at 4-inch height, and Raptor at 8-inch were the same; the 22 and 44 oz/ac rate at 8-inch height treatments were lower, and statistically the same yield. But the 22 oz/ac rate at both 4- and 8-inch height were the same.

Conclusion and Recommendation

In another Roundup Ready alfalfa trial, "The effects of glyphosate rate and application timing were investigated at 24 sites over five years, measuring the impact on alfalfa crop height and yield {in California, Utah, and Oregon}. Glyphosate applications were made during various seasons. Summer glyphosate applications did not injure alfalfa. Spring applications reduced crop height at 76% of the sites and biomass yield at 62% of the sites. At responsive sites, low (869 g ha-1 a.e. or 12.4 oz/ac a.e.) and high (1739 g ha-1 a.e. or 24.8 oz/ac a.e.) rates reduced yield by 0.53 (0.58 t/ac) and 1.06 Mg ha-1 (1.16 t/ac), respectively. Alfalfa treated with a high rate when 15-20 cm (5.9-7.9 inches) tall had mean yield reductions of 16-17% compared with untreated alfalfa". (Loveland 2020)

"Three variables were significant predictors of glyphosate injury: soil pH, glyphosate rate, and the number of days with sub-zero centigrade (sub 32 degrees F) temperatures post-dormancy before glyphosate application. Predicted yield reduction from a one-unit increase in soil pH was 0.60 Mg ha-1 (0.66 t/ac). Each extra day of crop exposure to sub-zero centigrade (sub 32 degrees F) temperatures before glyphosate application, increased the odds that glyphosate injury would occur by 13%."

It appears that once a Roundup Ready alfalfa cultivar, which is susceptible to bacterial stem blight, is taller than 6-inches, in a field with a higher soil pH and low phosphorus fertility (approximately 4 ppm), and with daily frost events after glyphosate application, then there is the strong possibility of injury based on this and research in California, Utah, and central Oregon. (Loveland 2020) Our results show that the frost events occurred before and after the application of glyphosate and may have caused the yield reduction, and or may also have been an interaction with the 8.0 soil pH.

When applying glyphosate to Roundup Ready alfalfa, it is a best management practice to apply the lowest rate on the label, depending upon weed species present, to alfalfa that is less than 6 inches tall. Monitor soil pH and phosphorus, so they are not another set of negative factors affecting yield. Follow the label instructions.

Table 6. Glyphosate rate and timing effect on Integra 8444R Roundup Ready alfalfa cultivar selected variate quality at the James Warkentin farm, Christmas Valley, Oregon in 2016.

Treatment Herbicide/ Rate / Plant Height*	Application Date	Crude Protein (%)	ADF (%)	aNDF (%)	RFV	RFQ	Ash (%)	IVT DMD48 (%)	K (%)	Starch (%)	Protein Yield (lb/ac)
Check	--	22.7	29.4	33.6	183	191	9.38	82.3	2.69	1.00	1070.6
Glyphosate 22 oz. 4-inch	Apr. 28	22.9	28.3	32.2	193	206	8.93	83.4	2.67	0.75	1046.7
Glyphosate 44 oz. 4-inch	Apr. 28	23.3	28.3	31.8	196	210	8.79	83.7	2.60	0.78	1094.1
Glyphosate 22 oz. 8-inch	May 9	22.2	29.4	33.9	183	190	8.53	81.8	2.56	0.97	988.9
Glyphosate 44 oz. 8-inch	May 9	22.7	29.0	32.9	188	200	8.41	82.7	2.57	0.88	932.3
Raptor 5 oz. 8-inch	May 9	23.0	29.2	33.3	185	194	8.70	82.4	2.61	0.76	1064.9
Mean		22.8	28.9	32.9	188	198	8.79	82.7	2.62	0.85	1032.9
Prob. > F		0.608	0.500	0.486	0.490	0.220	0.042	0.087	0.096	0.058	0.012
PLSD 0.10		NS	NS	NS	NS	NS	0.48	1.16	0.08	0.16	72.2
PLSD 0.05		NS	NS	NS	NS	NS	0.59	NS	NS	NS	87.8
CV%		4.0	3.6	5.1	6.2	6.5	4.4	1.1	2.6	15.3	5.6

[*] Plant height application goal.

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Basal and Flag Leaf Nitrogen Rate Effect on Hard Red Spring Wheat Grain Nutrient Concentration and Uptake in Central Oregon

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Russ Karow, Ernie Marx, and Tom Shibley

Introduction

There is insufficient data available on hard red grain nutrient concentration and uptake in Central Oregon. Alfalfa, grass, and cereal hay crops are harvested for their vegetative biomass which removes great amounts of nutrients from the fields, while cereals for grain leave behind the straw, and constituent nutrients. However, how much of the nutrients are removed by hard red spring wheat grain? Nutrient concentration is important for human health as hard red spring wheat is primarily consumed as bread. It also can be utilized for livestock feed if the grain does not meet quality standards for human food. Some have questioned that food commodities no longer have the "nutrition" or nutrient density they used to have. Grain samples from three 1999 on-farm trials at Madras, Culver and Prineville were tested for nutrients to determine if different nitrogen rates affect grain nutrient concentration and uptake. This information will develop a nutrient concentration and nutrient uptake baseline for hard red spring wheat in Central Oregon as of 1999.

Materials and Methods

Materials and methods for the trials are in the "nitrogen rate and timing effect on irrigated hard red spring wheat: 1999 on-farm trials in Central Oregon" - (Sexton et al. 2001). In short, N was applied as a single (basal) application at or before 3 leaf stage, or the same total rate of N was applied as a split application with 40 lbs/acre of the total being applied at the flag leaf stage. The "0 N" treatment only had the supplemental 40lbs/acre N at flag leaf. The three sites each had 10 treatments with three replicates as a randomized complete block design. In 2022, whole grain samples were sent to the Oregon State University Soil Health Laboratory, Corvallis, Oregon and analyzed for carbon (C), nitrogen (N), phosphorus (P), potassium (K), sulfur (S), calcium (Ca), magnesium (Mg), manganese (Mn), iron (Fe), zinc (Zn), boron (B), and copper (Cu) concentration. Yield is presented from the original article for ease of comparison. Crude protein (CP) is N percentage x 5.7. Nutrient concentration percentage for each replicate, nutrient uptake for pounds per acre (replicate nutrient % x average yield) and for pounds per bushel (pounds of nutrients / total bushels) were determined.

All replicate samples were analyzed for Express and Yecora Roja varieties. The variety Hank was missing some samples - treatments 1 to 10 had only 2, 1, 1, 2, 1, 1, 2, 1, 2, and 1 rep samples that were analyzed for nutrients. Statistical analyses were run for Express and Yecora Roja responses, not Hank.

Results

The crude protein, nutrient concentrations, lbs/acre uptake, and lbs/bu uptake for nutrients, along with previously published yield for the three locations are in tables 1-9. Boron concentration analysis was performed but was “below detectable concentration” for all three varieties at all locations.

Express Hard Red Spring Wheat– Brian Barney Farm – Prineville, Oregon Results

Express nutrient concentration (%), pounds per acre uptake (lb/ac) and pounds per bushel (lb/bu) uptake results are shown in tables 2-4.

It is important to note that Sexton et al. (2001) hypothesized that there was more nitrogen available below the 0–2-foot soil zone, and that this had a large influence on the results of the trial. Even though there were large yield differences, there were no nutrient concentration percentage differences due to basal and flag leaf N rate applications (Table 1).

Table 1. Basal and flag leaf top dress nitrogen rate effect on Express irrigated hard red spring wheat crude protein and nutrient concentration at the Brian Barney farm, Prineville, Oregon, 1999.

Total N Applied	Application type	Crude Protein	C	N	P	K	S	Ca	Mg	Mn	Fe	Zn	Cu	N:S	C:N
(lb/ac)		(%)								(ppm)				Ratio	
0	Single	15.1	42.2	2.65	0.42	0.56	0.18	0.060	0.18	59.3	34.0	32.6	8.8	14.4	16.1
40	Split	17.0	42.4	2.98	0.41	0.49	0.19	0.050	0.18	51.5	27.4	30.4	9.2	15.4	14.2
70	Single	16.1	42.3	2.82	0.39	0.51	0.19	0.053	0.17	44.1	33.7	33.9	8.5	15.1	15.0
70	Split	15.8	42.2	2.78	0.42	0.53	0.19	0.053	0.17	51.6	31.9	33.9	9.0	14.6	15.2
140	Single	16.7	42.4	2.93	0.41	0.55	0.19	0.060	0.18	52.9	31.8	30.2	9.1	15.2	14.5
140	Split	16.3	42.3	2.86	0.39	0.52	0.20	0.053	0.17	46.8	32.2	28.3	8.9	14.6	14.8
210	Single	16.6	42.2	2.91	0.40	0.57	0.19	0.063	0.18	49.8	35.6	32.1	7.6	15.3	14.6
210	Split	16.1	42.3	2.83	0.38	0.51	0.19	0.060	0.17	54.9	32.7	28.2	7.4	14.6	15.0
280	Single	15.0	43.7	2.64	0.44	0.52	0.18	0.057	0.19	54.5	37.7	39.1	9.8	14.4	16.7
280	Split	16.5	42.3	2.90	0.41	0.53	0.20	0.053	0.17	53.1	32.9	35.7	9.5	14.7	14.6
Mean		16.1	42.4	2.83	0.41	0.53	0.19	0.056	0.18	51.8	33.0	32.4	8.8	14.8	15.0
PLSD 0.10		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Prob > F		0.368	0.407	0.368	0.781	0.405	0.795	0.230	0.377	0.122	0.750	0.882	0.413	0.400	0.410
SEM		0.6	0.44	0.11	0.023	0.022	0.007	0.004	0.006	3.1	3.4	5.0	0.74	0.35	0.74
CV%		6.4	1.8	6.4	9.6	7.3	5.9	10.9	6.2	10.4	17.7	26.8	14.6	4.1	8.5

Crude Protein: 5.7 * N%.

In general, uptakes of all nutrients were significantly different between total N applications and between the single and split N applications (Table 2). In general, as nitrogen rates increased, yields increased, and nutrient uptake increased. Increasing N rate from basal 0 lb/ac N to 40 lb/ac N at flag leaf increased all nutrient uptakes except iron. Split application of 280 lb/ac increased uptake for all nutrients except P, K, Ca, Mg, and Fe. Split applications of N rates of 70, 140, 210 lb/ac decreased uptakes for C, N, P, K, S, Ca, Mg, Mn, Zn, and Cu nutrients, but not always significantly. There was more removal of nutrients with the fertilizer rates 0 with flag leaf 40 lb/ac for those same nutrients, except Ca and Fe. 280 lb/ac N as a split application increased C, N, S, and Cu uptake, while uptakes of P, Ca, Mg, Mn, and Fe were the same compared to the 280 lb/ac single application.

Table 2. Basal and flag leaf top dress nitrogen rate effect on Express irrigated hard red spring wheat yield and nutrient uptake (lb/ac.) at the Brian Barney farm, Prineville, Oregon, 1999.

Total N	Application type	Yield	CP Yield	C	N	P	K	S	Ca	Mg	Mn	Fe	Zn	Cu
lbs/ac		bu/ac	Uptake (lb/ac)											
0	Single	66	598	1,672	105	16.8	22.2	7.3	2.38	7.3	2.35	0.135	0.129	0.035
40	Split	81	826	2,058	145	19.9	23.8	9.4	2.43	8.6	2.50	0.133	0.148	0.045
70	Single	108	1,040	2,739	183	25.5	33.3	12.1	3.46	11.0	2.86	0.218	0.220	0.055
70	Split	86	818	2,175	143	21.8	27.5	9.8	2.75	8.9	2.66	0.165	0.175	0.046
140	Single	134	1,344	3,405	236	33.2	44.2	15.5	4.82	14.5	4.25	0.255	0.243	0.073
140	Split	101	987	2,562	173	23.8	31.7	11.9	3.23	10.3	2.84	0.195	0.171	0.054
210	Single	139	1,382	3,521	242	33.6	47.3	15.8	5.28	14.7	4.15	0.297	0.268	0.063
210	Split	118	1,142	2,991	200	27.1	36.3	13.7	4.25	12.0	3.89	0.232	0.199	0.052
280	Single	132	1,192	3,462	209	35.1	41.2	14.5	4.49	15.0	4.31	0.299	0.310	0.078
280	Split	141	1,397	3,580	245	34.4	44.6	16.6	4.51	14.4	4.49	0.278	0.302	0.080
Mean		111	1,073	2817	188	27.1	35.2	12.7	3.76	11.7	3.43	0.221	0.216	0.058
PLSD 0.10			99.5	83.7	17.5	4.3	3.8	1.2	0.59	1.1	0.52	0.059	0.092	0.013
Prob > F			<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	.028	<.001
SEM			40.6	34.1	7.1	1.8	1.5	0.5	0.24	0.45	0.21	0.024	0.037	0.005
CV%			6.6	2.1	6.6	11.2	7.6	6.6	11.1	6.7	10.7	18.8	29.9	15.7

Viewed per bushel (Table 3) there were no differences for any of the nutrients between single or split N applications, except for Zn. Zn uptake (lbs/bu) was highest for the 0 N rate and was significantly higher than all other N rates. The split application increased uptake (lb/bu) for the 70, 140, and 210 lb/ac total N rates, but the split application for “0” and 280 lb/ac total N rates decreased uptake compared to no added N and 280 lb/ac as a single application.

Table 3. Basal and flag leaf top dress nitrogen rate effect on Express irrigated hard red spring wheat nutrient uptake (lb/bu.) at the Brian Barney farm, Prineville, Oregon, 1999.

Total N	Application type	CP Yield	C	N	P	K	S	Ca	Mg	Mn	Fe	Zn	Cu
lbs/ac		Uptake (lb/bu)											
0	Single	9.1	25.3	1.59	0.25	0.34	0.11	0.036	0.11	0.036	0.0020	0.133	0.00053
40	Split	10.2	25.4	1.79	0.25	0.29	0.12	0.030	0.11	0.031	0.0016	0.114	0.00055
70	Single	9.6	25.4	1.69	0.24	0.31	0.11	0.032	0.10	0.026	0.0020	0.078	0.00051
70	Split	9.5	25.3	1.67	0.24	0.32	0.11	0.032	0.10	0.031	0.0019	0.104	0.00054
140	Single	10.0	25.4	1.76	0.25	0.33	0.12	0.036	0.11	0.032	0.0019	0.068	0.00054
140	Split	9.8	25.4	1.72	0.25	0.31	0.12	0.032	0.10	0.028	0.0019	0.088	0.00053
210	Single	9.9	25.3	1.74	0.24	0.34	0.11	0.038	0.11	0.030	0.0021	0.055	0.00046
210	Split	9.7	25.4	1.70	0.23	0.31	0.12	0.036	0.10	0.033	0.0020	0.062	0.00044
280	Single	9.0	26.2	1.58	0.27	0.31	0.11	0.034	0.11	0.033	0.0023	0.074	0.00059
280	Split	9.9	25.4	1.74	0.24	0.32	0.12	0.032	0.10	0.032	0.0020	0.067	0.00057
Mean		9.7	25.4	1.70	0.25	0.32	0.11	0.034	0.11	0.031	0.0020	0.084	0.00053
PLSD 0.10		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	0.017	NS
Prob > F		0.368	.407	0.368	0.781	0.405	0.795	0.230	0.377	0.122	0.750	<.001	0.413
SEM		0.4	0.26	0.06	0.014	0.013	0.004	0.002	0.004	3.103	0.0002	0.007	.000044
CV%		6.4	1.8	6.4	9.6	7.3	5.9	10.9	6.2	10.4	17.7	14.0	14.6

Yecora Roja Hard Red Spring Wheat Variety – Rich Lewis Farm – Madras, Oregon

Yecora Roja nutrient concentration (%), pounds per acre uptake (lb/ac) and pounds per bushel (lb/bu) uptake results are shown in Tables 4-6.

Table 4 shows Yecora Roja crude protein and nutrient concentration results. In general, N, and crude protein concentrations increased with increasing N rates. K concentration was highest at 280 lb/ac N as a split application. Ca concentration was increased by the higher N rates in general. There were no differences for all the other nutrient concentrations between the different N rates nor between single and split applications at the same rates.

Table 4. Basal and flag leaf top dress nitrogen rate effect on Yecora Roja variety of irrigated hard red spring wheat yield, crude protein, and nutrient concentration at the Rich Lewis Farm,, Madras, Oregon, 1999.

Total N	Application type	Crude Protein	C	N	P	K	S	Ca	Mg	Mn	Fe	Zn	Cu	N:S	C:N
(lb/ac)		(%)								(ppm)				Ratio	
0	Single	12.9	42.0	2.27	0.39	0.56	0.16	0.050	0.14	51.8	36.6	21.6	6.1	14.4	19.2
40	Split	14.9	42.2	2.62	0.40	0.54	0.17	0.050	0.15	53.6	31.4	23.6	7.3	15.1	16.4
70	Single	13.6	41.7	2.39	0.39	0.56	0.17	0.053	0.14	52.7	34.3	23.7	6.7	14.3	17.6
70	Split	13.3	41.6	2.34	0.34	0.53	0.18	0.500	0.13	43.3	37.2	16.7	7.8	13.2	17.8
140	Single	15.3	41.4	2.69	0.39	0.52	0.17	0.057	0.14	51.9	31.4	21.1	7.2	15.8	15.4
140	Split	14.7	42.0	2.58	0.37	0.55	0.17	0.053	0.14	49.2	35.1	20.2	5.6	15.2	16.3
210	Single	15.7	43.4	2.75	0.40	0.58	0.18	0.060	0.15	50.8	30.8	21.8	6.3	15.5	15.8
210	Split	16.8	42.1	2.94	0.37	0.54	0.18	0.057	0.14	44.0	30.4	20.0	5.4	16.4	14.3
280	Single	17.2	42.0	3.02	0.41	0.58	0.19	0.063	0.15	50.5	32.2	19.4	5.3	16.3	13.9
280	Split	17.3	42.1	3.03	0.48	0.67	0.18	0.060	0.18	54.2	32.3	32.2	8.5	16.6	13.9
Mean		15.2	42.0	2.66	0.39	0.56	0.17	0.055	0.15	50.2	33.2	22.0	6.6	15.3	15.9
PLSD 0.10		2.7	NS	0.47	NS	0.07	NS	0.008	NS	NS	NS	NS	NS	NS	NS
Prob > F		0.083	0.369	0.083	0.105	0.090	0.195	0.097	0.255	0.246	0.682	0.178	0.751	0.272	0.173
SEM		1.09	0.51	0.19	0.026	0.030	0.007	0.003	0.012	3.14	2.89	3.22	1.34	0.906	1.4
CV%		12.4	2.1	12.4	11.5	9.2	6.9	10.5	13.7	10.8	15.1	25.3	35.2	10.3	15.0

Crude Protein: 5.7 * N%.

Table 5 shows the lbs/acre uptake results for Yecora Roja. In general, all nutrient uptakes were significantly increased by increasing N rates except Fe and Cu. The 210 lb/ac N split application had the highest crude protein yield, and C, and N uptakes, but not significantly so for CP yield. 280 lb/ac N as a split application had the highest uptake for P, K, Mg, Ca, Mn, all greater than a pound per acre, while Fe, Zn, and Cu uptakes were less than on pound per acre. Ca and Mn uptakes were around 4-6 pounds/acre.

Table 5. Basal and flag leaf top dress nitrogen rate effect on Yecora Roja variety of irrigated hard red spring wheat nutrient uptake *(lb/ac)* at the Rich Lewis Farm, Madras, Oregon, 1999.

Total N	Application type	Yield	CP Yield	C	N	P	K	S	Ca	Mg	Mn	Fe	Zn	Cu
(lb/ac)		bu/ac	Uptake (lb/ac)											
0	Single	123	955	3,097	167.5	28.5	41.3	11.6	3.69	10.6	3.83	0.270	0.159	0.045
40	Split	141	1,262	3,568	221.4	33.8	45.7	14.7	4.23	13.0	4.53	0.266	0.199	0.062
70	Single	153	1,249	3,826	219.1	35.5	51.1	15.3	4.90	13.2	4.83	0.315	0.218	0.062
70	Split	144	1,151	3,597	201.9	29.4	45.8	15.3	4.32	10.9	3.74	0.321	0.144	0.067
140	Single	151	1,387	3,747	243.4	35.3	46.8	15.4	5.13	13.0	4.71	0.284	0.191	0.065
140	Split	158	1,394	3,980	244.6	35.4	52.1	16.1	5.06	13.3	4.66	0.333	0.191	0.053
210	Single	145	1,364	3,778	239.3	34.8	50.8	15.4	5.22	12.8	4.42	0.268	0.189	0.055
210	Split	178	1,790	4,494	314.0	39.9	57.3	19.2	6.05	15.0	4.70	0.324	0.214	0.058
280	Single	160	1,654	4,031	290.3	39.4	55.4	17.9	6.08	14.7	4.84	0.309	0.186	0.051
280	Split	165	1,712	4,169	300.3	47.9	66.3	18.2	5.94	17.8	5.37	0.320	0.319	0.084
Mean		152	1,392	3,829	244.2	36.0	51.3	15.9	5.06	13.4	4.56	0.301	0.201	0.060
PLSD 0.10			229	108	40.1	6.4	7.3	1.4	0.75	2.8	0.70	NS	0.078	NS
Prob > F			<.001	<.001	<.001	0.003	<.001	<.001	<.001	0.017	0.028	0.403	0.077	0.681
SEM			93.2	44.1	16.36	2.59	2.97	0.585	0.31	1.16	0.286	0.025	0.0319	0.013
CV%			11.6	2.0	11.6	12.5	10.0	6.4	10.5	14.9	10.9	14.3	27.4	36.8

Table 6 shows the bu/acre uptake results for Yecora Roja. In general, crude protein yield and nitrogen uptake (lb/bu) increased with increasing N rates, but only statistically significant to the 210 lb/ac N single application. 280 lb/ac N as a split application gave higher uptakes of K and Ca than the rest of the N rates. There was no significant difference between N rate treatments for P, S, Mg, Mn, Fe, Zn, and Cu.

Table 6. Basal and flag leaf top dress nitrogen rate effect on Yecora Roja variety of irrigated hard red spring wheat nutrient uptake *(lb/bu.)* at the Rich Lewis Farm, Madras, Oregon, 1999.

Total N	Application type	CP Yield	C	N	P	K	S	Ca	Mg	Mn	Fe	Zn	Cu
(lb/ac)			Uptake (lb/bu)										
0	Single	7.8	25.2	1.36	0.23	0.34	0.09	0.030	0.086	0.031	0.0022	0.050	0.00037
40	Split	9.0	25.3	1.57	0.24	0.32	0.10	0.030	0.092	0.032	0.0019	0.052	0.00044
70	Single	8.2	25.0	1.43	0.23	0.33	0.10	0.032	0.086	0.032	0.0021	0.044	0.00040
70	Split	8.0	25.0	1.40	0.20	0.32	0.11	0.030	0.076	0.026	0.0022	0.054	0.00047
140	Single	9.2	24.8	1.61	0.23	0.31	0.10	0.034	0.086	0.031	0.0019	0.048	0.00043
140	Split	8.8	25.2	1.55	0.22	0.33	0.10	0.032	0.084	0.030	0.0018	0.036	0.00034
210	Single	9.4	26.1	1.65	0.24	0.35	0.11	0.036	0.088	0.030	0.0019	0.043	0.00038
210	Split	10.1	25.2	1.76	0.22	0.32	0.11	0.034	0.084	0.026	0.0018	0.031	0.00033
280	Single	10.3	25.2	1.81	0.25	0.35	0.11	0.034	0.092	0.030	0.0019	0.033	0.00032
280	Split	10.4	25.3	1.82	0.29	0.40	0.11	0.038	0.108	0.033	0.0019	0.052	0.00051
Mean		9.1	25.2	1.60	0.24	0.34	0.10	0.033	0.088	0.030	0.0020	0.044	0.00040
PLSD 0.10		1.6	NS	0.28	NS	0.04	NS	0.005	NS	NS	NS	NS	NS
Prob > F		0.083	0.369	0.063	0.105	0.090	0.193	0.097	0.255	0.246	0.682	0.493	0.751
SEM		0.65	0.31	0.115	0.016	0.018	0.004	0.002	0.007	0.0019	0.00017	.0086	0.00008
CV%		12.4	2.1	12.4	11.5	9.2	6.9	10.5	13.7	10.8	15.1	33.6	35.2

Hank Hard Red Spring Wheat concentration – Macy Farms – Culver, Oregon

Nutrient concentration, pounds per acre uptake, and pounds per bushel uptake results of Hank are in tables 7-9. These results cannot be meaningfully assessed. Many samples were missing (see materials and methods section) and therefore no statistical analysis was run.

Hank HRS wheat concentration results are shown in Table 7. Crude protein and N percentage increased up to the 140 lb/ac N split application.

Table 7: Basal and flag leaf top dress nitrogen rate effect on Hank variety of irrigated hard red spring wheat yield, crude protein, and nutrient concentration (%) at Macy Farms, Culver, Oregon, 1999.

Total N	Application type	Crude Protein	C	N	P	K	S	Ca	Mg	Mn	Fe	Zn	Cu	N:S	C:N
(lb/ac)		(%)								(ppm)				Ratio	
0	Single	13.4	43.5	2.35	0.44	0.61	0.17	0.055	0.17	45.2	35.4	32.9	9.3	13.8	18.5
40	Split	12.0	41.9	2.10	0.47	0.64	0.16	0.060	0.18	46.0	42.6	30.2	7.7	13.1	19.9
70	Single	11.9	41.8	2.08	0.45	0.65	0.16	0.060	0.17	48.7	37.9	33.4	9.7	13.0	20.1
70	Split	15.9	42.1	2.79	0.46	0.59	0.19	0.045	0.18	45.0	29.6	43.3	10.8	14.6	15.1
140	Single	14.3	41.9	2.50	0.47	0.72	0.17	0.070	0.18	35.8	45.8	32.8	7.0	14.7	16.7
140	Split	17.8	42.4	3.12	0.42	0.54	0.21	0.040	0.16	46.1	23.3	43.8	7.5	14.9	13.6
210	Single	14.0	41.9	2.46	0.55	0.73	0.18	0.055	0.21	54.3	39.4	47.8	12.0	13.6	17.0
210	Split	13.9	41.9	2.43	0.44	0.64	0.17	0.060	0.17	34.0	32.1	26.6	6.9	14.3	17.3
280	Single	13.5	42.0	2.38	0.40	0.58	0.18	0.055	0.16	35.1	50.1	27.5	7.7	13.5	17.7
280	Split	15.7	42.4	2.76	0.41	0.64	0.18	0.060	0.16	40.9	47.7	30.6	6.8	15.3	15.4
Mean		14.2	42.2	2.50	0.45	0.63	0.18	0.056	0.17	43.1	38.5	34.9	8.5	14.1	17.1

Crude Protein: 5.7 * N%.

Table 8 shows Hank HRS wheat nutrient uptake (lb/ac) results. CP yield, C, N, P, K, S, Mg, Mn, Zn, and Cu uptakes topped out with the 210 lb/ac N single application. Ca uptake was maximum at the 140 lb/ac N single application, while Fe uptake was maximum topped at 280 lb/ac N rate in both the single and split applications.

Table 8. Basal and flag leaf top dress nitrogen rate effect on Hank variety of irrigated hard red spring wheat nutrient uptake (lb/ac.) at Macy Farms , Culver, Oregon, 1999.

Total N	Application type	Yield	CP Yield	C	N	P	K	S	Ca	Mg	Mn	Fe	Zn	Cu
(lb/ac)		bu/ac	Uptake (lb/ac.)											
0	Single	39	313	1,018	55.0	10.3	14.3	4.0	1.29	4.0	1.06	0.083	0.077	0.022
40	Split	55	395	1,381	69.3	15.5	21.1	5.3	1.98	5.9	1.52	0.141	0.100	0.025
70	Single	72	512	1,805	89.9	19.4	28.1	6.9	2.59	7.3	2.10	0.164	0.144	0.042
70	Split	64	611	1,617	107.1	17.5	22.7	7.3	1.73	6.7	1.73	0.114	0.166	0.041
140	Single	103	881	2,588	154.5	29.0	44.5	10.5	4.33	11.1	2.21	0.289	0.203	0.043
140	Split	86	918	2,188	161.0	21.7	27.9	10.8	2.06	8.3	2.38	0.120	0.226	0.039
210	Single	114	959	2,864	168.3	37.3	49.9	12.3	3.76	14.0	3.71	0.269	0.327	0.082
210	Split	110	914	2,768	160.4	29.0	42.2	11.2	3.96	11.2	2.24	0.212	0.176	0.046
280	Single	101	820	2,547	143.9	23.9	34.8	10.6	3.33	9.7	2.13	0.303	0.167	0.046
280	Split	105	991	2,673	173.9	25.8	40.3	11.3	3.78	10.1	2.58	0.301	0.193	0.043
Mean		85	731	2,145	128.3	23.0	32.6	9.0	2.88	8.8	2.17	0.200	0.178	0.043

Table 9 shows Hank HRS wheat nutrient uptake (lb/bu) results. There was less N, K, Ca, Mg, and Fe, in general in the 70. 140, 210 Splits compared to the basal N rate, but not always consistently so. Pounds per bushel Zn uptake was dramatically higher in the check (0 N), compared to the other N rates and timing. Most of the other nutrients appeared to not be affected differentially by the different N applications.

Table 9. Basal and flag leaf top dress nitrogen rate effect on Hank variety of irrigated hard red spring wheat nutrient uptake (lb/bu.) at Macy Farms at Culver, Oregon in 1999.

Total N	Application type	CP Yield	C	N	P	K	S	Ca	Mg	Mn	Fe	Zn	Cu
(lb/ac)		Uptake (lb/bu)											
0	Single	8.0	26.1	1.41	0.26	0.37	0.10	0.033	0.102	0.027	0.0021	0.238	0.00056
40	Split	7.2	25.1	1.26	0.28	0.38	0.10	0.036	0.108	0.028	0.0026	0.140	0.00046
70	Single	7.1	25.1	1.25	0.27	0.39	0.10	0.036	0.102	0.029	0.0023	0.135	0.00058
70	Split	9.5	25.3	1.67	0.27	0.35	0.11	0.027	0.105	0.027	0.0018	0.169	0.00065
140	Single	8.6	25.1	1.50	0.28	0.43	0.10	0.042	0.108	0.021	0.0028	0.068	0.00042
140	Split	10.7	25.4	1.87	0.25	0.32	0.13	0.024	0.096	0.028	0.0014	0.087	0.00045
210	Single	8.4	25.1	1.48	0.33	0.44	0.11	0.033	0.123	0.033	0.0024	0.105	0.00072
210	Split	8.3	25.2	1.46	0.26	0.38	0.10	0.036	0.102	0.020	0.0019	0.063	0.00041
280	Single	9.1	25.2	1.43	0.24	0.35	0.11	0.033	0.096	0.021	0.0030	0.076	0.00046
280	Split	9.4	25.5	1.66	0.25	0.38	0.11	0.036	0.096	0.025	0.0029	0.065	0.00041
Mean		8.5	25.3	1.50	0.27	0.38	0.11	0.034	0.104	0.026	0.0023	0.115	0.00051

References:

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Using Legumes to Control Weeds and Increase Soil Nitrogen Fertility in Organic Soft White Spring Wheat Production

Sarah Lee Lawrence, Mylen Bohle, and Tim Van Domelen

Introduction

In India there are native legumes that resemble clover that have been traditionally grown as a permanent cover crop within grain crops. We investigated the symbiotic relationship that the legumes could have with organic grown spring wheat in Central Oregon. Ideally, a legume that would not overwhelm the wheat but still suppress weeds and produce a profitable yield. Many farmers are skeptical of organic farming because they believe they can only use an organic system in which their conventional practices are substituted with similar organic inputs. Such an approach can be cost prohibitive and may or may not promote soil health.

Controlling weeds is a struggle and can be discouraging for organic producers. Can companion crop planting produce adequate yields and be economically profitable to farm organically. If weeds were controlled organically and the prevailing price of organic commodities are higher, would more producers consider switching to organic production?

A major disadvantage when transitioning to organic production of crops is the three years of practicing organic farming without receiving organic prices Some consumers will pay slightly more for “transitional” crops. Cover cropping itself is often expensive -tillage, seed, planting, and irrigation costs – without income. Planting a legume for forage or grain or utilizing livestock to harvest the crop can help in the transition period. This research compared a systems approach to raising organic grain that can help the producer during transition and beyond. Companion planting has the potential to enrich the soil, produce a crop, and suppress weeds: three major challenges.

Brief Review of Literature

Several years past, National Public Radio reported on the possibility of companion planting with the native legumes in India. Sir Albert Howard, who is considered the founder of the organic farming movement, spent a great deal of time in India. He spent his life observing farming practices and was particularly taken by the “leguminous weeds, which thrive so luxuriantly as bottom growth in the wheat fields of the Punjab” (Howard, 1953). In the Punjab region of India, where wheat fields are irrigated, “wheat is grown year after year without manure, apparently without producing any diminution in the fertility of the soil” (Howard, 1953).

In searching articles in the grain section of the *Organic Ag Info* site which addresses organic and conventional crop comparisons and rotations, only one article was specific to intercropping and that information was not available online.

There were articles about conventional relay cropping of wheat and soybeans, where soybean is sown into standing wheat. There were studies on cultivars and systems in Iran. There was an article from India about increasing land use efficiency and weed suppression by intercropping wheat and chickpeas; both harvested for grain. That study was done conventionally, but results showed that total productivity and land use efficiency were higher under the intercropping system compared to monocrops of either species. There was also a significant reduction in weed density.

The closest study found for this trial, for which a proposal had been written to the Western Sustainable Agriculture Research & Education, was from the University of Manitoba. That study evaluated intercropping with wheat to determine whether added elements of diverse companion crops would provide benefits to organic wheat production and reduce levels of weeds and diseases. Both the cultivar mixture study and intercrop study took place at Carman Manitoba in 2004 and 2005 and at Clearwater Manitoba in 2004. At both sites, the experiments were managed organically. Results showed that the cover crop treatments of oat, barley, rye, flax, mustard had lower returns because the cover crops did not provide a saleable product, nor did they generally have significant positive effects on wheat yield. In fact, the cover crops resulted in negative returns in two cases. However, legumes performed better. Wheat grown with a red clover cover crop was moderately successful Hairy vetch and annual ryegrass competed too aggressively with the wheat crop. It was surmised that there could be the possibility of having a positive effect on organic wheat production if intercropping a legume with a low canopy.

Brennan looked at seeding rate and planting arrangement effects on growth and weed suppression of a legume-oat cover crop for organic vegetable systems. While the aim of the study was not to produce grain, their results highlighted the weed suppression capabilities of their legume species. Most importantly, “increasing the typical seeding rate by three-fold consistently reduced the weed biomass by severalfold” (Brennan, et al. 2009).

Another study in Brazil in 1989 found that in the first year, the companion planting of wheat and several legumes had a negative effect on crop yield. It wasn’t until the second year that nitrogen contribution from the residue from the previous crop increased the harvest by 84% (Tomm and Foster, 2001). The experiment was conventional and on dry land, which could behave differently than on irrigated ground.

An unrelated study, but extremely fascinating trial was one done by John Burket at the Oregon State University. The trial compared organic broccoli productivity that followed several cover crops which included clover, rye, and peas. Broccoli followed the cover crops with three treatments: no added N, 125 units of N, and 250 units of N. Broccoli that followed the clover produced the same yield in all three N treatments, whereas the other cover crops (rye and peas) produced lower yields of broccoli without the added N.

Some of these studies showed that the intercropped legumes did not seem to feed the immediate grain crop, but instead put N in the soil for future crops. But the legumes did suppress weeds in the present crop.

Dovel, et al. 1995a, 1995b, planted annual legumes with an oat hay crop. Some of the entries significantly increased crude protein and relative feed value of the hay. Acid detergent fiber was decreased significantly, but neutral detergent fiber was not different from the check that had no annual legume companion. There was no yield increase at Klamath Falls over two cropping years.

Annual legumes planted with spring barley at Klamath Falls, by Randy Dovel et al., 1995c, 1996 did not increase yield over the check in two years of trials. Quality of the barley grain was affected negatively with some of the companion planting of annual legumes. Effect of weed control on the present year crops or nitrogen fertility effect on the subsequent crops was not determined.

Trial Objectives

1. To find a cover crop that provides nitrogen for grain production without overwhelming the grain. Which cover crop works best with the grain?
2. To determine which cover crop provides the best competition for early weeds, because the cover crop could feed the weeds as well. So, the cover crop must shade the weeds. Which cover crop works best against weeds?
3. To find the optimum seeding rates for the companion planted legume crops.

Material and Methods

Only organic approved materials have been applied to the test field since the spring of 2007 when Glyphosate was applied to control quack grass to begin the transition to organic production. This field is located on the Lawrence Farm 10 miles west of Terrebonne, Oregon. Austrian winter peas were planted in the fall of 2008 and harvested for seed and the field was plowed in the spring of 2009 and summer fallowed until the fall of 2009. Hairy vetch was planted in early September 2009 and irrigated. Deer heavily grazed the field from planting till spring. A weed survey was taken throughout the field to document weeds present prior to tillage. Weeds present in early June, in addition to hairy vetch, prior to disking included: flixweed, tansy mustard, tumble mustard, downy bromegrass/cheatgrass, shepherd's purse, redstem filaree, dandelion, Chinese lettuce, chickweed, and wheat.

Soil samples were taken with 6 sub samples from each replication to document soil fertility. One above ground biomass (hairy vetch, volunteer wheat, broadleaf, and grass weeds) sample was taken from a 0.5-meter square area to document biomass weight and nutrient concentration and uptake in each replication. The plant samples were clipped within a half-inch of the soil. These samples were taken prior to the field being disked in early June 2010. The plant samples were transported to COAREC, Powell Butte, Oregon for drying at 140 degrees F and the soil samples were air-dried prior to shipping. The soil and plant samples were analyzed by Agricheck Laboratory, Inc. at Umatilla, Oregon (now Kuo Lab). Initial soil and plant nutrient test results are in Tables 1 and 2, respectively.

In early June, the 25-acre field was first planted to 'Alpowa' soft white spring wheat at 30 seeds per ft2, with a 10-foot-wide double disk drill. Dr. Stephen Jones (WSU, personal communication) has identified that this cultivar works better than others under organic production management. The length of the field was 1,320 feet and the width 1,000 feet;

treatment strips were 30 ft x 1,000 ft. The trial was a randomized complete block with 3 replications. There are 12 treatments. Six legumes at 1x seeding rate; 5 legumes at 2x seeding rate; and a control strip of mono-cropped wheat for a total of 36 strips of equal length and width. The legumes were planted at 1.0 and 2.0 x seeding rates over the top of the wheat (see Table 3). Four annual legumes (Perisan clover, arrowleaf clover, sub clover, black medic), and a biennial legume (yellow sweet blossom clover) were the legumes planted. Crimson clover was planted in the border areas at 1.5 x and 3.0 x seeding rates. The treatments with the 2.0 x seeding rates were planted over twice (with the 1.0 x seed rate) with a 10-foot double disk drill with 6-inch row spacing to achieve the desired rates. Directly after the wheat was planted, the legumes were planted over the top using the small seed box on the grain drill, without the tubes, so the seeds were dropped and scattered on the surface and rolled in. The appropriate inoculum for each species was mixed with the seed in the drill box at planting.

The wheel line irrigation system ran perpendicular to the test strips, so all treatments experienced the same fluctuations in irrigation due to wind and timing. The irrigation system was 40 ft x 60 ft with a rolling wheel line. The field was irrigated as needed with 8-hour sets with 5/32-inch impact nozzles. Off-set irrigation was employed every other irrigation.

One quarter-meter square quadrants were harvested from each treatment replication on August 18, 2010. The samples were taken at milky dough to soft dough stage. Plants were at different stages of maturity across the field. Aboveground biomass was clipped, then separated into broadleaf and grass weeds, legumes, and wheat. Wheat heads were counted. Then the wheat, broadleaf weeds and grass weeds were dried at 140 degrees F until there was no change in weight and were then weighed. Dry matter and moisture percentage was calculated. The weights were used to determine percent biomass of each plot. The samples were taken at this stage to determine composition of plant species. Biomass yields are presented on an oven-dry matter basis. Whole plant biomass samples of wheat, broadleaf and grass weeds were not tested for total above ground biomass N uptake.

Six hundred (600) ft^2 (5 ft x120 ft) of each plot was harvested with a Wintersteiger small plot combine in mid-September 2010. The wheat harvested from each plot was bagged in the field and then weighed after transport to COAREC, Madras. Two pound samples were collected from each treatment. The samples were tested for moisture, protein (whole grain NIRS), and test weight by the OSU Wheat Laboratory in Corvallis, OR. Yield is presented on 10% grain moisture and protein at 12% moisture basis.

Grain nitrogen uptake was calculated (yield * protein/ 5.7). Harvest index was calculated by dividing wheat grain yield divided by wheat biomass weight at milky-soft dough growth stage.

Grain nitrogen recovery-A percentage was calculated by dividing the grain N uptake (lb/ac) by the combined N of the plow down hairy vetch and weeds (N lb/ac) plus soil NO_3 (lb/ac).

Grain nitrogen recovery-B percentage was calculated by dividing the grain N uptake (lb/ac) by the combined N of the plow down hairy vetch and weeds (N lb./ac) plus soil NO_3 (lb/ac) and soil NH_4 (N lb./ac).

Statistical analysis was performed with MSTAT (Michigan) software.

Results and Discussion

Yield, test weight, protein %, grain N uptake, wheat heads, harvest index, and Grain N recovery A and B percentage data are presented in Table 4.

None of the variates were significantly different among the treatments. The species and seed rates had no positive or increased effect compared to the check for grain yield or crude protein. None of the treatments were significantly better than the check, which was previous legume plow down with no companion planted annual legume. The plow down legume (hairy vetch) did produce an average of 75.9 bu/ac and 10.5% crude protein. The mean of the trial was 72.1 bu/ac and 10.4% crude protein. The range of yield was 69 .0 to 76.4 bu/ac for the 12 treatments. In practice, there would be a tradeoff for allowing the hairy vetch crop to grow longer into late spring to provide more fixed N before plowing down and planting the soft white spring wheat crop. Soft white spring wheat could have been planted a month earlier and yield potential would have been greater if there would have been sufficient N for the crop. Soft white spring wheat yield potential is met at around 10.5% crude protein and seven out of the twelve treatments produced 10.5% or higher protein concentration (the range was 9.8% to 10.9%). None of the treatments were significantly different.

A deer population moderately grazed the field from fall to spring prior to plow down This could have affected the amount of legume plow down and thus nitrogen available to the crop. Yield potential was also likely negatively affected by the planting date, but we chose to allow the hairy vetch to grow prior to plow down. This allowed for more fixed nitrogen to be available for the crop.

Biomass yields and plant composition percentages for samples taken on August 18, 2010, are presented in Table 5.

The only significant difference was the legume biomass weight and percent of total weight - sub clover 2x and Persian clover 1x seeding rates had higher legume weight and percentages than most of the other species and seeding rates. But Persian clover 1x was not different from arrowleaf clover 2x, crimson clover 1x and Persian clover 2x. Arrowleaf clover 1x seed rate had greater legume biomass than yellow blossom sweetclover 2x seed rate.

The range of broadleaf weeds and grass weeds percentage of total biomass was 0 to 1.7% and 0.3 to 6.4%, respectively, and none were significantly different among treatments. Many regressions to determine if any of the weed and legume components had a significant effect on grain yield and crude protein, revealed nothing; all were less than a R^2 of 0.100.

These additional aftermath legumes could have a positive effect on the N fertility for the next crop, the following year. No soil tests were taken at the end of the season or the following year to document any added benefit for the next crop. Whole plant samples were not tested for total above ground biomass N uptake. Usually there is very little N remaining in the straw after grain harvest, for the following crop.

Conclusions

Not one of the legume species or seed rate treatments had a positive impact on yield or protein. Nor did any of the treatments significantly control weeds. An interesting possibility that could be a positive attribute is the effect that a legume, such as the biennial yellow blossom sweet clover, could have if the field were reirrigated after harvest to allow it to grow into the following year to fix more N. A legume like hairy vetch that would also over winter could also be no-till drilled into the existing stand of sweet clover, if needed. The fall through spring growth could be tilled in just prior to planting to provide some of the required N for the following crop.

The spring plow down of the hairy vetch did provide nitrogen for almost 76 bushels per acre of soft white spring wheat. Regardless of organic or non-organic farming methods, use of a legume cover crop for increasing N soil fertility is an excellent management tool.

From the results of this trial, the lead author has since grown a "clover" crop with cereals for grain, which suppressed the growth of the clover, but did not seem to affect the growing crop either positively or negatively. The benefit occurred with irrigating the field after harvest, in which the clover grew back quite well, and the aftermath was grazed by livestock. There should have been a positive effect on the subsequent crop but was not measured.

More research is needed to determine cover crop legume species adaptability, seed rates, and planting times as companion crops with the present wheat crop, and to determine grazing aftermath forage and fertilizer economic value, as following year green manure crops, and thus value effect on subsequent crops in central Oregon.

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Table 1. Soil Test results from samples taken early June 2010 for the on-farm annual legume weed control effect on soft white wheat trial at Rainshadow Organics, the Lawrence Farm, Terrebonne, Oregon.

	Depth (in.)	pH	Sol. Salt mmhos	O.M. %	P ppm	K ppm	Ca (meq	Mg meq	NO3 lb/ac	NH4 lb/ac	S ppm	B ppm	Zn ppm	Mn ppm	Cu ppm	Fe ppm	Total Bases
North Rep	0-10	5.6	0.06	2.8	34	107	6.1	2.8	13	32	11.2	0.2	1.6	19	2.0	98	9.2
Middle Rep	0-10	5.9	0.05	2.2	26	100	6.2	3.3	9	28	8.7	0.1	1.3	16	1.4	71	9.8
South Rep	0-10	5.5	0.06	3.4	32	82	5.5	2.8	10	22	11.3	0.2	1.8	18	1.5	98	8.5
Mean	*0-10*	*5.7*	*0.06*	*2.8*	*31*	*96*	*5.9*	*3.0*	*11*	*27*	*10.4*	*0.2*	*1.6*	*18*	*1.6*	*89*	*9.2*

Table 2. Plant Tissue Analysis of the fall planted vetch and other biomass clipped in early June 2010 prior to plow down in the on-farm annual legume weed control effect on soft white wheat trial at Rainshadow Organics, Lawrence Farm, Terrebonne, OR.

Replication (#)	Biomass (lb/ac)	Total N (%)	N (lb/ac)	S (%)	S (lb/ac)	P (%)	P (lb/ac)	K (%)	K (lb/ac)
North Rep (3)	1,497	4.02	60.2	0.34	5.1	0.22	3.3	2.32	34.7
Middle Rep (2)	1,467	4.00	58.7	0.34	5.0	0.18	2.6	2.47	36.2
South Rep (1)	1,335	4.81	64.2	0.32	4.3	0.11	1.5	2.40	32.0
Mean	*1,433*	*4.27*	*61.0*	*0.33*	*4.8*	*0.17*	*2.46*	*2.40*	*34.3*

Table 3. Seeding rates for the annual legume species (variety VNS) planted in the on-farm annual legume weed control effect on soft white wheat trial at Rainshadow Organics, Lawrence Farm, Terrebonne, OR, 2010.

Legume species	Seed rate (lb/ac)	Legume species	Seed rate (lb/ac)	Legume species	Seed rate (lb/ac)
Black Medic 1x	15	Subclover 1x	27	Arrowleaf clover 1x	13.5
Black Medic 2x	30	Subclover 2x	54	Arrowleaf clover 2x	27
Yellow sweet clover 1x	18	Persian clover 1x	6.75	Crimson clover 1x	15
Yellow sweet clover 2x	36	Persian clover 2x	13.5	Control	0

Table 4: Yield, test weight, protein %, grain N uptake, wheat heads, harvest index, and grain N recovery A and B percentage data from the annual legume intercropped spring wheat trial at Rainshadow Organics Farm, Terrebonne, Deschutes County, Oregon, 2010.

Legume species	Legume Seed rate (lb/ac)	Yield (bu/ac)	Test Weight (lb/bu)	Protein (%)	Grain N Uptake (lb/ac)	Wheat Heads (#/ft$^{2)}$	Harvest Index (%)	Grain N Recovery- A (%)	Grain N Recovery- B (%)
Black Medic 1x	15	71.8	58.3	10.3	88.8	54.6	43	123	90
Black Medic 2x	30	74.2	58.1	10.0	91.0	48.3	52	126	92
Yellow sweet clover 1x	18	69.8	57.9	10.1	85.1	49.4	49	118	86
Yellow sweet clover 2x	36	71.9	59.1	10.9	86.9	43.1	56	120	88
Subclover 1x	27	70.9	58.0	9.8	87.2	41.1	55	121	88
Subclover 2x	54	69.0	58.5	10.7	82.1	42.2	47	114	83
Persian clover 1x	6.75	76.4	58.2	10.6	91.7	39.6	66	127	92
Persian clover 2x	13.5	68.5	58.4	10.5	83.0	52.6	49	115	84
Arrowleaf clover 1x	13.5	74.9	58.3	10.6	90.1	47.5	52	125	91
Arrowleaf clover 2x	27	70.0	58.2	10.1	85.3	42.8	49	118	86
Crimson clover 1x	15	72.3	59.0	10.9	90.7	47.0	53	126	91
Control	0	75.9	58.3	10.5	91.5	46.9	53	127	92
Mean		72.1	58.4	10.4	87.8	46.3	0.52	122	89
PLSD (0.10)		NS	NS	NS	NS	NS	NS	--	--
Prob > F		0.8846	0.3297	0.4142	0.8348	0.3250	0.1705	--	--
CV%		9.1	1.0	5.6	8.8	15.6	14.9	--	--

Table 5. Biomass yields and plant composition percentages for the annual legume intercropped soft white spring wheat trial at Rainshadow Organics, Terrebonne, Deschutes County, Oregon, August 18, 2010.

Legume species	Seed rate (lb/ac)	Total Biomass (lb/ac)	Wheat Biomass (lb/ac)	Wheat Biomass (%)	Broadleaf[1] Weeds (lb/ac)	Broadleaf Weeds (%)	Grass[2] Weeds (lb/ac)	Grass Weeds (%)	Annual Legume Weight (lb/ac)	Annual Legume (%)	Total Weeds (lb/ac)	Total Weeds (%)	Total Weed Plus Legume (lb/ac)
Black medic 1x	15	9,994	9,809	98.0	5	0.0	111	1.2	69	0.7	116	1.3	185
Black medic 2x	30	8,663	8,482	98.0	62	0.6	33	0.4	87	1.0	95	1.0	181
Yellow sweet clover 1x	18	9,096	8,671	95.6	21	0.3	321	3.2	82	0.9	343	3.5	424
Yellow sweet clover 2x	36	7,682	7,429	96.7	43	0.5	148	1.9	63	0.9	191	2.4	254
Sub clover 1x	27	8,004	7,611	94.6	115	1.7	114	1.6	164	2.1	229	3.3	392
Sub clover 2x	54	8,845	8,410	94.4	6	0.1	20	0.3	409	5.3	26	0.3	435
Persian clover 1x	6.75	7,034	6,492	92.2	26	0.4	156	2.5	359	5.0	183	2.9	542
Persian clover 2x	13.5	8,356	7,746	92.5	15	0.2	388	4.8	206	2.5	403	5.0	610
Arrowleaf clover 1x	13.5	8,832	8,607	97.1	44	0.5	96	1.3	85	1.0	140	1.8	225
Arrowleaf clover 2x	27	8,779	7,952	90.4	46	0.5	547	6.4	235	2.7	593	6.9	828
Crimson clover 1x	15	8,535	8,122	95.6	128	1.2	92	0.9	192	2.3	221	2.1	413
Control	0	8,641	8,534	98.8	22	0.3	85	0.9	0	0.0	108	1.2	108
Mean		8,539	8,156	95.3	44	0.5	176	2.1	162	2.0	220	2.6	383
PLSD (0.10)		NS	NS	NS	NS	NS	NS	NS	169	2.4	NS	NS	NS
Prob > F		0.7546	0.6814	0.3694	0.8730	0.8709	0.6838	0.7032	0.0097	0.0024	0.7904	0.7995	0.4307
CV%		18.4	20.0	4.4	217.0	221.3	181.0	178.2	74.3	85.1	156.7	155.1	91.3

[1] Redroot pigweed, Black nightshade, Lambsquarters, Smartweed, and Field bindweed. [2] Witchgrass

Winter Cereals for Forage Applied Water Use

Mylen Bohle and David Hannaway

Introduction

Depending on winter and spring precipitation, the amount of irrigation water applied to spring cereals will be dramatically different in the late spring to early summer periods. There have been years when there was no spring soil moisture at planting time. During a few years, there has been enough winter, spring, and early summer moisture to harvest a large amount of forage with little to no irrigation.

When years of drought continue, year after year, irrigation water availability is a huge issue. Forage production decreases dramatically, and livestock may need to be sold prematurely. Emergency feed production from cereal species can be a partial solution to producing emergency feed. Planting a winter cereal in the Fall to help with maintaining or increasing forage needed for livestock can be a great choice to be able to utilize any winter through early summer precipitation, along with limited irrigation water, or even with full irrigation water allocation.

If limited irrigation water availability quantity is known, this information can aid producers in choosing which species and varieties would be the best choice to plant to produce forage. Note Some *of these varieties may not be currently available*.

Materials and Methods

The following oat, barley, wheat, rye, and triticale winter cereal data are from the 1991-1993 crop species and varieties trials planted at the Central Oregon Ag Research and Extension Center, Powell Butte, site. More extensive description of materials and methods are provided in Bohle et al, 2002. The experiment station annual irrigation records were accessed to document water applied. The records documented the solid set spacing dimensions, nozzle size, and nozzle pressure, along with the number of hours for each event. Thus inches-per-hour of water applied was calculated. The hours were converted to inches per irrigation and added.

Harvest dates at "early clipping, late- boot, regrowth from late-boot, and soft-dough growth stage, were then used to subtract irrigation events back 6-9 days to previous irrigation events to allow a simulated suitable time for the dry- down of the foliage and soil, so harvest could occur. Yield was divided by total inches of water applied to document applied water use to determine yield (pounds) per inch of water applied and inches needed to produce a ton of dry matter yield. A simple linear regression was used to develop the graphs.

Due to the way the irrigation system was constructed at the Powell Butte site, extra lines were sometimes needed to be run on different trials to reduce the pressure when watering other trials, so extra water was added in some years. *Due to the lack of an on-site weather station, rain and snow precipitation were not available.* Table 1 is a partial calendar of "day of year" dates to help assess water us was during that month.

Table 1. Day of year (doy) from January 1 starting with April 1 to September 1, 1991 - 1993.

Year	Apr. 1	May 1	Jun. 1	Jul. 1	Aug. 1	Sep. 1
1991	91	121	152	182	213	244
1992	92	122	153	183	214	245
1993	91	121	152	183	213	244

Results and Discussion

Figures 1-3 are graphs with linear regression trendlines for yields and applied water use to aid in choosing the right cereal species and variety based on the water applied and future water availability. The "dots" above the trendline are the "most water use efficient" for water applied. The dots below the trend line are the "least efficient. Check the yield compared to the water applied and the corresponding table to find the cereal entry(ies) that coincide.

The data tables 2-11 are presented sorted from least amount of water applied to greatest amount of water applied and secondarily, by yield. Yield, harvest date, water applied, and DM yield (pounds) per inch of water applied and inches per ton of DM yield are presented in the tables.

Table 2 data is presented as very early forage produced and in this particular year (1991) very little irrigation water was needed to produce this amount of cereal forage. This data would represent early spring grazing. Winter injury affected some of the entries, some more so than others, in 1991.

Review the yield / water applied graph figures. Then one would choose any entry above the trend line, based on the water availability, and then go to the late boot or soft dough tables to choose the species and variety. Any entry above the trend line will be the most water use efficient for getting the most yield per inch of water applied.

In irrigation water drought years, this is an important selection. In full irrigation water availability years, this selection is not as critical. As irrigation water availability is more restricted in future years, selecting the most water-use-efficient cereal for forage for the water available will become an important part of the selection process.

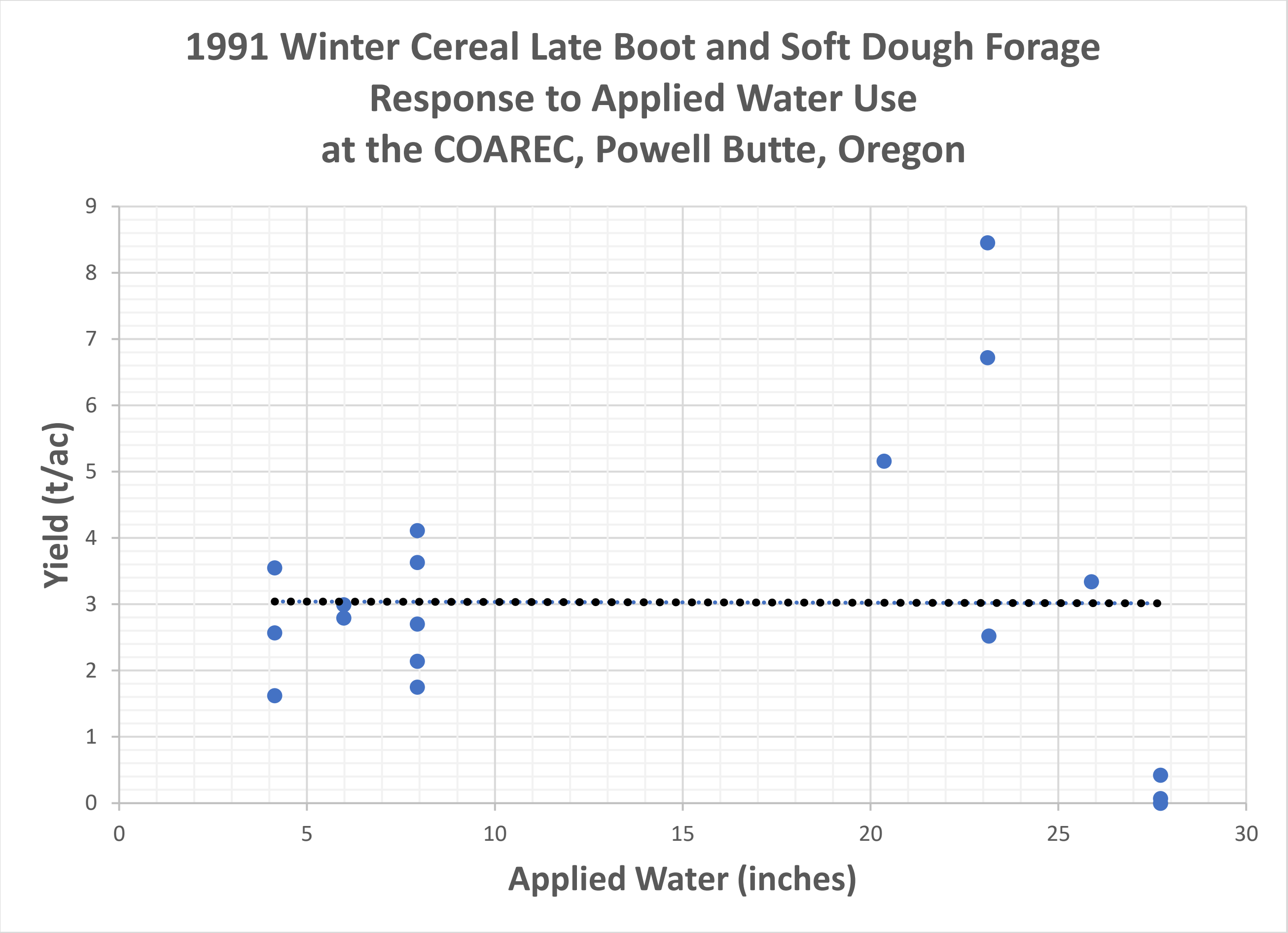
Table 2. 1991 winter cereal forage trial early clipping harvest (May 3) yield, harvest date, water applied, yield (pounds and tons) per inch of water applied at COAREC, Powell Butte, Oregon. (Planted October 24, 1990) (pounds per 0.667 ft2 converted to yield of tons per acre)

1991 Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of Water Applied (lb/in)	Inches of Water Applied per DM Ton Yield (in/t)
Early Clipping Harvest						
Wheeler	Rye	2.16	123	1.38	3,130	0.64
Hancock	Rye	1.56	123	1.38	2,261	0.88
Fall Tripper	Triticale/Pea	1.09	123	1.38	1,580	1.27
Wintri	Triticale	0.98	123	1.38	1,420	1.41
Flora	Triticale	0.82	123	1.38	1,188	1.68
Monopole	HRWW	0.78	123	1.38	1,130	1.77
Stephens	SWWW	0.77	123	1.38	1,116	1.79
Centennial	Triticale	0.62	123	1.38	899	2.23
Yamhill	SWWW	0.58	123	1.38	841	2.38
Rheidol	Rye	0.55	123	1.38	797	2.51
Forty-Fold	SWWW	0.34	123	1.38	493	4.06
Gene	SWWW	0.28	123	1.38	406	4.93
Whitman	Triticale	0.22	123	1.38	319	6.27
Henry	Barley	0.09	123	1.38	130	15.33
Maury	Barley	0.02	123	1.38	29	69.00
Amity	Oat	0.00	123	1.38	0	0.00
Mean		0.68	123	1.38		

1991 Irrigation: 40 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 40 PSI at nozzle, 0.23-inches per hour application rate. Season First irrigation: April 18 (doy 108); Last irrigation: August 28 (doy 236).

Figure 1 presents late boot and soft dough yields compared to irrigation water applied. Regrowth from late boot stage yield and applied water use data are also in table 3, but are not presented in the graph. There was some winter kill that affected some of the species and varieties, which is evident by the yields and applied water use response. DM – dry matter.

Figure 1.



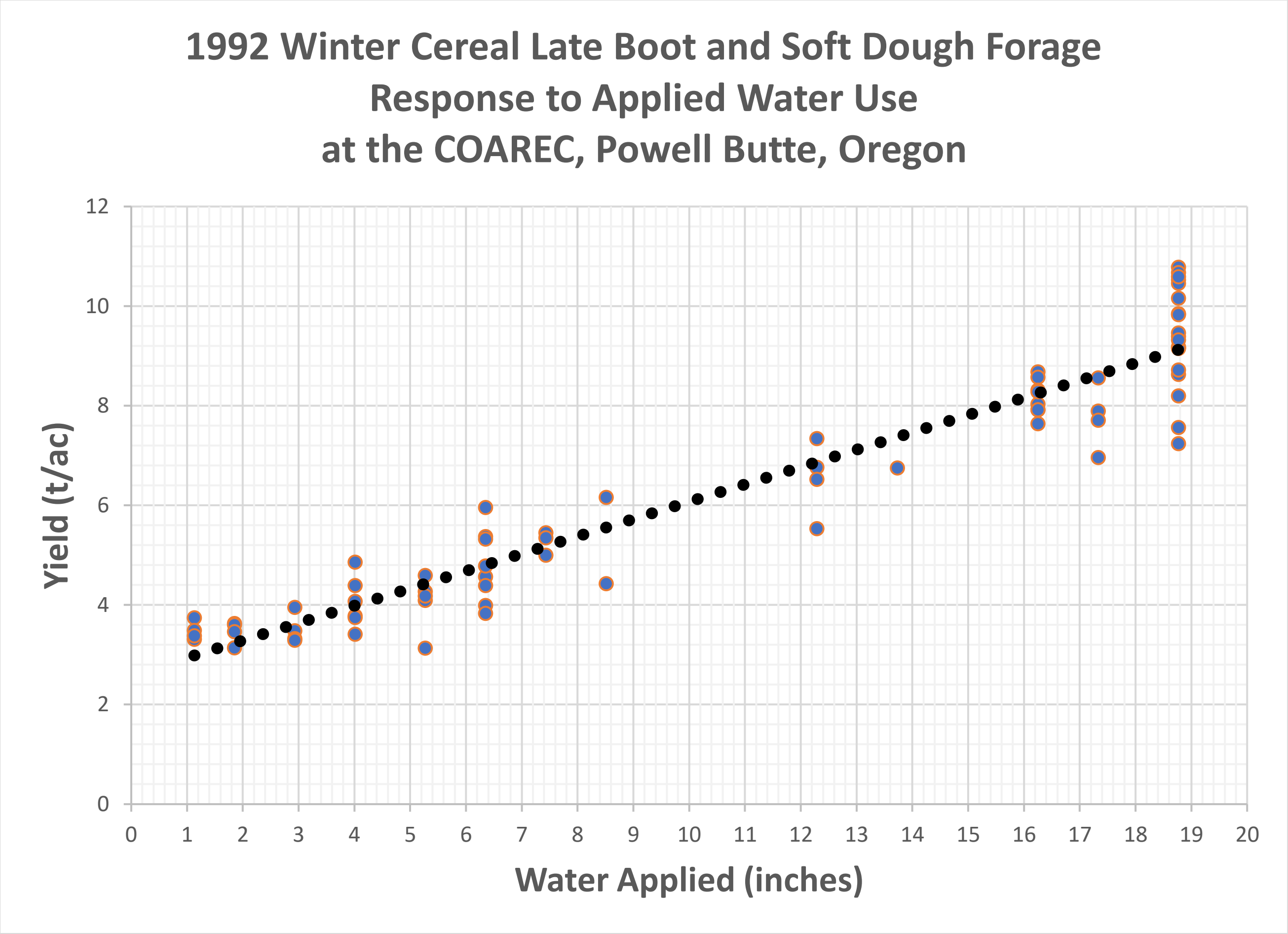
Late boot and soft dough data in this figure are presented in table 3

Table 3. 1991 winter cereal forage trial late boot, soft dough, and regrowth from late boot yield, harvest date, water applied, yield (pounds) per inch of water applied, and inches of water applied per ton DM yield at the COAREC, Powell Butte, Oregon in 1991. (Planted October 24, 1990)

1991 Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of Water Applied (lb/in)	Inches of Water Applied per DM Ton Yield (in/t)
Late Boot Harvest						
Wheeler	Rye	3.55	150	4.14	1,715	1.17
Hancock	Rye	2.57	150	4.14	1,242	1.61
Rheidol	Rye	1.62	150	4.14	783	2.56
Centennial	Triticale	2.99	159	5.98	1,000	1.38
Fall Tripper	Triticale/Pea	4.11	165	7.94	1,035	1.01
Wintri	Triticale	3.63	162	7.94	914	1.14
Flora	Triticale	2.70	161	7.94	680	1.53
Stephens	SWWW	2.14	161	7.94	539	1.93
Whitman	Triticale	1.75	161	7.94	441	2.37
Mean		*2.79*	*158*	*5.98*	*933*	*1.48*
Soft Dough Harvest						
Forty Fold	SWWW	5.16	208	20.36	507	0.80
Monopole	HRWW	8.45	211	23.12	731	0.49
Yamhill	SWWW	6.72	211	23.12	581	0.62
Gene	SWWW	2.52	211	23.15	218	1.64
Henry	Barley	0.42	237	27.72	30	9.86
Maury	Barley	0.07	237	27.72	5	59.14
Amity	Oat	0.00	--	--	--	--
Mean		*3.34*	*222*	*25.88*	*258*	*1.24*
Regrowth from Late Boot Harvest						
Flora	Triticale	1.23	238	13.68	180	3.37
Whitman	Triticale	1.07	239	13.68	156	3.87
Wintri	Triticale	0.67	239	13.68	98	6.18
Fall Tripper	Triticale/Pea	0.62	239	13.68	91	6.68
Stephens	SWWW	0.42	240	13.68	61	9.86
Centennial	Triticale	0.35	240	15.64	45	11.83
Rheidol	Rye	1.92	239	17.48	220	2.16
Hancock	Rye	1.04	240	17.48	119	3.98
Wheeler	Rye	0.92	239	17.48	105	4.50
Mean		*0.92*	*239*	*15.64*	*118*	*4.50*

1991 Irrigation: 40 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 40 PSI at nozzle, 0.23-inches per hour application rate. Season First irrigation: April 18 (day 108); Last irrigation: August 24 (doy 236). DM – dry matter.

Figure 2.



1992 Late boot and soft dough data are presented in tables 5 and 6.

Early harvest of the 1992 cereal for forage trial data is presented in table 4. Data are not presented in figure 2. There was no water applied to the trial prior to harvesting at this growth stage this particular year.

Late boot (table 5) and soft dough (table 6) harvest and water applied data are presented in the figure 2 graph.

First regrowth from late boot stage harvest yield and applied water use data are presented in table 7, which is not included in Figure 2. The amount of regrowth yield value compared to the water applied and power used (maybe additional fertilizer?) expenses would need to be determined whether there was economic benefit. This may be different for different farms and ranches, annually.

Again, the cost benefit would need to be determined for the 2nd regrowth from late boot growth stage data, which is presented in table 8, of which the data were presented in figure 2.

Table 4. 1992 winter cereal forage early clipping harvest (April 23-25) yield, harvest date, water applied, yield (pounds) per inch of water applied, and inches of water applied per DM ton yield at the COAREC, Powell Butte. (Planting Date: October 1991) (pounds per 0.667 ft2 converted to yield tons per acre)

1991 Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield Per Inch of Water Applied (lb/in)	Inches of Water Applied per DM Ton Yield (in/t)
Early Clipping Harvest						
Rheidol	Rye	4.97	115	0	9,940	0
Maury	Barley	4.19	115	0	8,380	0
Wheeler	Rye	4.13	115	0	8,260	0
Hoody	Barley	3.82	115	0	7,640	0
Hancock	Rye	3.80	115	0	7,600	0
Trical 102	Triticale	3.53	115	0	7,060	0
Stephens	SWWW	3.40	115	0	6,800	0
Arnzt	Rye	3.35	115	0	6,700	0
Henry	Barley	3.26	115	0	6,520	0
Baldman	Triticale	3.19	115	0	6,380	0
Rohde	Club SWW	3.15	115	0	6,300	0
Newcale	Triticale	3.09	115	0	6,180	0
Bedortha	Rye	3.08	115	0	6,160	0
Tam 109	HRWW	2.98	115	0	5,960	0
Longhorn	HRWW	2.95	115	0	5,900	0
Monopole	HRWW	2.94	115	0	5,880	0
Wintri	Triticale	2.87	115	0	5,740	0
239	Triticale	2.87	115	0	5,740	0
Forty Fold	SWWW	2.86	115	0	5,720	0
Boyer	Barley	2.80	115	0	5,600	0
Hyak	Club SWW	2.75	115	0	5,500	0
Fall Tripper	Triticale/Pea	2.73	115	0	5,460	0
Cowhand	Triticale	2.72	115	0	5,440	0
Breaker	Triticale	2.69	115	0	5,380	0
Flora	Triticale	2.67	115	0	5,340	0
Whitman	Triticale	2.61	115	0	5,220	0
Centennial	Triticale	2.56	115	0	5,120	0
Gene	SWWW	2.49	115	0	4,980	0
Yamhill	SWWW	2.47	115	0	4,940	0
Pika	Triticale	2.37	115	0	4,740	0
Trical 6600	Triticale	2.36	115	0	4,720	0
Amity	Oat	2.28	115	0	4,560	0
Patriot	Barley	2.23	115	0	4,460	0
Tallman	Triticale	2.11	115	0	42,20	0
Grey Winter	Oat	1.98	115	0	39,60	0
Mean		*2.98*	*115*	*0*	*5,960*	*0*

1991 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.36-inches per hour application rate. Season First irrigation: April 18 (day 108); Last irrigation: August 24 (doy 236). DM – dry matter.

Table 5. 1992 winter cereal forage late boot harvest yield, harvest date, water applied, yield (pounds) per inch of water applied and inches of water applied per DM ton yield at the COAREC, Powell Butte, Oregon. (Planted October 1991)

1991 Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield Per Inch of Water Applied (lb/in)	Inches of Water Applied per DM Ton Yield (in/t)
Late Boot Harvest						
Rheidol	Rye	3.74	119	1.13	6,619	0.30
Hancock	Rye	3.49	120	1.13	6,177	0.32
Bedortha	Rye	3.31	120	1.13	5,858	0.34
Arnzt	Rye	3.38	121	1.13	5,982	0.33
Maury	Barley	3.63	125	1.85	3,924	0.51
Henry	Barley	3.60	125	1.85	3,892	0.51
Wheeler	Rye	3.46	125	1.85	3,741	0.53
Newcale	Triticale	3.14	125	1.85	3,395	0.59
Whitman	Triticale	3.48	127	2.93	2,375	0.84
Cowhand	Triticale	3.32	128	2.93	2,266	0.88
Boyer	Barley	3.29	128	2.93	2,246	0.89
Centennial	Triticale	3.95	129	2.93	2,696	0.74
239	Triticale	4.07	131	4.01	2,030	0.99
Longhorn	SWWW	3.78	131	4.01	1,885	1.06
Patriot	Barley	3.41	131	4.01	1,701	1.18
Hoody	Barley	4.86	132	4.01	2,424	0.83
Fall Tripper	Triticale/Pea	4.39	134	4.01	2,190	0.91
Tam 109	SWWW	3.75	134	4.01	1,870	1.07
Flora	Triticale	3.13	135	5.27	1,188	1.68
Trical 6600	Triticale	4.27	136	5.27	1,620	1.23
Stephens	SWWW	4.09	136	5.27	1,552	1.29
Breaker	Triticale	4.59	138	5.27	1,742	1.15
Baldman	Triticale	5.37	139	6.35	1,691	1.18
Wintri	Triticale	5.32	139	6.35	1,676	1.19
Hyak	Club WW	3.99	139	6.35	1,257	1.59
Gene	SWWW	3.83	139	6.35	1,206	1.66
Trical 102	Triticale	5.96	141	6.35	1,877	1.07
Yamhill	SWWW	4.57	141	6.35	1,439	1.39
Grey Winter	Oat	4.78	142	6.35	1,506	1.33
Rohde	Club WW	4.39	142	6.35	1,383	1.45
Monopole	HRWW	5.00	143	7.43	1,346	1.49
Forty Fold	SWWW	5.45	145	7.43	1,467	1.36
Tallman	Triticale	5.35	146	7.43	1,440	1.39
Pika	Triticale	6.16	148	8.51	1,448	1.38
Amity	Oat	4.43	150	8.51	1,041	1.92
Mean		4.18	134	5.27	1,586	1.26

1992 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.36-inches per hour application rate. Season first irrigation: April 20 (doy 110); last irrigation: October 14 (doy 287). DM – dry matter.

Table 6. 1992 winter cereal forage soft dough harvest yield, harvest date, water applied, yield (pounds) per inch of water applied and inches of water applied per DM ton yield at the COAREC, Powell Butte, Oregon. (Planted October 1991)

1991 Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield Per Inch of Water Applied (lb/in)	Inches of Water Applied per DM Ton Yield (in/t)
Soft Dough Harvest						
Hoody	Barley	7.34	163	12.29	1,194	1.67
Maury	Barley	6.76	163	12.29	1,100	1.82
Henry	Barley	6.52	163	12.29	1,061	1.88
Patriot	Barley	5.53	163	12.29	900	2.22
Boyer	Barley	6.75	169	13.73	983	2.03
Hancock	Rye	8.68	178	16.25	1,068	1.87
Arnzt	Rye	8.57	178	16.25	1,055	1.90
Wheeler	Rye	8.31	178	16.25	1,023	1.96
Bedortha	Rye	8.28	178	16.25	1,019	1.96
Newcale	Triticale	8.03	178	16.25	988	2.02
Forty Fold	SWWW	7.92	178	16.25	975	2.05
Longhorn	HRWW	7.92	179	16.25	975	2.05
Rheidol	Rye	7.64	178	16.25	940	2.13
Amity	Oat	7.89	181	17.33	911	2.20
Grey Winter	Oat	7.71	181	17.33	890	2.25
Hyak	Club SWW	6.96	182	17.33	803	2.49
Breaker	Triticale	10.78	188	18.77	1,149	1.74
Trical 6600	Triticale	10.67	194	18.77	1,137	1.76
Wintri	Triticale	10.59	194	18.77	1,128	1.77
239	Triticale	10.53	190	18.77	1,122	1.78
Monopole	HRWW	10.46	190	18.77	1,115	1.79
Baldman	Triticale	10.16	190	18.77	1,083	1.85
Stephens	SWWW	9.85	186	18.77	1,050	1.91
Flora	Triticale	9.83	187	18.77	1,047	1.91
Cowhand	Triticale	9.46	189	18.77	1,008	1.98
Pika	Triticale	9.39	185	18.77	1,001	2.00
Fall Tripper	Triticale/Pea	9.32	194	18.77	993	2.01
Centennial	Triticale	9.18	189	18.77	978	2.04
Yamhill	SWWW	9.16	188	18.77	976	2.05
Trical 102	Triticale	9.15	191	18.77	975	2.05
Rohde	Club SWW	8.72	192	18.77	929	2.15
Tallman	Triticale	8.63	190	18.77	920	2.17
Tam 109	HRWW	8.20	188	18.77	874	2.29
Gene	SWWW	7.56	185	18.77	806	2.48
Whitman	Triticale	7.24	185	18.77	771	2.59
Mean		8.56	182	17.33	988	2.02

1992 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.36-inches per hour application rate. Season first irrigation: April 20 (doy 110); last irrigation: October 14 (doy 287). DM – dry matter.

Table 7. 1992 First regrowth harvest from late boot stage of the winter cereal forage yield, harvest date, water applied, yield (pounds) per inch of water applied and inches of water applied per DM ton yield at the COAREC, Powell Butte, Oregon. (Planted October 1991)

1991 Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield Per Inch of Water Applied (lb/in)	Inches of Water Applied per DM Ton Yield (in/t)
First Regrowth Harvest from Late Boot Harvest						
Amity	Oat	1.05	200	11.34	185	10.80
Maury	Barley	1.02	175	12.96	157	12.71
Henry	Barley	0.96	174	12.96	148	13.50
Patriot	Barley	0.75	185	13.32	113	17.76
Hoody	Barley	0.61	185	13.32	92	21.84
Grey Winter	Oat	1.03	200	13.50	153	13.11
Boyer	Barley	0.69	193	15.84	87	22.96
Forty Fold	SWWW	0.61	219	17.82	68	29.21
Longhorn	HRWW	1.11	206	18.00	123	16.22
Newcale	Triticale	0.94	200	18.00	104	19.15
Tam 109	HRWW	0.89	206	18.00	99	20.22
Hyak	Club SWW	0.39	218	18.09	43	46.38
Rheidol	Rye	1.67	200	18.72	178	11.21
Trical 102	Triticale	0.75	219	18.90	79	25.20
Gene	SWWW	0.51	224	20.34	50	39.88
Rohde	Club SWW	0.42	225	20.34	41	48.43
Monopole	HRWW	1.04	226	20.70	100	19.90
Tallman	Triticale	0.41	234	21.42	38	52.24
Baldman	Triticale	0.98	231	21.78	90	22.22
Yamhill	SWWW	0.72	227	21.78	66	30.25
Pika	Triticale	0.53	240	21.78	49	41.09
Wintri	Triticale	0.97	234	22.50	86	23.20
Flora	Triticale	0.90	231	22.86	79	25.40
Trical 6600	Triticale	0.48	229	22.86	42	47.63
Stephens	SWWW	0.42	227	22.86	37	54.43
Arnzt	Rye	1.12	215	23.04	97	20.57
Hancock	Rye	0.93	214	23.04	81	24.77
Cowhand	Triticale	0.87	222	23.04	76	26.48
Whitmin	Triticale	0.80	221	23.04	69	28.80
Breaker	Triticale	0.54	234	23.58	46	43.67
Wheeler	Rye	0.92	222	24.12	76	26.22
Fall Tripper	Triticale/Pea	0.76	232	24.12	63	31.74
Bedortha	Rye	0.92	222	24.84	74	27.00
239	Triticale	0.49	234	24.84	39	50.69
Centennial	Triticale	0.79	227	25.20	63	31.90
Mean		0.79	216	18.90	84	23.92

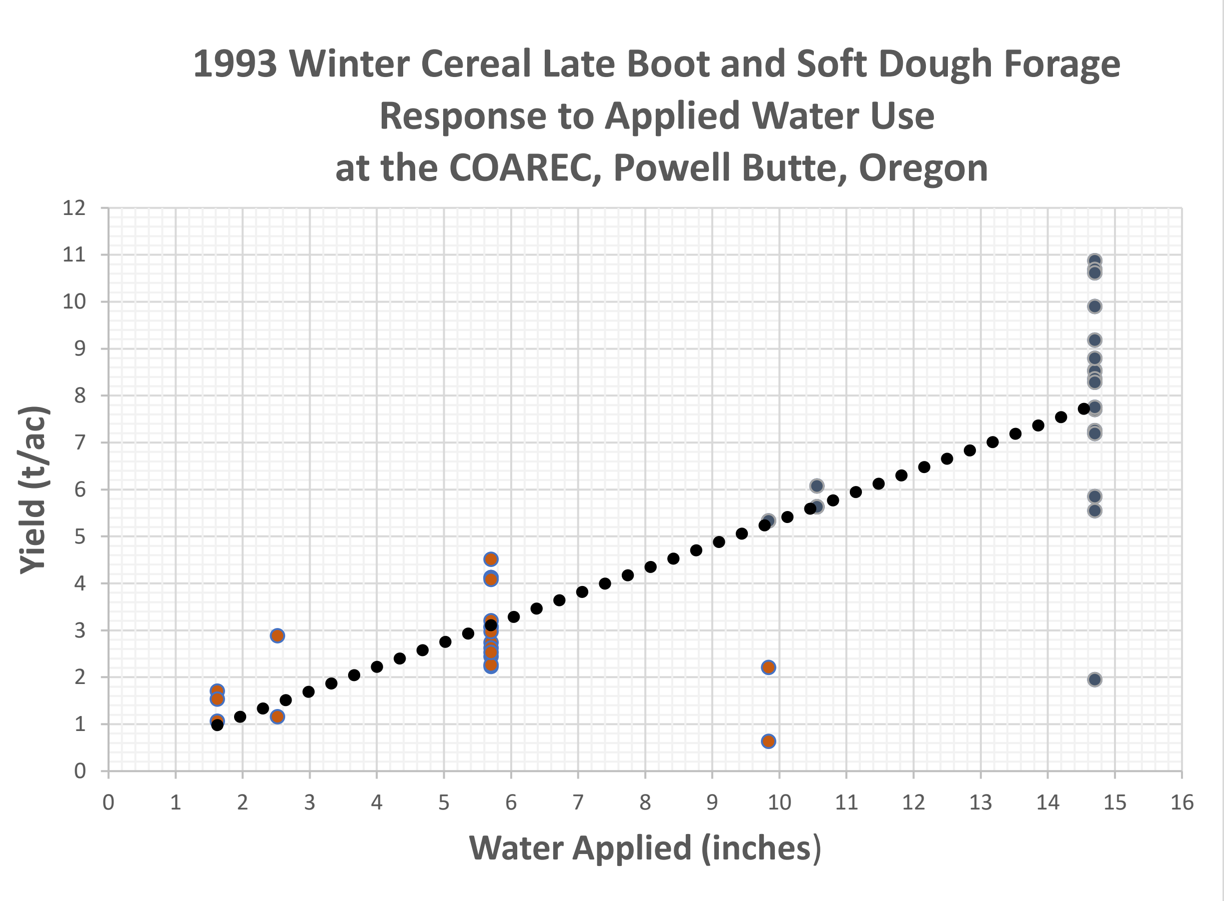
1992 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.36-inches per hour application rate. Season first irrigation: April 20 (doy 110); last irrigation: October 14 (doy 287). DM – dry matter.

Table 8. 1992 second regrowth harvest of the winter cereal forage yield, harvest date, water applied, yield (pounds) per inch of water applied and inches of water applied per DM ton yield at COAREC, Powell Butte, Oregon. (Planted October 1991)

1992 Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of Water Applied (lb/in)	Inches of Water Applied per DM Ton Yield (in/t)
Second Regrowth Harvest from Late Boot Harvest						
Grey Winter	Oat	0.64	287	16.38	78.1	25.59
Amity	Oat	0.59	287	16.38	72.0	27.76
Mean		0.62	287	16.38	75.7	26.42

1992 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.36-inches per hour application rate. Season first irrigation: April 20 (doy 110); last irrigation: October 14 (doy 287). DM – dry matter.

Figure 3.



1993 late boot and soft dough data are presented in tables 9 and 10.

Late boot and soft dough stage yields and applied water use data are presented in Table 9 and 10. Of which the data is presented also in figure 3.

Regrowth from late boot growth stage yields and applied water use are presented in table 11. These data are not presented in figure 3.

Table 9. 1993 winter cereal forage late boot harvest yield, harvest date, water applied, yield (pounds) per inch of water applied and inches of water applied per DM ton yield at the COAREC, Powell Butte, Oregon. (Planted October 15, 1992)

1993 Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of Water Applied (lb/in)	Inches of Water Applied per DM Ton Yield (in/t)
Late Boot Harvest						
Wheeler	Rye	1.70	138	1.62	2,099	0.95
Rheidol	Rye	1.53	138	1.62	1,889	1.06
Hancock	Rye	1.06	138	1.62	1,309	1.53
Henry	Barley	2.88	143	2.52	2,286	0.88
Maury	Barley	1.16	142	2.52	921	2.17
Pika	Triticale	4.51	165	5.70	1,582	1.26
Trical 102	Triticale	4.12	162	5.70	1,446	1.38
Breaker	Triticale	4.12	162	5.70	1,446	1.38
Forty Fold	SWWW	4.08	163	5.70	1,432	1.40
Apollo	HRWW	3.20	164	5.70	1,123	1.78
Monopole	HRWW	3.07	163	5.70	1,077	1.86
Yamhill	SWWW	3.06	163	5.70	1,074	1.86
Hoody	Barley	2.97	163	5.70	1,042	1.92
Whitman	Triticale	2.74	153	5.70	961	2.08
Gene	SWWW	2.62	159	5.70	919	2.18
Longhorn	HRWW	2.44	153	5.70	856	2.34
Patriot	Barley	2.26	159	5.70	793	2.52
Tam 109	HRWW	2.23	153	5.70	782	2.56
Grey Winter	Oat	2.21	176	9.84	449	4.45
Amity	Oat	0.63	176	9.84	128	15.62
Mean		2.53	157	5.70	888	2.25

1993 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.36-inches per hour application rate. Season first irrigation: May 12 (doy 132); last irrigation: July 30 (doy 211). DM – dry matter.

Table 10. 1993 winter cereal forage soft dough harvest yield, harvest date, water applied, yield (pounds) per inch of water applied and inches of water applied per DM ton yield at the COAREC, Powell Butte, Oregon. (Planted October 15, 1992)

1993 Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of water applied (lb/day)	Inches of Water Applied per DM Ton Yield (in/t)
Soft Dough Harvest						
Maury	Barley	5.33	180	9.84	1,083	1.85
Hoody	Barley	6.07	188	10.56	1,150	1.74
Henry	Barley	5.63	184	10.56	1,066	1.88
Patriot	Barley	5.63	186	10.56	1,066	1.88
Breaker	Triticale	10.87	206	14.70	1,479	1.35
Trical 102	Triticale	10.69	206	14.70	1,454	1.38
Pika	Triticale	10.61	206	14.70	1,444	1.39
Forty Fold	SWWW	9.90	202	14.70	1,347	1.48
Rheidol	Rye	9.18	202	14.70	1,249	1.60
Whitman	Triticale	8.79	206	14.70	1,196	1.67
Longhorn	HRWW	8.54	202	14.70	1,162	1.72
Yamhill	SWWW	8.52	202	14.70	1,159	1.73
Hancock	Rye	8.36	202	14.70	1,137	1.76
Monopole	SWWW	8.28	202	14.70	1,127	1.78
Tam 109	SWWW	7.70	202	14.70	1,048	1.91
Apollo	SWWW	7.25	202	14.70	986	2.03
Gene	SWWW	7.19	202	14.70	978	2.04
Grey Winter	Oat	5.85	209	14.70	796	2.51
Wheeler	Rye	5.55	202	14.70	755	2.65
Amity	Oat	1.95	209	14.70	265	7.54
Mean		7.75	200	14.70	1054	1.90

1993 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.36-inches per hour application rate. Season - first irrigation: May 12 (doy 132); last irrigation: July 30 (doy 211).
DM – dry matter.

Table 11. Winter cereal forage regrowth from late boot harvest yield, harvest date, water applied, yield (pounds) per inch of water applied and inches of water applied per DM ton yield at the COAREC, Powell Butte, Oregon in 1993. (Planted October 15, 1992)

1993 Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of Water Applied (lb/in)	Inches of Water Applied per DM Ton Yield (in/t)
Regrowth from Late Boot Harvest						
Grey Winter	Oat	1.13	218	6.30	359	5.58
Amity	Oat	0.45	218	6.30	143	14.00
Trical 102	Triticale	2.66	218	10.44	510	3.92
Whitman	Triticale	2.36	218	10.44	452	4.42
Patriot	Barley	1.56	218	10.44	299	6.69
Hoody	Barley	1.51	218	10.44	289	6.91
Longhorn	HRWW	1.39	218	10.44	266	7.51
Gene	SWWW	1.21	218	10.44	232	8.63
Tam 109	HRWW	1.20	218	10.44	230	8.70
Forty Fold	SWWW	1.03	218	10.44	197	10.14
Monopole	HRWW	0.96	218	10.44	184	10.88
Yamhill	SWWW	0.92	218	10.44	176	11.35
Pika	Triticale	0.81	218	10.44	155	12.89
Breaker	Triticale	0.76	218	10.44	146	13.74
Apollo	HRWW	0.73	218	10.44	140	14.30
Hancock	Rye	2.82	218	12.90	437	4.57
Maury	Barley	2.24	218	13.62	329	6.08
Henry	Barley	2.00	218	13.62	294	6.81
Rheidol	Rye	3.90	218	14.52	537	3.72
Wheeler	Rye	3.19	218	14.80	431	4.64
Mean		1.64	218	10.44	314	6.37

1993 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.36-inches per hour application rate. Season first irrigation: May 12 (doy 132); last irrigation: July 30 (doy 211). DM - dry matter.

Conclusion

When full to especially limited irrigation water availability is known, whether full season for reduced acres to early turnoff for all acres, this cereal forage applied water use information can aid a producer in choosing which species and variety would be the best choice to plant to produce forage.

Literature Cited

Bohle, M. Ballerstedt, P., Dovel, R., Karow, R, and Hannaway, D. (2002) Winter cereal forage varieties for central Oregon. Central Oregon Ag Research Center Annual Report. Oregon State University Ag Experiment Station. Special Report 1046. 33 pages. https://agsci.oregonstate.edu/sites/agscid7/files/coarec/publications/02_winter_cereal_forage.pdf

Spring Cereal Forage Applied Water Use

Mylen Bohle and David Hannaway

Introduction

Depending on winter and spring precipitation, the amount of irrigation water applied to spring cereals will be dramatically different in the late spring to early summer periods. There have been years when there was no spring soil moisture at planting time. During a few years, there has been enough winter, spring, and early summer moisture to harvest a large amount of forage with little to no irrigation.

Spring cereals grown for forage can provide a large quantity of fair-to-moderate quality forage for livestock, especially in years of plentiful water. But when drought continues, year after year, irrigation water availability is a huge issue. Irrigated and dryland forage production decreases dramatically, and livestock may need to be sold prematurely. Emergency feed production from cereal species can be a partial solution to producing emergency feed. If winter cereals were not planted in the fall to help with maintaining or increasing forage needed for livestock, an alternative is planting spring cereals to utilize any late winter to early summer precipitation, along with irrigation.

If limited irrigation water availability quantity is known, this information can aid producers in choosing which spring cereal species and varieties would be the best choice to plant to produce forage. **Please note, some varieties may no longer be available.*

Materials and Methods

The following oat, barley, wheat, rye, and triticale spring cereal data are from the 1990-1993 cereal species and variety trials planted at the Central Oregon Ag Research and Extension Center at Powell Butte, Oregon. More extensive description of materials and methods are provided in Bohle et al, (2002). The station irrigation records were accessed with solid-set spacing dimensions, nozzle size, nozzle pressure, and the number of hours for each event. Thus, inches-per-hour of water applied was able to be calculated. The hours were converted to inches per irrigation.

Harvest dates, at late-boot or soft-dough growth stage, were used to subtract irrigation events back 6-9 days to previous irrigation events to allow a suitable time for the dry-down of the foliage and soil so harvest could occur. Yield was divided by total inches of water applied to document applied water use to determine yield per inch of water applied. Water applied was divided by yield (tons) to determine inches per ton of dry matter produced.

Note: Due to the way the irrigation system was constructed at the Powell Butte site, extra lines were often needed to reduce line-pressure. This resulted in extra water applied in some years. Due to the lack of an on-site weather station, rain and snow precipitation was not considered as part of the water used by the cereals.

Table 1 is a partial calendar of "day of year" dates to help assess water use was during that month.

Table 1. Day of year (doy) from January 1, starting with April 1 to September 1, for the spring cereal forage planting date day of year, 1990 – 1993.

Year	Apr. 1	Planting Date (doy*)	May 1	Jun. 1	Jul. 1	Aug. 1	Sep. 1
1990	91	96	121	152	182	213	244
1991	91	113	121	152	182	213	244
1992	92	97	122	153	183	214	245
1993	91	125	121	152	183	213	244

*doy – day of year from January 1.

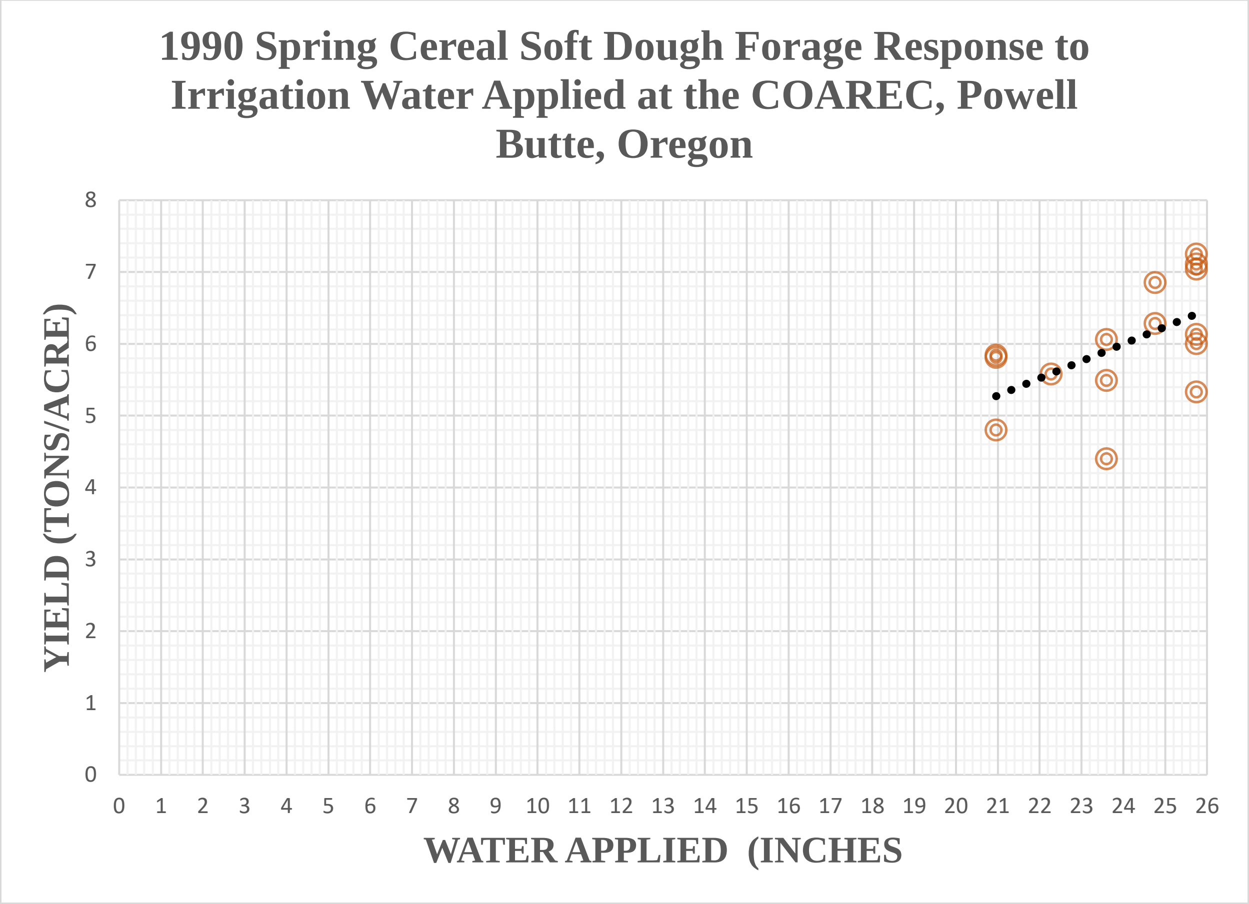
Results and Discussion

Figures 1 to 4 are graphs with linear regression trendlines for yields and applied water use. The "dots" above the trendline are the "most water use efficient" for water applied. The dots below the trend line are the "least efficient." Check the yield compared to the water applied and the corresponding table to find the cereal entry(ies) that coincide.

The data tables (Tables 2 to 8) are sorted from least amount of water applied to greatest amount of water applied, and secondarily by yield. Late-boot and soft-dough growth stage yield, harvest date, water applied, and dry matter yield in pounds per inch of water applied, and inches per ton are presented in Tables 2 to 7. Table 8 is 1993 regrowth from late-boot harvest.

Review the graphs or tables and choose the amount of available water for the season. Then, choose the highest yield within the water applied amount to make the choice of what is the best species and variety to plant. In irrigation water drought years, this is an important selection. In full irrigation water availability years, this selection is not as critical. As irrigation water availability is more restricted in future years, selecting the most water-use-efficient cereal for forage for the water available will become an important part of the selection process.

Figure 1.



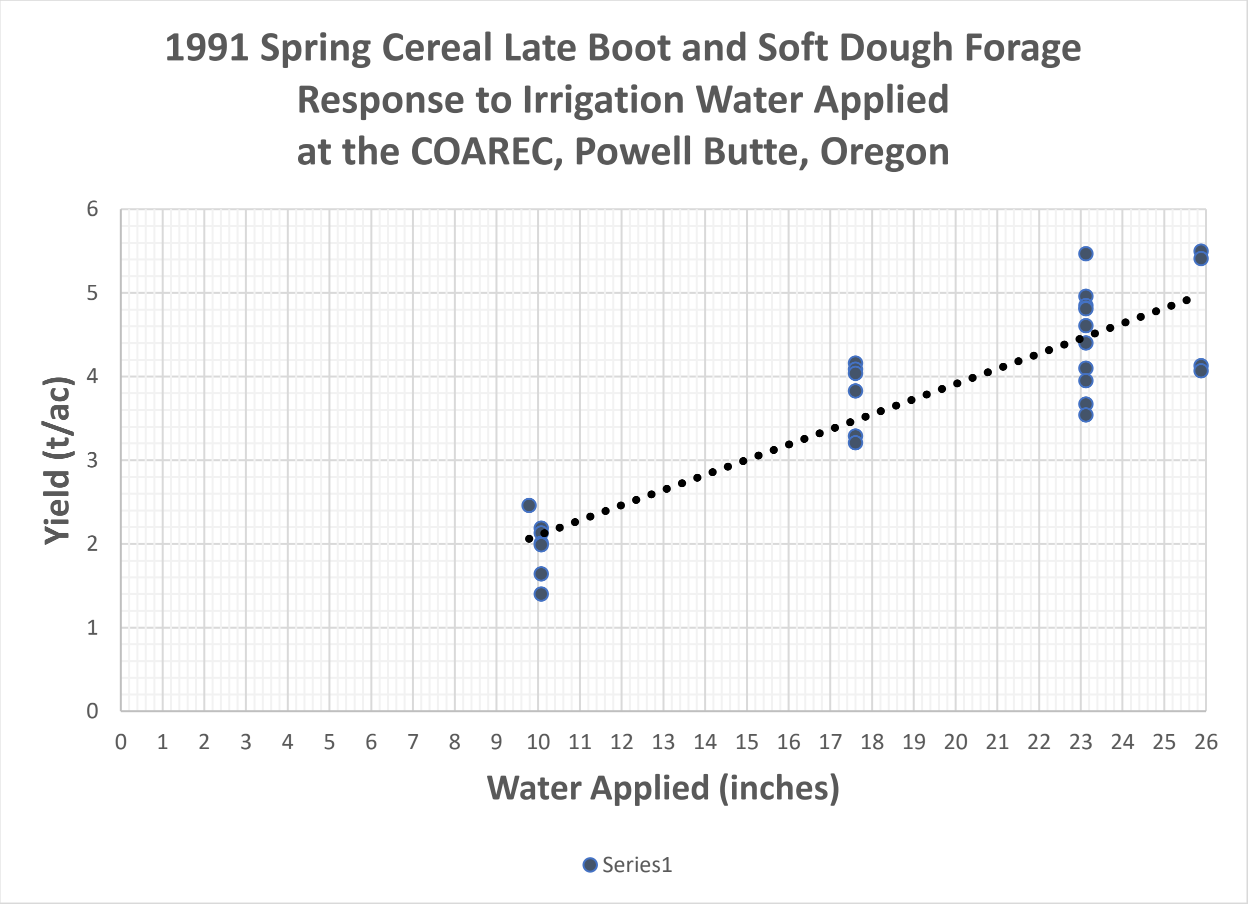
Data for this figure are in Table 2.

Table 2. 1990 spring cereal forage trial soft dough harvest yield, harvest date, water applied, yield (pounds per inch and inches per ton) per inch of water applied at the COAREC, Powell Butte, Oregon. (Planted April 6, doy - 96)

Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of Water Applied (lb/in)	DM Yield per inch of Water Applied (in/t)
Soft Dough Harvest						
Westford	Barley	5.84	202	20.96	557	3.59
Haybet	Barley	5.81	198	20.96	554	3.61
Whitford	Barley	4.80	198	20.96	458	4.37
Koldbar	Barley	5.58	202	22.28	501	3.99
Cayuse	Oat	6.06	207	23.60	514	3.89
Kanota	Oat	5.49	207	23.60	465	4.30
Belford	Barley	4.40	204	23.60	373	5.36
Otana	Oat	6.85	210	24.76	553	3.61
Swan	Oat	6.28	209	24.76	507	3.94
Juan	Triticale	7.25	213	25.75	563	3.55
Monida	Oat	7.11	211	25.75	552	3.62
Karl	Triticale	7.04	212	25.75	547	3.66
Twin	SWSW	6.13	213	25.75	476	4.20
Dirkwin	SWSW	6.00	213	25.75	466	4.29
Sierra	Oat	5.33	212	25.75	414	4.83

1990 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at Nozzle, 0.36-inches per hour application rate. Season First irrigation: April 13; Last irrigation: August 15. DM – dry matter.

Figure 2.



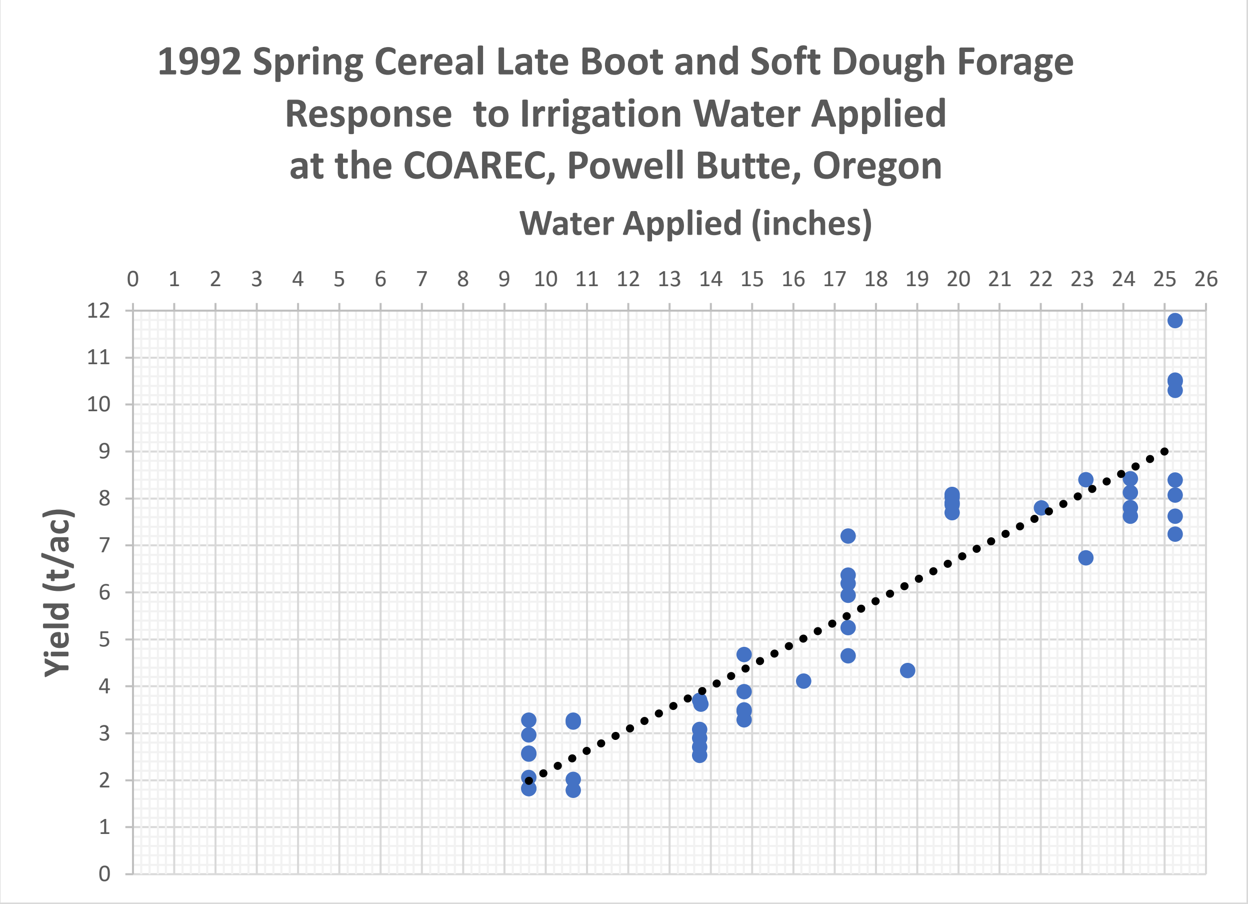
Data for this figure are in Table 3.

Table 3. 1991 spring cereal forage trial yield, harvest date, water applied, yield (pounds per inch and inches per ton) of water applied at the COAREC, Powell Butte, Oregon. (Planted April 22, doy - 113)

Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of Water Applied (lb/in)	DM Yield per inch of Water Applied (in/t)
Late Boot Harvest						
Gazelle	Rye	2.46	177	9.78	503	3.98
Juan	Triticale	2.19	186	10.07	435	4.60
Common	Rye	2.13	183	10.07	423	4.73
Grace	Triticale	2.01	186	10.07	399	5.01
Eronga 83	Triticale	1.99	184	10.07	395	5.06
Karl	Triticale	1.64	183	10.07	326	6.14
Alamos 83	Triticale	1.40	183	10.07	278	7.19
Soft Dough Harvest						
Belford	Barley	4.16	204	17.6	473	4.23
Koldbar	Barley	4.09	204	17.6	465	4.30
Haybet	Barley	4.04	204	17.6	459	4.36
Unkown	Barley	3.83	204	17.6	435	4.60
Westford	Barley	3.29	204	17.6	374	5.35
Whitford	Barley	3.21	204	17.6	365	5.48
Otana	Oat	5.47	215	23.12	473	4.23
Monida	Oat	4.96	214	23.12	429	4.66
Texas Red	Oat	4.85	217	23.12	420	4.77
Montezuma	Oat	4.82	214	23.12	417	4.80
Riel	Oat	4.81	216	23.12	416	4.81
Swan	Oat	4.61	214	23.12	399	5.02
Kanota	Oat	4.40	214	23.12	381	5.25
Park	Oat	4.10	216	23.12	355	5.64
Grizzley	Oat	3.95	217	23.12	342	5.85
Sierra	Oat	3.67	215	23.12	317	6.30
Cayuse	Oat	3.54	214	23.12	306	6.53
Dirkwin	SWSW	5.50	221	25.88	425	4.71
Twin	SWSW	5.41	221	25.88	418	4.78
Stampede	Oat	4.13	221	25.88	319	6.27
Winter Grey	Oat	4.07	221	25.88	315	6.36

1991 Irrigation: 40 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 40 PSI at nozzle, 0.23-inches per hour application rate. Season First irrigation: April 18; Last irrigation: September 20. DM – dry matter.

Figure 3.



Data for this graph are in Tables 4 and 5.

Table 4. 1992 spring cereal forage late boot harvest yield, harvest date, water applied, yield (pounds per inch and inches per ton) per inch of water applied at the COAREC, Powell Butte, Oregon. (Planted April 6, doy - 97)

Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of Water Applied (lb/in)	DM Yield per inch of Water Applied (ton/in)
Late Boot Harvest						
Chopper	Barley	3.28	159	9.59	684	2.92
Wiemer	Barley	2.97	159	9.59	619	3.23
Montezuma	Oat	2.58	159	9.59	538	3.72
Gazelle	Rye	2.56	156	9.59	534	3.75
Bedortha	Rye	2.06	158	9.59	430	4.66
Arnzt	Rye	1.83	159	9.59	382	5.24
Common	Rye	1.82	159	9.59	380	5.27
Karl	Triticale	3.28	161	10.67	615	3.25
Belford	Barley	3.24	162	10.67	607	3.29
Eronga 83	Triticale	2.02	162	10.67	379	5.28
Alamos 83	Triticale	1.79	161	10.67	336	5.96
Fortuna	HRSW	3.70	168	13.73	539	3.71
Glenman	HRSW	3.08	169	13.73	449	4.46
Grace	Triticale	2.90	169	13.73	422	4.73
Dirkwin	SWSW	2.71	170	13.73	395	5.07
Juan	Triticale	2.53	168	13.73	369	5.43
Mondia	Oat	3.62	168	13.76	526	3.80
Westford	Barley	4.68	170	14.81	632	3.16
Texas Red	Oat	3.89	173	14.81	525	3.81
Lew	HRSW	3.50	170	14.81	473	4.23
Trical 2700	Triticale	3.47	170	14.81	469	4.27
Riel	Oat	3.29	171	14.81	444	4.50
Grizzley	Oat	4.11	175	16.25	506	3.95
Winter Grey	Oat	4.65	183	17.33	537	3.73
Stampede	Oat	4.34	189	18.77	462	4.32

1992 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.36-inches per hour application rate. Season First irrigation: April 20; Last irrigation: August 6.

DM – dry matter.

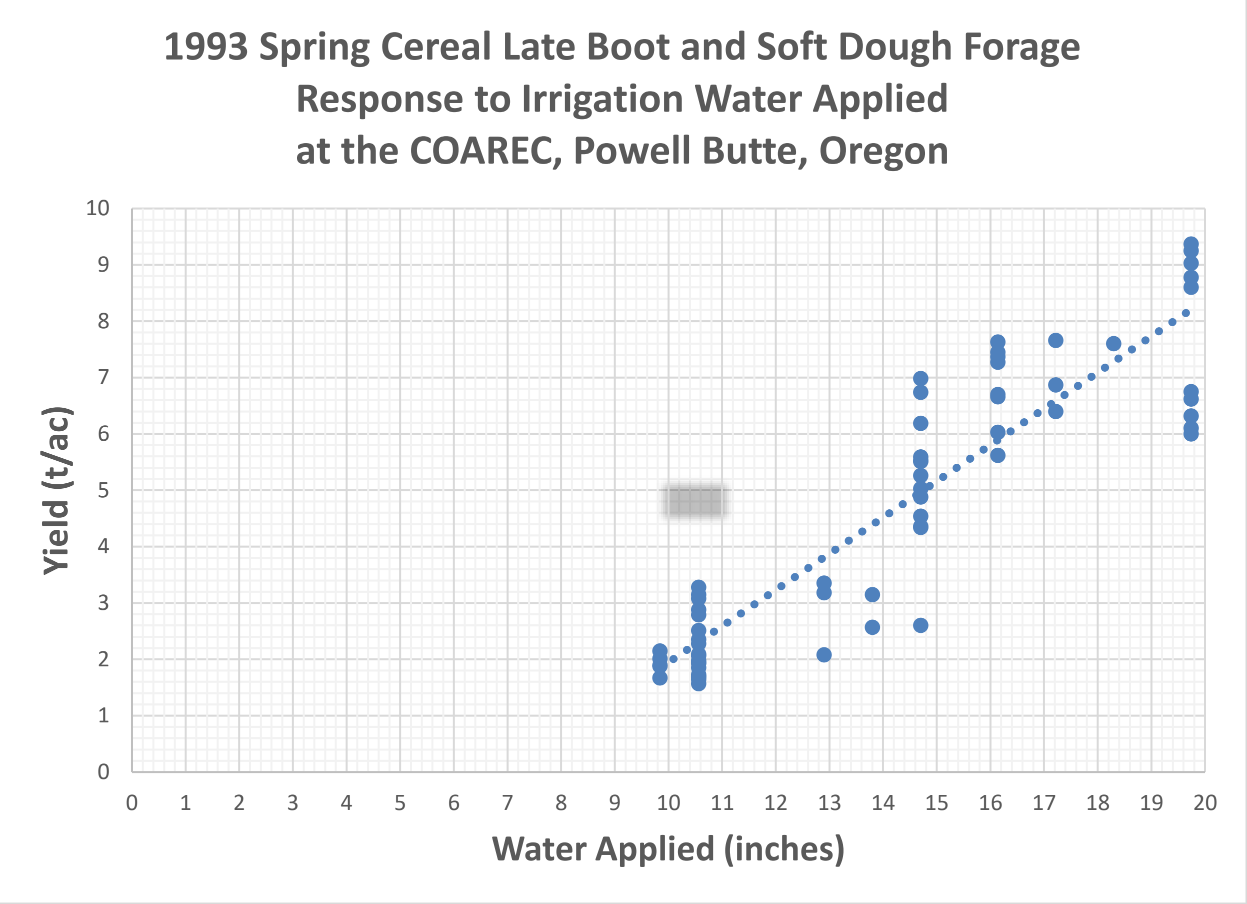
Table 5. 1992 spring cereal forage soft dough harvest yield, harvest date, water applied, yield (pounds per inch and inches per ton) per inch of water applied at the COAREC, Powell Butte, Oregon. (Planted April 6, doy - 97)

Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of Water Applied (lb/in)	DM Yield per inch of Water Applied (in/t)
Soft Dough Harvest						
Westford	Barley	7.20	184	17.33	831	2.41
Belford	Barley	6.37	184	17.33	735	2.72
Chopper	Barley	6.19	183	17.33	714	2.80
Montezuma	Oat	5.94	184	17.33	686	2.92
Wiemer	Barley	5.25	184	17.33	606	3.30
Monida	Oat	8.09	199	19.85	815	2.45
Texas Red	Oat	8.03	199	19.85	809	2.47
Grizzley	Oat	7.91	199	19.85	797	2.51
Fortuna	HRSW	7.87	199	19.85	793	2.52
Riel	Oat	7.70	199	19.85	776	2.58
Lew	HRSW	7.80	209	22.01	709	2.82
Stampede	Oat	8.40	212	23.09	728	2.75
Winter Grey	Oat	6.74	212	23.09	584	3.43
Karl	Triticale	8.42	216	24.17	697	2.87
Glenman	HRSW	8.13	216	24.17	673	2.97
Alamos 83	Triticale	7.81	216	24.17	646	3.09
Dirkwin	SWSW	7.62	216	24.17	631	3.17
Juan	Triticale	11.79	218	25.25	934	2.14
Grace	Triticale	10.52	217	25.25	833	2.40
Trical 2700	Triticale	10.49	218	25.25	831	2.41
Eronga 83	Triticale	10.30	219	25.25	816	2.45
Arnzt	Rye	8.39	219	25.25	665	3.01
Common	Rye	8.07	219	25.25	639	3.13
Bedortha	Rye	7.62	218	25.25	604	3.31
Gazelle	Rye	7.24	219	25.25	573	3.49

1992 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.23-inches per hour application rate. Season First irrigation: April 20; Last irrigation: August 6.

DM – dry matter.

Figure 4.



Data for this figure are in Tables 6 and 7.

Table 6. 1993 spring cereal forage late boot harvest yield, harvest date, water applied, yield (pounds per inch and inches per ton) per inch of water applied at the COAREC, Powell Butte, Oregon in 1993. (Planted May 4, doy - 125)

Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of Water Applied (lb/in)	DM Yield per inch of Water Applied (ton/in)
Late Boot Harvest						
Montezuma	Oat	2.15	179	9.84	437	4.58
Faust	Barley	2.01	181	9.84	409	4.90
Gazelle	Rye	1.89	179	9.84	384	5.21
Swan	Oat	1.88	179	9.84	382	5.23
Alberta	Barley	1.67	183	9.84	339	5.89
Cayuse	Oat	3.28	188	10.56	621	3.22
Otana	Oat	3.15	189	10.56	597	3.35
Mondia	Oat	3.08	189	10.56	583	3.43
Magnum II	Oat	2.88	188	10.56	545	3.67
Ajay	Oat	2.79	188	10.56	528	3.78
Haybet	Barley	2.51	186	10.56	475	4.21
Twin	SWSW	2.35	190	10.56	445	4.49
Dirkwin	SWSW	2.28	189	10.56	432	4.63
Belford	Barley	2.09	188	10.56	396	5.05
Eureka	Barley	2.06	186	10.56	390	5.13
Fortuna	HRSW	1.98	186	10.56	375	5.33
Juan	Triticale	1.94	190	10.56	367	5.44
Nepal	Barley	1.93	186	10.56	366	5.47
Lew	HRSW	1.85	188	10.56	350	5.71
Florida 201	Triticale	1.73	188	10.56	328	6.10
Eronga 83	Triticale	1.70	188	10.56	322	6.21
Frank	Triticale	1.68	188	10.56	318	6.29
Meloy	Barley	1.64	186	10.56	311	6.44
Glenman	HRSW	1.57	187	10.56	297	6.73
Ensiler	Oat	3.35	192	12.90	519	3.85
Park	Oat	3.18	192	12.90	493	4.06
Rid Awn	Barley	2.08	191	12.90	322	6.20
Westford	Barley	3.15	195	13.80	457	4.38
Trical 2700	Triticale	2.57	195	13.80	372	5.37
Magnum	Oat	4.54	202	14.70	618	3.24
Stampede	Oat	4.36	205	14.70	593	3.37
Whitman	Triticale	2.60	206	14.70	354	5.65

1993 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.23-inches per hour application rate. Season First irrigation: May 12; Last irrigation: September 10. DM – dry matter.

Table 7. Spring cereal forage soft dough harvest yield, harvest date, water applied, yield (pounds per inch and inches per ton) per inch of water applied at the COAREC, Powell Butte, Oregon in 1993. Planted May 4, doy - 125)

Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Water Applied (in)	DM Yield per inch of Water Applied (lb/in)	DM Yield per inch of Water Applied (in/t)
Soft Dough Harvest						
Cayuse	Oat	6.98	214	14.70	950	2.11
Ajay	Oat	6.74	214	14.70	917	2.18
Montezuma	Oat	6.19	209	14.70	842	2.37
Eureka	Barley	5.59	213	14.70	761	2.63
Swan	Oat	5.53	209	14.70	752	2.66
Meloy	Barley	5.51	213	14.70	750	2.67
Haybet	Barley	5.26	213	14.70	716	2.79
Nepal	Barley	5.03	213	14.70	684	2.92
Faust	Barley	4.88	209	14.70	664	3.01
Alberta	Barley	4.34	209	14.70	590	3.39
Ensiler	Oat	7.63	217	16.14	945	2.12
Magnum II	Oat	7.45	217	16.14	923	2.17
Mondia	Oat	7.37	217	16.14	913	2.19
Park	Oat	7.27	217	16.14	901	2.22
Otana	Oat	6.70	217	16.14	830	2.41
Westford	Barley	6.66	217	16.14	825	2.42
Belford	Barley	6.03	217	16.14	747	2.68
Rid Awn	Barley	5.62	216	16.14	696	2.87
Magnum	Oat	7.66	225	17.22	890	2.25
Stampede	Oat	6.87	225	17.22	798	2.51
Fortuna	HRSW	6.40	225	17.22	743	2.69
Gazelle	Rye	7.60	228	18.30	831	2.41
Eronga 83	Triticale	9.37	242	19.74	949	2.11
Juan	Triticale	9.25	244	19.74	937	2.13
Trical 2700	Triticale	9.03	249	19.74	915	2.19
Frank	Triticale	8.78	242	19.74	890	2.25
Florida 201	Triticale	8.60	242	19.74	871	2.30
Whitman	Triticale	6.75	249	19.74	684	2.92
Dirkwin	SWSW	6.62	231	19.74	671	2.98
Twin	SWSW	6.32	230	19.74	640	3.12
Glenman	HRSW	6.10	231	19.74	618	3.24
Lew	HRSW	6.00	231	19.74	608	3.29

1993 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.23-inches per hour application rate. Season First irrigation: May 12; Last irrigation: September 10. DM – dry matter.

Table 8. 1993 spring cereal forage regrowth from late boot harvest yield, harvest date, days after late boot harvest, days after late boot harvest, and DM yield (pounds per day) regrowth at the COAREC, Powell Butte, Oregon. (Planted May 4, doy -125)

Variety	Species	DM Yield (t/ac)	Harvest Date (doy)	Days After Late Boot Harvest (days)	DM Yield per day of regrowth (lb/day)
Regrowth From Late Boot Harvest					
Montezuma	Oat	2.55	237	35	146
Swan	Oat	2.49	237	32	156
Monida	Oat	2.42	243	51	95
Florida 201	Triticale	2.40	255	67	72
Ajay	Oat	2.33	243	51	91
Otana	Oat	2.25	243	54	83
Eronga 83	Triticale	2.13	255	60	71
Cayuse	Oat	1.93	243	54	71
Gazelle	Rye	1.82	249	61	60
Magnum II	Oat	1.54	243	55	56
Glenman	HRSW	1.47	249	43	68
Park	Oat	1.37	243	48	57
Frank	Triticale	1.30	255	69	38
Ensiler	Oat	1.24	247	57	44
Whitman	Triticale	1.14	255	66	35
Rid Awn	Barley	1.08	241	62	35
Dirkwin	SWSW	1.06	249	61	35
Meloy	Barley	1.05	237	46	46
Belford	Barley	0.96	237	51	38
Twin	SWSW	0.96	249	68	28
Lew	HRSW	0.94	249	63	30
Juan	Triticale	0.92	255	65	28
Faust	Barley	0.88	237	51	35
Fortuna	HRSW	0.85	249	70	24
Westford	Barley	0.82	237	58	28
Haybet	Barley	0.69	239	51	27
Trical 2700	Triticale	0.67	255	67	20
Alberta	Barley	0.62	237	49	25
Nepal	Barley	0.60	237	49	24
Eureka	Barley	0.57	237	54	21
Stampede	Oat	0.46	255	69	13
Magnum	Oat	0.33	255	68	10

1993 Irrigation: 30 x 40 feet solid set spacing, 9/64-inch Rainbird nozzles, 55 PSI at nozzle, 0.23-inches per hour application rate. Season - First irrigation: May 12; Last irrigation: September 10. Dm – dry matter. Note: *No records available for regrowth irrigation time period.*

Conclusion

This cereal forage water use information can aid producers to make appropriate choices of what species and what varieties to plant to make the best use of available water. This is especially important in limited irrigation seasons.

Literature Cited

Bohle, M. Ballerstedt, P., Dovel, R., Karow, R, and Hannaway, D. (2002) Spring cereal forage varieties for central Oregon. Central Oregon Ag Research Center Annual Report. Oregon State University Ag Experiment Station. Special Report 1046. 27 pages.
https://agsci.oregonstate.edu/sites/agscid7/files/coarec/publications/02_spring_cereal_forage.pdf

Sulfur Rate Effect on Soil pH, Sodium, Soluble Salts, and Forage Species on a Dryland Pasture in Bear Valley, Seneca, Oregon

Mylen Bohle, Gary Delaney, Wayne Mosher, Jack Southworth, David Hannaway,
Lorraine Vogt, Tom Shibley, Mike Reed, and David Chapman

Introduction

There are numerous acres in eastern Oregon that have saline and/or saline sodic soils. Areas in north Grant County around Seneca have saline soils. A producer in the valley wondered if he applied sulfur to a field if he might get a yield response or be able to grow other forage plants. Seneca area long term precipitation average is 14.4 inches and there is still deep soil moisture in mid-summer. A trial was conducted to determine the effect of different rates of incorporated sulfur application on soil pH, sodium, and soluble salts. Several introduced forage species were evaluated.

Materials and Methods

Soil samples were collected on November 3, 1999, on the Jack Southworth Ranch at Seneca, Oregon (Table 1). The soil was sampled at 0-3, 3-6, and 6-12-inch depths. The field is mid-Thibault, just north and west of the town of Seneca. The sulfur rate trial was constructed in a randomized complete block design with 4 replications. Plots were 10 feet wide by 20 feet long. Five treatments were applied by hand: 0, 1,000, 2,000, 4,000, and 6,000 lb/acre of 100% sulfur equivalent (source: popcorn sulfur 99% S). The plots were lightly tilled, twice, with a John Deere 855 tractor, and a 4-foot rotovator and tilled from north to south, each pass, lengthwise of the plots. Grasses, legumes, and forbs were planted with a 10-feet single disk drill March 22, 2000 (Table 2). Treatment plots were not harvested. Alfalfa plants in each plot were counted (Table 3). An attempt was made to document the other forage species growing in each plot – counting individual plants. Soil samples were taken in the trial in 2004 and 2005. Soil analysis was performed by the OSU Plant and Soil Laboratory in Corvallis, Oregon. MSTAT from Michigan State University was used for statistical analysis.

Mark Keller, soil scientist with NRCS, conducted a soil survey. A hole was dug to 24 inches, about 50 feet west of the sulfur trial in the Mid-Thibault field, on September 5, 2001. The hole was further explored with a soil auger to 60 inches.

Table 1. Beginning soil test results for the sulfur rate effect from November 3, 1999, at the Jack Southworth Ranch, Seneca, Oregon.

	Soil Depth (inches)			
Soil Fertility Test Results	0-3	3-6	6-12	0-12 (Grass* Growth Area)
pH	9.3	8.8	8.5	9.1
P (ppm) Olsen	12	8	8	18
K (ppm)	2,050	1,160	701	3,720
Ca meq/100g	33.8	37.1	44.0	36.0
Mg Meq/100g	13.3	14.0	12.1	9.0
Na Meq/100g	8.43	4.39	2.20	1.84
SO_4-S (ppm)	101	104	85.1	38.2
CEC Meq/100g	29.2	28.3	27.6	26.9
Sol. Salts mmhos/cm	2.4	1.9	1.3	6.3
C (%)	8.6	8.2	7.7	6.3
N (%)	0.50	0.46	0.40	0.39

*Species was creeping meadow foxtail and had very good growth.

Table 2. Forage species planted in the Sulfur trial on March 22, 2000, at the Jack Southworth Ranch, Seneca, Oregon.

Grass Species (Common name)	**Grass Varieties**
Altai wildrye	VNS
Creeping meadow foxtail	Garrison
Crested wheatgrass	Hycrest, CD II
Hybrid wheatgrass	Newhy
Intermediate wheatgrass	Oahe
Meadow bromegrass	Regar
Pubescent wheatgrass	Luna
Reed canary grass	Palaton
Russian wildrye	Bozoisky Select
Slender wheatgrass	Pryor
Smooth bromegrass	Manchar
Tall fescue	3 VNS
Timothy	Clair
Legume Species (Common Name)	**Legume Varieties**
Sainfoin	Eski,
Strawberry clover	Salina
Red clover	Kenland
Hairy Vetch	VNS
Canada crownvetch	VNS
Alfalfa	VNS
Alsike clover	VNS
Birdsfoot trefoil	VNS
Cicer milkvetch	VNS
White clover	VNS
Forb Species (Common Name)	**Forb Variety**
Small burnet	Delar

VNS – variety not stated.

Results and Discussion

Results of the soil analysis from September 5, 2001: at 42 inches, there was a saturated soil that was a sandy gravel texture. The pH was 8.8, 8.6, 7.6, and 7.6 at soil surface, 6, 24, and 32-inches deep. The soil color became redder with depth, until reaching the 42-inch depth and the soil color changed to brown. This single 60-inch hole provided knowledge of the type and quality of the soil on the ranch (Mark Keller personal observation)

Five years after applying the sulfur treatments, Table 3 provides analysis of soil changes. Even though no statistical analysis was conducted, all 4 replications of the 6,000 lb/ac rate of popcorn sulfur had a lower pH than the check, an average of 0.5 units lower. Sodium concentration for the 6,000 lb./ac. rate was lower or equal to the check in all 4 reps. The 6,000 lb/ac S rate mean was 0.4 meq/100g lower. Soluble salts were dramatically increased from a mean of 1.8 to 4.1 cs/cm; all 4 reps of the 6,000 lb/ac popcorn sulfur rate had higher soluble salts than the check. So, although one problem was somewhat ameliorated, lower pH, but then higher soluble salts resulted. There is no irrigation and not enough rain to leach sodium and soluble salts out of the surface soils in these fields.

Table 3. Tilled-in popcorn sulfur (99% S) rate, applied November 4, 1999, effect on 0-3-inch soil depth pH, sodium, and soluble salts sampled mid-September 2004, in Bear Valley at the Jack Southworth Ranch, Seneca, Oregon.

Sulfur Rate (lb/acre)	Rep	pH	Na (meq/100g)	Soluble Salts (ms/cm)
0	1	9.0	5.4	2.3
0	2	8.6	3.3	1.3
0	3	8.6	3.6	1.7
0	4	8.5	3.4	2.0
0	Mean	8.68	3.9	1.8
6,000	1	8.3	4.4	4.3
6,000	2	8.3	2.6	2.4
6,000	3	8.0	3.6	5.0
6,000	4	8.1	3.4	4.6
6,000	Mean	8.18	3.5	4.1

Another sampling of all treatments was done in 2005, for the 0 to 3-inch soil depth for pH, sodium, and soluble salts (Table 4). Except for the 1,000 lb/ac S rate, pH steadily decreased from 8.78 (check) to 8.18 (6,000 lb/ac), after 6 years. A reduction of 0.6 pH units is an important result. There were no significant differences between S rates for sodium concentration. Soluble salts dramatically increased from 1.8 cs/cm to 5.35 cs/cm, up to the 4,000 lb/ac S rate, significantly so. The 4,000 lb/ac rate was no different than the 6,000 lb/ac rate for soluble salts. The 6,000 lb/ac rate had a significantly lower pH compared to the 4,000 lb/ac S rate.

Table 4. Zero to three-inch soil depth pH, sodium, and soluble salt results from different rates of sulfur applied and shallow tilled-in, November 4, 1999, and sampled on August 25, 2005, at the Jack Southworth Ranch in Bear Valley, Seneca, Oregon.

Sulfur Applied (lb/acre)	pH	Na (meq/100g)	Soluble Salts (ms/cm)
0	8.78	3.93	1.83
1,000	8.88	4.63	2.63
2,000	8.58	5.53	4.95
4,000	8.48	4.80	5.35
6,000	8.18	3.50	4.08
Rep 1	8.76	5.40	4.00
Rep 2	8.56	4.24	3.72
Rep 3	8.46	3.94	3.54
Rep 4	8.44	4.32	3.80
Mean	8.6	4.48	3.77
Prob. > F	0.0001	0.2344	0.0072
PLSD 0.10	0.17	NS	1.56
PLSD 0.05	0.21	NS	1.91
PLSD 0.01	0.29	NS	2.67
CV%	1.6	27.7	32.9

Table 5 are results from a soil test in 2009 that was taken where alfalfa plants were growing; and based on the sulfur content, we believe it is from this trial (the corner wooden hubs deteriorated; therefore the plots and boundary of the trial was lost – so an attempt to sample all the treatment plots again in 2009, could not be conducted). Ideally pH should be 6.5-7.5, but less than 8.4. This pH was 8.1. Soluble salt content should be less than 1.5 ms/cm, and sodium should be less than 225 ppm, for optimal plant growth, depending upon species. That is not the case with these soil test results – sodium (1,420 ppm) and soluble salts (6.2 ms/cm) are much higher, which will restrict alfalfa and different grass species growth.

These alfalfa plants had established and were growing but were not thriving. Boron was 14.5 ppm or 1.45E-5 g/m^3. Alfalfa can tolerate boron levels at 4.0-6.0 g/cm^3. Soil and plant phosphorus concentration and uptake are very low; while plant potassium concentration and uptake are somewhat low, but not terribly so. Another reason for low concentration and uptake of P and possibly K by the alfalfa plant could be the cold spring-time soils in Bear Valley. All the other plant nutrients concentrations and uptake are rated sufficient or high. More work needs to be done to see if annual spring applications of phosphorus fertilizer would increase yield. Annual springtime applications of P might improve the availability of P in the soil, and perhaps K, in these cold soil conditions as well. And as noted by the percent nitrogen converted to crude protein, the plant would be good feed at > 17% crude protein.

Table 5. Soil and alfalfa plant nutrient concentrations and uptake results from a July 21, 2009, sampling, in an area we believe is in the sulfur rate trial based on sulfur content, with alfalfa plants growing, at the Jack Southworth Ranch in Bear Valley, Seneca, Oregon.

Nutrient	Soil Depth (0-12 inches)	Alfalfa Plant	Alfalfa Plant Uptake (lb/ton DM)
pH	8.1		
Phosphorus (ppm)	5	0.16 %^{1}	3.2^1
Potassium (ppm)	1,690	2.04 %^{1}	40.8^1
Magnesium (ppm)	1,440	1.05 %^{3}	21.0^3
Sodium (ppm)	1,420	--	--
Calcium (ppm)	6,040	1.85^2	37.0^2
Boron (ppm)	14.5	64^3	0.128^3
Copper (ppm)	0.1	11^2	0.022^2
Manganese (ppm)	6.3	34^2	0.068^2
Zinc (ppm)	0.1	29^2	0.058^2
Iron (ppm)	3.2	72^2	0.144^2
SO_4-S (ppm)	656.5	--	--
Sulfur (%)	--	0.41^2	8.2^2
CEC (meq/100g)	28.7	--	--
Soluble Salt (ms/cm)	6.2	--	--
Molybdenum (ppm)	--	23^3	0.046^3
Carbon (%)	--	41.9	838.0
Nitrogen (%)	--	2.77^2 (17.3%) *	55.4^2

*Crude Protein. Nutrient concentrations and uptake: ^{1} = low, ^{2} = sufficient; ^{3} = high

The number of different species in all the different sulfur rate treatment plots are presented in Table 6. Whether there was one plant or many plants of a species, it was documented as present.

The reference section provides sources that categorize the levels of salt tolerance for different grasses, legumes, and forbs. Alfalfa varieties are being bred to be more salt tolerant. Some of the grass species varieties currently available might have higher tolerances to saline soils.

Table 6. Species present in the Sulfur Rate Trial on September 23, 2003, at the Jack Southworth Ranch, Seneca, Oregon.

Sulfur Rate (lb/ac)	Species present in each rep* (x) and number of species in rep and total species for the sulfur rate[1]																		
Reps 1-4	SLT	CR	NH	SH	RW	TF	MF	RC	T	INT	BR	FR	OR	B	GB	ALF	SL	M	WW	Total*
0																				
1					x	x	x		x		x	x	x		x		x			9
2				x		x	x				x	x				x				6
3				x		x	x			x	x	x	x							7
4				x			x		x		x	x	x				x			7
# of plots	0	0	0	3	1	3	4	0	2	1	4	4	3	0	1	1	2	0	0	12[1]
1,000																				
1				x	x	x	x			x	x	x								7
2				x	x	x	x			x	x				x	x				8
3				x			x				x	x	x			x	x			7
4						x	x			x	x	x	x			x	x			8
# of plots	0	0	0	3	2	3	4	0	0	3	4	3	2	0	1	3	2	0	0	11[1]
2,000																				
1	x	x	x	x	x	x	x	x	x	x	x									11
2				x		x				x	x		x			x	x			7
3				x	x	x	x					x	x			x	x			8
4				x		x	x				x		x		x	x				7
# of plots	1	1	1	4	2	4	3	1	1	2	3	1	3	0	1	3	2	0	0	16[1]
4,000																				
1				x	x	x	x			x	x	x	x		x					9
2				x		x	x		x		x	x		x		x				8
3				x		x	x				x	x	x				x			7
4				x			x			x	x		x		x	x	x		x	9
# of plots	0	0	0	4	1	3	4	0	1	2	4	3	3	1	2	2	2	0	1	14[1]
6,000																				
1		x				x	x			x		x	x			x				7
2						x	x	x		x	x	x				x				7
3		x		x		x		x		x	x		x			x		x		9
4				x		x	x			x	x	x				x				7
# of plots	0	2	0	2	0	4	3	2	0	4	3	3	2	0	0	4	0	1	0	11[1]
0 – 6,000 Total Plots	1	3	1	16	6	17	18	3	4	11	14	10	10	1	5	11	8	1	1	

Species Key (Part of the key is missing for a couple of entries): SLT – ? Saltgrass, CR – Crested wheatgrass, NH - Newhy hybrid, SH – Sheep fescue, RW – Russian wildrye, TF - Tall fescue, MF – Creeping Meadow foxtail, RC – Reed canarygrass, T – Timothy, INT – Intermediate wheatgrass, BR – Meadow or Smooth bromegrass, FR - ? , OR – Orchardgrass, B – Birdsfoot trefoil, GB – Great Basin wildrye, Alf – Alfalfa, SL – Slender wheatgrass, M – Matua brome, WW – Western wheatgrass. * The number of species in each plot. [1]Total number of species documented in S treatment between all 4 reps.

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Effect of tolpyralate herbicide on expression of Verticillium wilt symptoms in peppermint

John Spring

Introduction

Verticillium wilt is an important disease in peppermint production, both globally and across Oregon. The disease is caused by the soil-borne fungus *Verticilium dahliae*, which is generally transmitted from field to field via infected planting stock, or by movement of infected soil with equipment. Infestations reduce oil yields and stand life, and severe losses from the disease make production economically infeasible in many infested fields. Once Verticillium is introduced to a field, currently available management options are limited or economically impractical in many cases. The high longevity of the pathogen in the soil means that once a field is infested with a mint pathotype of Verticillium, it can be challenging to economically produce peppermint in that field again for decades, at least with currently available management options, varieties, and market realities.

In 2020, a small-plot field trial testing crop safety of several experimental herbicides was initiated during winter dormancy in a 2nd year field of irrigated, single-cut ‘M-83-7’ peppermint near Culver, OR. In the first year of production, no indication of Verticillium wilt was observed, and oil yields were good. In the second year of production, however, portions of the field exhibited severe Verticillium wilt symptoms, including the entire trial area. At swathing, experimental plots treated with post-emergence applications of the herbicide tolpyralate (Shieldex, a Group 27 HPPD-inhibiting herbicide) showed a striking reduction in the prevalence and severity of visually apparent disease symptoms relative to other treatments and the non-treated control. As a group, the small number of commercially available HPPD-inhibitors are generally unsafe on broadleaf crops, and have not been widely tested in mint. Tolpyralate is a relatively recent compound in this mode of action (first US registration in 2017 in corn) that has seen some developmental work in peppermint over the past 5 years. For obvious reasons, previous field trials with tolpyralate were deliberately placed in fields without Verticillium issues. Thus, while admittedly limited in scope, this field observation of the effect of tolpyralate on Verticillium wilt symptoms was probably the first of its kind, and may hint at potential for a novel management input for the disease.

To attempt replication of initial field observations, a greenhouse trial was conducted at CAOREC over the spring-summer of 2022 to investigate the effect of post-emergent applications of tolpyralate on expression of Verticillium wilt symptoms in a positively infected, susceptible peppermint variety under controlled conditions.

Materials and Methods

A trial was conducted in the COAREC greenhouse from April-October 2022. Design was a randomized complete block with 6 replicates, with an individually potted plant as the replicated unit. Node cuttings of certified ‘Black Mitcham’ rootstock were grown in the laboratory until plantlets reached 2-4” in height and had 4 to 6 leaves and well-developed roots. On 4/19/22, plants were separated, and infested treatments immersed for 5 min in a conidial suspension of the mint pathotype *Verticillium dahliae* isolate M-111 (10^6 conidia/mL in sterile water). Non-infested controls were treated identically in sterile water only. Plants were immediately potted into peat-based potting mix in 1-gallon pots and maintained in the COAREC greenhouse the rest of the season. Plants were watered and fertilized as necessary over the growing season. Using an experimental spray chamber, a range of tolpyralate rates were applied to verticillium-infested peppermint plants at each of two growth stages (i. 4-6" height (sprayed 5/12/22), and ii. and at first expression of verticillium symptoms, when plants were approximately 10-12" tall (sprayed 6/1/22)). Additional treatments included infested and non-infested controls, and a non-translocated contact herbicide (carfentrazone + diquat) to control for defoliation effects (Figure 1). Above-ground biomass (hay yield) was measured in 3 harvests across the growing season (cut on 8/8, 8/29, and 10/3). Biomass yields were transformed into a 'yield ratio', expressing individual plant performance relative to the mean yield of the inoculated, non-treated (non-sprayed) check. Ratios of 1 indicate hay yields equal to the infested, non-sprayed plants, ratios over 1 indicate higher yields than the check, and ratios under 1 indicate lower yields. At the 2nd and 3rd cuttings, disease severity was measured on a categorical scale developed by Dr. Dung. The scale ranges from 0 to 6, with no disease symptoms at 0 and severe symptoms in dying plants at 6.

Results and Discussion

Development of moderate to severe Verticillium wilt symptoms was rapid in inoculated plants early in the growing season, and very clear differences were seen between non-infested controls and infested plants at the first cutting. Later in the season however, relative severity of symptoms declined in many inoculated plants for unknown reasons, which complicates interpretation of results. A high degree of variability was also present in the trial, and also greatly complicates interpretation.

Early treatments with Shieldex (4-6" height application timing) at all rates tested caused substantial damage to small, greenhouse-grown plants, and plants in these treatments remained generally smaller and exhibited more severe disease symptoms than the inoculated non-sprayed control across the entire growing season (Figure 1). Some difference in damage may be present between rates (particularly with the 0.3oz rate of Shieldex causing less damage than higher rates), but in no case was biomass yield of inoculated plants increased or severity of disease symptoms clearly decreased by any herbicide treatment at this application timing.

For treatments applied at the onset of visible disease symptoms, there is some indication of a treatment effect. Hay yield of plants treated with 0.65 oz/A Shieldex is consistently slightly higher than infested, non-sprayed controls across all cuttings (Figure 1). Visually apparent symptoms of disease were also consistently reduced in this treatment relative to the infested, non-sprayed controls (Figures 1 and 2). While less consistent across evaluation timings, at times several other treatments (Shieldex at 0.3 and 1.35 oz/A, as well as the contact herbicide treatment) show slightly increased yields and/or decreased disease severity relative to the controls. While results are unfortunately far from conclusive, the consistent performance of 0.65oz/A Shieldex in slightly increasing biomass production and reducing severity of expressed Verticillium wilt symptoms in inoculated plants indicates that a true treatment effect may be present, and warrants further investigation. It is hoped that a field trial planned for 2023 may provide more robust results.

Acknowledgements

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Figure 1. Trial results. Yield ratios for each treatment are shown relative to mean aboveground biomass (hay yield) of *Verticillium*-inoculated, non-sprayed plants across each of 3 cuttings. *(A yield ratio of 1 means biomass is equal to control plants, a ratio >1 means treated plants yielded more than controls, and ratio <1 means treated plants yielded less than controls.)* Disease severity was rated immediately prior to 2nd and 3rd biomass harvests on a 0 to 6 categorical scale, where 0 is no disease, and 6 is severely symptomatic, dying plants. In all plots, points show individual plant values, middle crosshatches show treatment median, and bars show median absolute deviation (a robust measure of treatment variation).

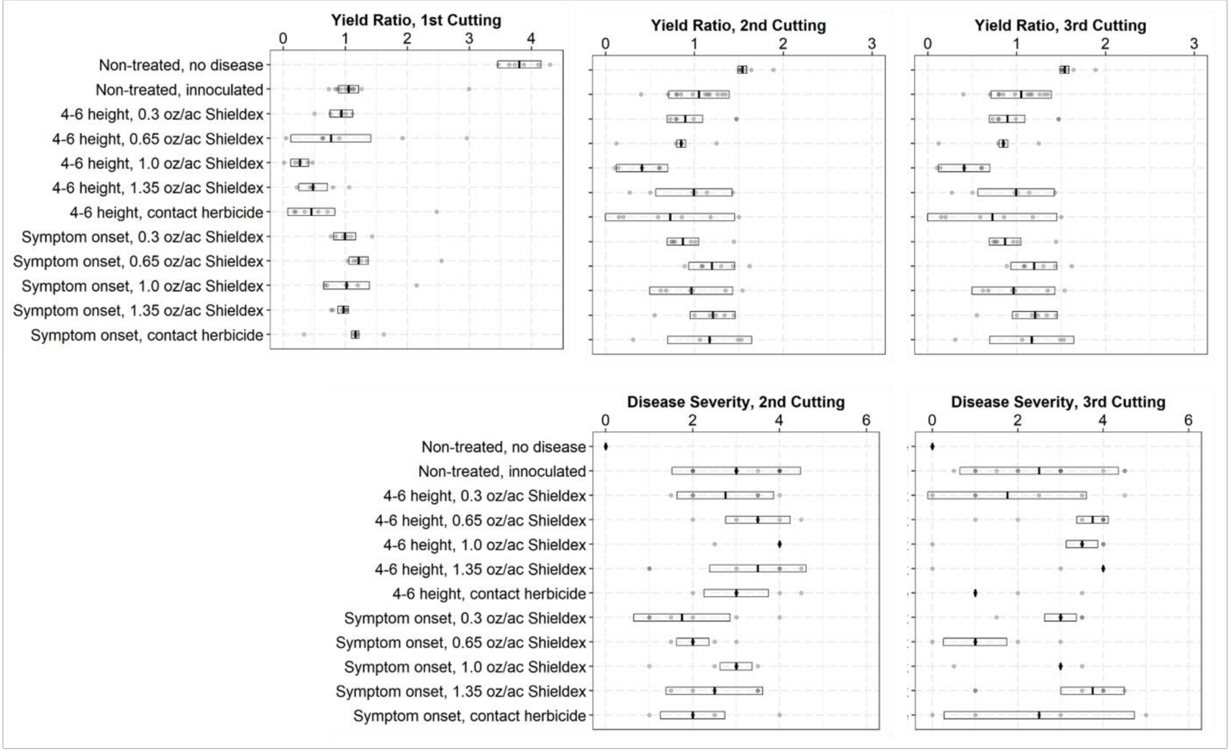
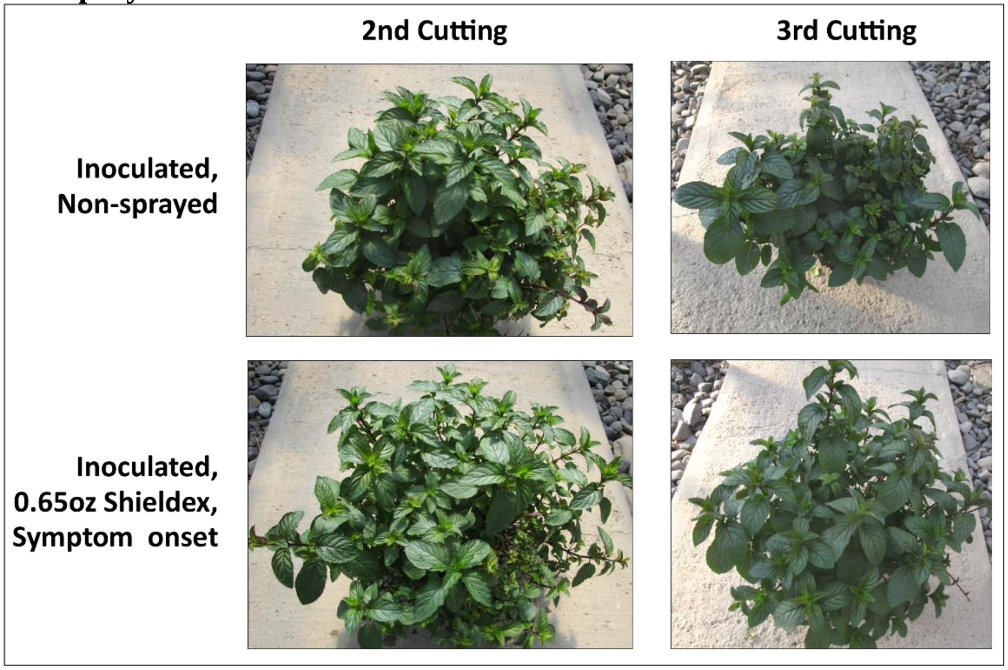


Figure 2. Examples of disease severity reduction observed from 0.65oz/A Shieldex applied to *Verticillium*-inoculated plants at onset of visible symptoms in comparison to inoculated non-sprayed controls.



Identifying Economic Action Thresholds to Inform Verticillium Wilt Management Decisions

Jeness Scott and Jeremiah Dung

Introduction

Verticillium wilt, caused by *Verticillium dahliae*, is a major constraint to mint production in the United States. Initial inoculum of *V. dahliae* consists of soilborne microsclerotia, which form in senescing plants and can survive in soils for over ten years. Integrated pest management (IPM)-based strategies for Verticillium wilt of mint are needed to enable sustainable mint production in the United States. A fundamental concept of IPM is the concept of action (or treatment) thresholds. An action threshold is the point at which pest or pathogen populations require treatment to prevent economic loss. Several methods have been developed to sample and quantify *V. dahliae* from soils, including traditional plating and DNA-based molecular techniques. However, there are no clear guidelines on what constitutes an economic action threshold for soilborne inoculum of *V. dahliae* in mint, and the inoculum levels required to cause Verticillium wilt may vary among different mint cultivars. The objective of this project was to identify inoculum thresholds for *V. dahliae* in mint cultivars grown in the United States in a greenhouse experiment.

Materials and Methods

Rooted mint plugs were obtained from the Jackson-Brush Plant Lab (Norris, MT) and propagated in perlite. Five peppermint (*Mentha* x *piperita*) cultivars Black Mitcham, M-83-7, Redefined Murray Mitcham, Todd’s Mitcham, and B-90-9), two Scotch spearmint (*M.* x *gracilis*) cultivars (Scotch and S770), two native spearmint (*M. spicata*) cultivars (native, and N83-5) and two cornmint (*M. arvensis*) cultivars (Paraguayan and Shivalik) were included in the trial. Microsclerotia of *V. dahliae* isolates from mint were produced on potato dextrose agar medium and collected by wet sieving before being quantified using a hemacytometer. Soils were infested with 1, 5, 10, 20, 50, or 100 microsclerotia/g soil. A non-infested control was included. All treatments were replicated four times and arranged in a randomized complete block design in a greenhouse. Verticillium wilt symptoms were assessed eight times using a disease severity index (DSI) ranging from 0 = no visible symptoms to 5 = dead/nearly dead plant. DSI values were converted to area under disease progress curve (AUDPC) values. Aboveground leaves and stems were harvested three times to determine the effect of inoculum levels on hay yields. Dry hay yields were converted to yield ratios, where a yield ratio < 1 indicated reduced yields compared with the mean yield of the non-inoculated control treatment.

Results and Discussion

Three disease and yield evaluations were performed for *M. arvensis* cultivars and four disease and yield evaluations were conducted for the *M.* x *piperita*, *M.* x *gracilis*, and *M. spicata* cultivars. A significant effect of cultivar ($P < 0.0001$) and inoculum level ($P < 0.0001$) was observed for AUDPC values among *M.* x *piperita* cultivars and a significant effect of cultivar was observed for *M.* x *gracilis* ($P = 0.03$). Significant differences between cultivars or inoculum levels were not observed for *M. arvensis* or *M. spicata*. In general, mean AUDPC values tended to increase as inoculum level increased. AUDPC data is summarized in Table 1.

By the end of the trial, significant differences effects of cultivar (*P* = 0.0002) and inoculum level (*P* = 0.005) were observed for yield ratios among *M.* x *piperita* cultivars (Table 2). Redefined Murray Mitcham, M-83-7, and Todd's Mitcham all exhibited significantly greater yield ratio values than Black Mitcham, which had the highest lowest yield ratio in the trial. Yield ratio values for B-90-9 were not significantly different than Black Mitcham. A significant difference (*P* = 0.04) in yield ratios were observed between the two *M. spicata* cultivars (Table 3). Significant effects of cultivar or inoculum level were not observed on yield ratios for *M. arvensis* (Table 4) or *M.* x *gracilis* (Table 5) cultivars (*P* > 0.05).

Verticillium wilt management is particularly challenging in perennial crops such as mint, and control practices are mostly targeted towards avoiding or reducing primary inoculum prior to planting. The results from this project can help growers and stakeholders identify fields with damaging levels of *V. dahliae* and inform decisions on cultivar selection, field placement, or eradication practices prior to planting mint.

Table 1. Area under disease progress curve values for five peppermint (*Mentha* x *piperita*) cultivars (Black Mitcham, M-83-7, Redefined Murray Mitcham, Todd's Mitcham, and B-90-9), two Scotch spearmint (*M.* x *gracilis*) cultivars (Scotch and S770), two native spearmint (*M. spicata*) cultivars (native and N83-5), and two cornmint (*M. arvensis*) cultivars (Paraguayan and Shivalik) grown in the presence of 0, 1, 5, 10, 20, 50, or 100 *Verticillium dahliae* microsclerotia/cc soil.

	***V. dahliae* microsclerotia/cc soil**						
Mint cultivar	**0**	**1**	**5**	**10**	**20**	**50**	**100**
Black Mitcham	0.0	19.8	46.0	91.1	72.3	110.0	129.1
B-90-9	0.0	2.8	15.3	27.0	84.5	110.9	131.6
M-83-7	0.0	7.3	3.8	23.4	42.4	54.0	43.1
Redefined Murray Mitcham	0.0	7.3	20.6	9.9	0.0	13.5	49.5
Todd's Mitcham	0.0	14.5	5.4	13.5	40.6	25.1	58.4
Scotch	0.0	24.1	30.6	9.9	13.3	27.3	14.6
S770	0.0	7.1	10.9	39.8	7.5	7.5	11.3
N-83-5	0.0	3.8	7.5	3.8	3.8	3.8	11.3
Native spearmint	0.0	0.0	0.0	7.5	0.0	0.0	10.9
Paraguayan	0.0	0.0	0.0	7.0	0.0	3.6	0.0
Shivalik	0.0	7.0	7.0	0.0	3.6	3.6	0.0

Table 2. Final yield ratios of peppermint (*Mentha* x *piperita*) cultivars planted in Verticillium-infested soil. Yield ratios < 1 indicated reduced yields compared with the mean yield of the non-inoculated control treatment. Treatments followed by the same letters are not significantly different from each other using Fisher's protected LSD test.

Cultivar	Yield ratio
B-90-9	0.72 b
Black Mitcham	0.76 b
M-83-7	0.86 b
Redefined Murray Mitcham	1.08 a
Todd's Mitcham	0.91 ab

Table 3. Final yield ratios of native spearmint (*Mentha spicata*) cultivars planted in *Verticillium*-infested soil. Yield ratios < 1 indicated reduced yields compared with the mean yield of the non-inoculated control treatment. Treatments followed by the same letters are not significantly different from each other using Fisher's protected LSD test.

Cultivar	Yield ratio
Native spearmint	0.94 b
N-83-5	1.06 a

Table 4. Final yield ratios of cornmint (*Mentha arvensis*) cultivars planted in *Verticillium*-infested soil. Yield ratios < 1 indicated reduced yields compared with the mean yield of the non-inoculated control treatment.

Cultivar	Yield ratio
Paraguayan	1.09
Shivalik	1.08

Table 5. Final yield ratios of Scotch spearmint (*Mentha* x *gracilis*) cultivars planted in *Verticillium*-infested soil. Yield ratios < 1 indicated reduced yields compared with the mean yield of the non-inoculated control treatment.

Cultivar	Yield ratio
Scotch spearmint	0.99
Scotch S770	0.98

Central Oregon Potato Extension Program, 2022

Heike Williams and John Spring

Abstract

The prevalence of aphids and potato psyllids were monitored weekly in 9 seed tuber production fields in Jefferson County from June 21 to August 23, 2022, and potato tuberworm moths from June 21 to September 13, 2022. To meet budget constraints for 2022 funding, monitoring of beet leafhopper and molecular testing of samples for BLTVA was reduced to the first four weeks of the season (June 21 to July 20). Counts were conducted to monitor pest populations and assess potential risk of disease transmission. Weekly findings were distributed to growers, crop consultants and industry representatives through electronic newsletter.

Overall green peach and potato aphid numbers were low. Most weeks, no green peach and potato aphids were found in traps in most fields, and occasional detections were under 4 green peach and/or potato aphids per trap. Other aphid numbers were high in the first and third week of the season and declined thereafter. Only 1 potato tuberworm moth (PTW) was identified in the last week of monitoring, in contrast to 2021, where PTW were identified consistently in 1 to 4 traps per week starting in week 5 (July 20 to 28). Counts of potato psyllids closely followed the dynamic of previous years, with the number of fields where psyllids were identified increasing over the course of the season (from 1 of 9 fields in week 1, to 7 of 9 fields in week 8) and increasing numbers of specimens per trap (from 1 in the first 5 weeks to 17 in week 9). All identified psyllids tested negative for Lso, the pathogen causing zebra chip disease. This year beet leafhoppers (BLH) were identified in every trap in the first four weeks at levels about halfway between 2020 and 2021. All subsamples of BLH (7.9% of all specimens identified) tested negative for the BLTVA phytoplasma that causes potato purple top disease in 2022, despite positive detections in 2021. Early blight prediction modeling and crop water use data provided helpful information for seed potato management. Plants emerging on June 6 reached the 300 P-day mark on July 23.

Materials and Methods

Aphid, Potato Tuberworm, Psyllid, and Beet Leafhopper trapping IPM project

<u>Aphids</u>. Aphids are important pests in potato crops and can affect yield by removing nutrients from plants, stunting growth, or transmitting disease. Aphids are known vectors for several viruses, with the most important for our area being Potato Virus Y (PVY). Weekly monitoring of aphid traps serves as a tool to determine when aphid populations are increasing and when field treatment becomes necessary.

A yellow bucket filled with water was used as a trap in each commercial potato field throughout Central Oregon to collect winged aphids. Traps were distributed on June 21, 2022, in all fields. Final collections occurred at the end of week 9, August 23, before the start of vine kill. Trapped aphids were collected weekly by straining the aphids from the water using a mesh aquarium net. Samples were transported to the COAREC laboratory in water and kept refrigerated until examination. Aphids were separated from other insects and identified as green peach aphids, potato aphids or other aphids using a microscope. Counts, dates, and locations were used to identify aphid movement in the area.

Potato Tuberworm. The potato tuberworm is one of the most important pests infesting potatoes worldwide. Potato tuberworm moths appeared in the area in 2013. Their larval stage has the potential to impact production due to larvae mining in tubers. In the past, the presence of potato tuberworm in central Oregon was sporadic but increased to weekly detection in 2014.

Pheromone-baited delta traps were placed at the edge of nine commercial potato fields from June 21 to September 13. Sticky liners were removed weekly and inspected for presence of male moths. Pheromone lures were replaced every 4 weeks. Unlike traps for other pests, delta traps stayed in place throughout vine kill until harvest, which started in week 12 of the monitoring period (September 6 to 13, or shortly after).

Potato Psyllid. Zebra chip (ZC) disease was first identified in the Pacific Northwest in 2011 and remains an important issue. The pathogen causing ZC is '*Candidatus* Liberibacter solanacearum' (Lso), a type of bacterium vectored by the potato psyllid (*Bactericera cockerelli* Sulc). On June 21, 2022, a total of nine sticky traps were distributed in commercial fields and maintained until vine kill. Double-sided yellow sticky cards measuring 4" x 6" were placed 5 to 10 feet inside the field of planted potatoes at canopy height and replaced weekly for potato psyllid activity monitoring. Sticky card removal occurred at the end of week 9 (August 23) shortly before the start of vine kill.

Beet Leafhopper. Beet leafhoppers (BLH) continue to be a concern for the potato industry as the primary vector of beet leafhopper-transmitted virescence agent (BLTVA) phytoplasma, the causative agent of potato purple top disease. Terminal leaves of infected plants turn reddish or purplish and curl, causing infected plants to die early. In addition, nodes swell and turn purplish, internodes are shortened, and aerial tubers may form. The disease is likely transmitted mostly in early summer, and was first positively detected in central Oregon by this project in 2021 Monitoring for this pest and testing for BLTVA phytoplasma in a subsample of identified beet leafhoppers was continued in 2022. Due to budget constraints in 2022, monitoring of BLH was limited to the first 4 weeks (June 21 to July 19) due to high cost of molecular testing. Research conducted in the Columbia Basin (https://link.springer.com/article/10.1007/s12230-009-9117-8) indicates that risk of infection with BLTVA is highest in younger plants, and declines fairly sharply at some point in the season (typically between 4 and 6 weeks after emergence). In addition, we found that in 2021 composite BLH samples testing positive for BLTVA in Central Oregon were highest in the first 3 weeks and declined to zero later in the season (71% of samples positive in weeks 1-3, 20% positive in weeks 4-6, and 0 positive for remainder of growing season). To trap beet leafhoppers yellow sticky cards measuring 4" x 6" were placed at the edge of nine commercial potato fields, out of range of irrigation water, and preferably near weeds. Yellow sticky cards were collected and changed on a weekly basis.

Generate early blight prediction model and weekly water use data information.
Weekly early blight prediction models were published using observed emergence dates. The model predicts the first seasonal rise in the number of spores of the early blight fungus based on the accumulation of 300 physiological days (P-days) from emergence. Once 300 P-days have

accumulated, the first fungicide for early blight control should be applied. This usually occurs when rows have closed.

Water use data information was included in the weekly newsletter using daily evapotranspiration data published by the Bureau of Reclamation https://www.usbr.gov/pn/agrimet/. The information is intended to assist growers in irrigation management decisions. Potato is a moisture sensitive crop with a shallow active root zone compared to cereals and forages. Availability of moisture in the root zone is crucial for high yields and is influenced by soil properties such as texture and percent organic matter. Moisture demand increases as the crop begins to develop after emergence and peaks 7-9 weeks later during the tuber bulking growth stage.

Create seasonal, weekly newsletter to provide growers with insect and disease updates.
A weekly electronic newsletter, 'Potato Patches', was sent to potato industry participants from the week of June 27 to the week of September 12, 2022. It included the early blight prediction model, weekly water use data, weekly aphid identification, as well as potato tuberworm moth, potato psyllid, and beet leafhopper population numbers. Locations of trap sites and population numbers were identified for grower use only.

Results and Discussion

Aphids. This year, aphid numbers were highest in the first week (June 21 to 28) due to "Other" aphids ranging from 13 to 166 per trap. Total weekly detection in all traps decreased continuously after week 3 and dropped below 5 per trap starting in week 5 (July 19 to 26), similar to low aphid infestation levels in the previous two years (Fig 1). The number of all aphids identified throughout the monitoring period amounted to 1,035 in nine fields (avg. 115 per field), compared to 438 in eleven fields (avg. 40 per field) in 2021, and to 2019 in 13 fields (avg. 171 per field).

As in the previous two years, numbers of green peach aphids (GPA) and potato aphids (PA) were low in 2022. "Other Aphids" (OA) made up the large majority (96%) of total aphids, with GPA being 1% and PA 3% of total aphids (Fig.2).

Fig. 3 and 4 illustrate the low infestation level of GPA and PA, respectively, in the last three years compared to 2019. When looking at individual fields, PA counts ranged from 0 to 4 in any week and trap, and the maximum number of GPA in any given trap was 3. OA numbers ranged from 0 to 166 per trap in the first three weeks (avg. 32 per trap), stayed below 20 aphids per trap in the fourth week and were ≤ 4 in the remaining weeks of the monitoring period.

Potato Tuberworm. In 2022 only one potato tuberworm moth (PTW) was identified in week 12, similar to 2019 and 2020 where no potato tuberworm moths were identified during the entire monitoring period. This contrasts with 2021, where the detection of potato tuberworm moths ranged from 0 to 22 per trap, and from 0 to 26 in all traps per week (Fig.5).

Potato Psyllid. In 2022, the weekly number of potato psyllids identified in all traps closely followed the dynamic seen in the two previous years (Fig.6). Infestation levels slowly increased and peaked in week 9 (August 16 to 23). At the peak in week 9 between 1 and 17 psyllids were identified in each of 5 fields, and in week 8 between 1 and 5 specimens were found in 7 of 9 fields. As in the past three years, these numbers are much lower than in 2016, where total numbers of psyllids averaged 66 insects per week from July 26 to the time of vine kill. All psyllids detected in 2022 were sent to OSU-HAREC for Lso testing. As in previous years, all tested negative.

Beet leafhopper. In 2022, beet leafhoppers (BLH) were identified in every trap every week over the course of the four-week monitoring period for this species. Infestation levels lay halfway between those in 2020 and 2021 (Fig.7). Trap numbers totaled 40 to 301 per field, while in 2020 and 2021 total numbers of specimens per field in the first 4 weeks ranged from 1 to 90 and from 47 to 601, respectively. Low or moderate infestations (25 or less BLH per trap) were seen in 3 of 9 fields throughout the monitoring period, compared to 2 of 11 fields in 2021.
Due to the high numbers of BLH detected, it was not economically feasible to test all specimens for BLTVA. Sticky cards were subsampled (7.9% of all specimens identified) for compounded samples with 10 specimens in each vial, separately for each field, and sent to HAREC for analysis. All specimens tested negative in 2022. This contrasts with 2021 where subsamples of BLH tested positive for BLTVA, the first positive tests in central Oregon since initiation of testing in 2015.

Early blight prediction model. June 6 was used as average emergence date for all fields compared to June 1 and 10 as the dates used in the past two years. Emergence in all fields was fairly consistent due to spring precipitation and not needing to water potatoes up. Fields accumulated 300 P-days by July 23. For comparison, plants emerging on June 1 and June 10 in 2021 reached the 300 P-day mark on July 21 and July 29, respectively. The newsletter alerted farmers to the recommendation of fungicide application for varieties susceptible to early blight.

Water use data. Actual water use in the last 3, 7 and 14 days and the estimated water use for the next 7 days was included in the weekly newsletter using daily evapotranspiration data published by the Bureau of Reclamation. Fig. 8 shows the daily average irrigation water use based on the actual water use in the previous week.

Conclusions

Weekly potato pest monitoring reports were sent to growers, crop consultants and industry participants by email. The information provided opportunities for efficient and economical control of pests and disease. Trapping continues to be an important tool for potato seed producing areas to monitor pests capable of transmitting diseases.

Reports also include prediction of crop water use for the upcoming week, which is important for proper crop management throughout the growing season and during maturation to assist with harvest and prevent storage rot. Use of the early blight prediction model assists growers and crop consultants as they time fungicide sprays to prevent disease outbreaks.

This project confirmed continued presence of potato psyllid and to a lower extent potato tuberworm moth in Jefferson County. All potato psyllids collected tested negative for Lso. Despite detection of BLTVA-positive beet leafhoppers in 2021 monitoring, none of the beet leafhoppers tested in the first 4 weeks of the monitoring season in 2022 carried BLTVA (subsamples consisting of 5.8% of all BLH collected over the season).

Weekly monitoring continues to be a significant source of information for integrated pest management in Central Oregon potato fields.

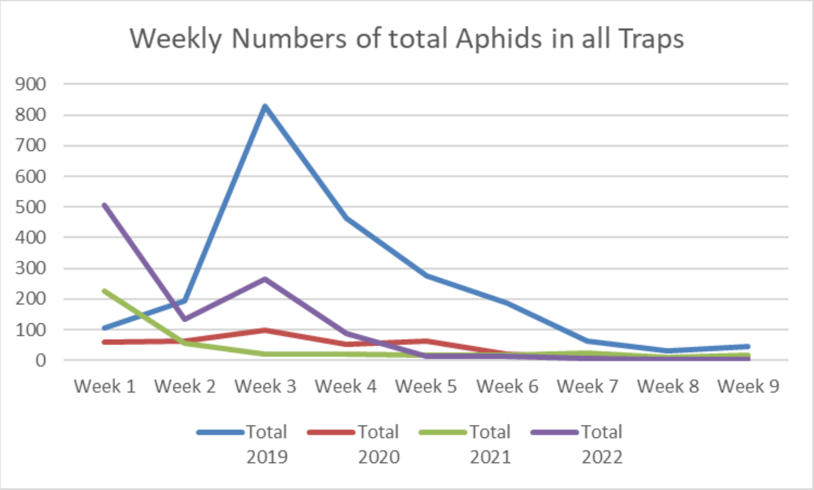


Fig. 1 Total number of aphids trapped weekly in commercial potato seed fields in Jefferson County, OR, 2019 to 2022

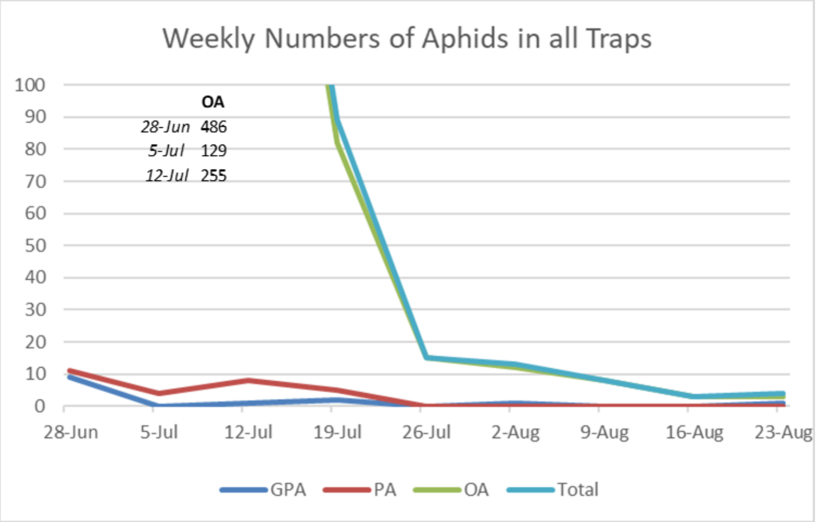


Fig. 2 Weekly number of aphids per type in commercial potato seed fields in Jefferson County, OR, in 2022 (GPA=Green Peach Aphids, PA=Potato Aphids, OA=Other Aphids)

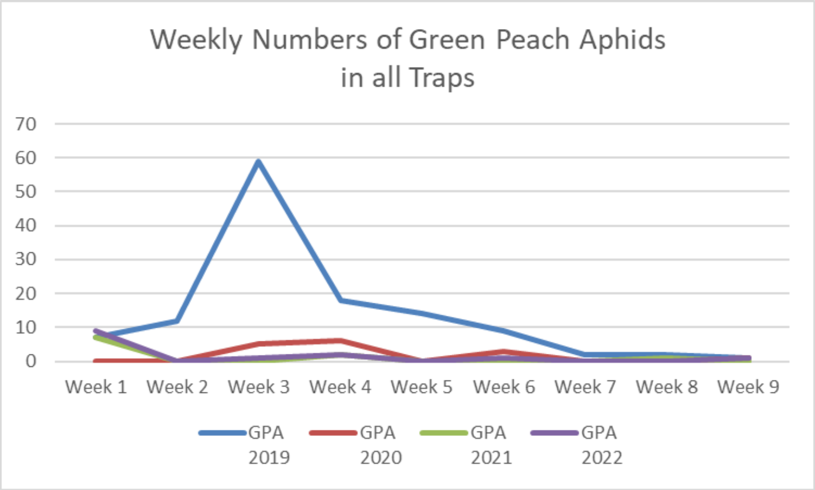


Fig. 3 Number of Green Peach Aphids trapped weekly in commercial potato seed fields in Jefferson County, OR, 2019 to 2022

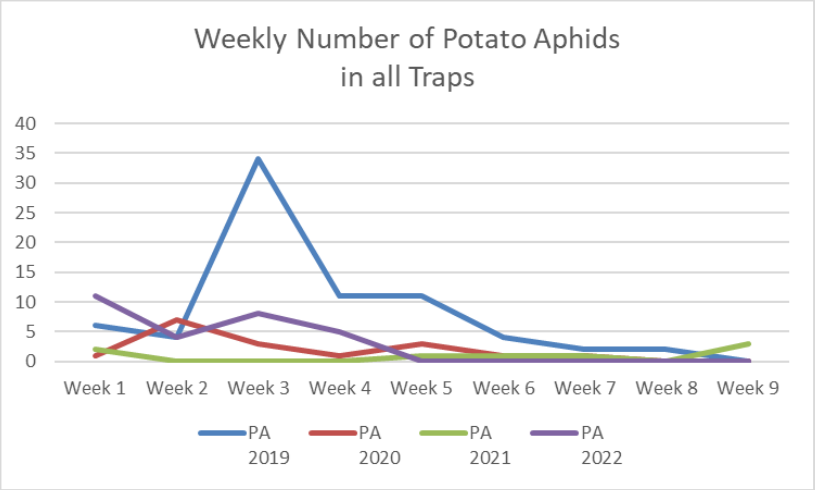


Fig. 4 Number of Potato Aphids trapped weekly in commercial potato seed fields in Jefferson County, OR, 2019 to 2022

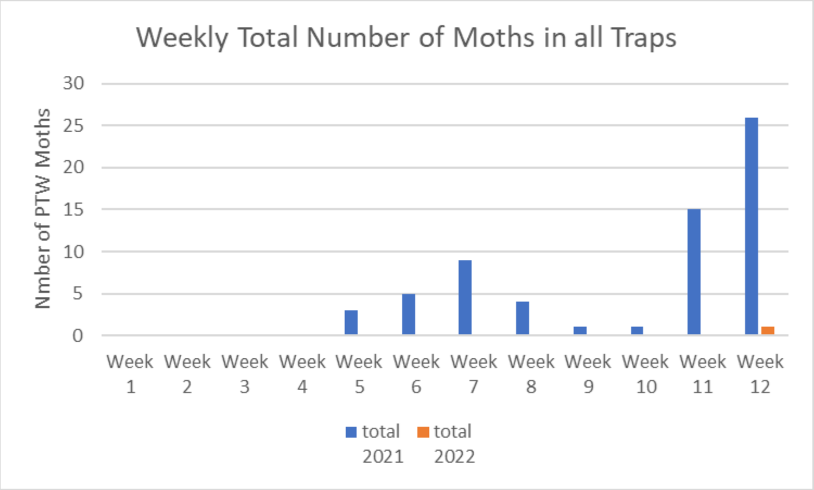


Fig. 5 Total number of Potato Tuberworm Moths trapped weekly in commercial potato seed fields in Jefferson County, OR, in 2021 and 2022

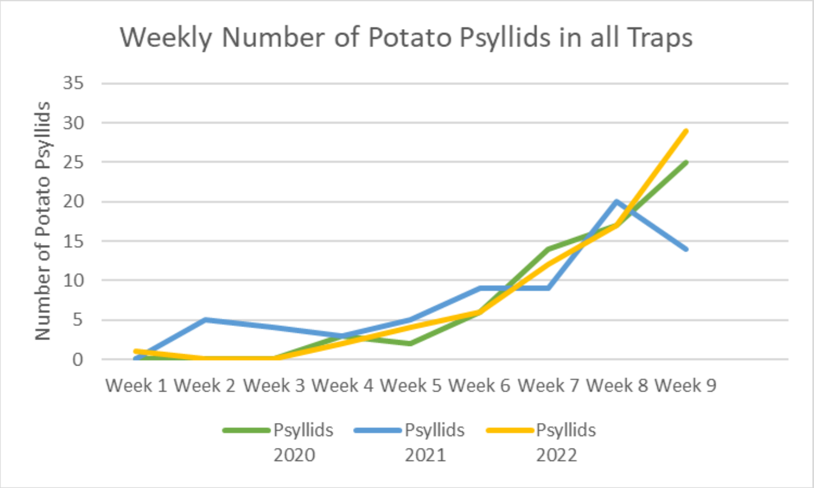


Fig. 6 Total number of Potato Psyllids trapped weekly in commercial potato seed fields in Jefferson County, OR, 2020 to 2022

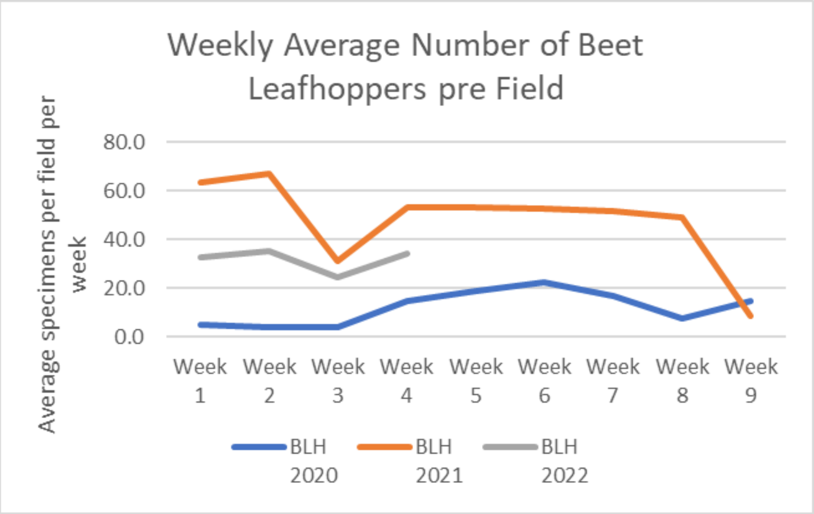


Fig. 7 Average number of beet leafhoppers per field trapped weekly in commercial potato seed fields in Jefferson County, OR, 2020 to 2022

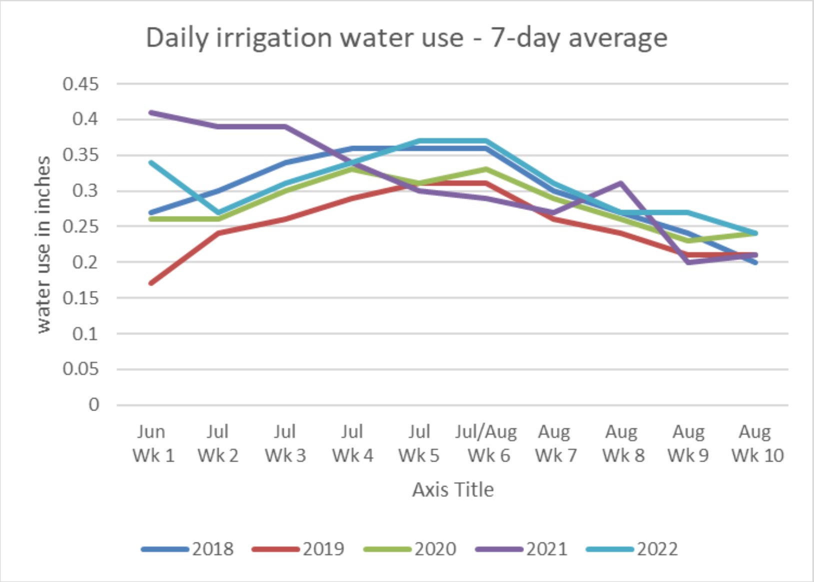


Fig. 8 Daily 7-day average of irrigation water use in potato seed fields in Jefferson County, OR, 2018 to 2022

Pilot Balloon Observations, 2022
Jefferson County Smoke Management

Amanda Alps, Tamara Dupont, and Jeremiah Dung

Introduction

The Pilot Balloon (PIBAL) program began in 1998 and is a major component of the daily decision-making process used in managing open field burning of grass seed and wheat fields in Jefferson County. PIBALs are used to track upper level wind direction and speed. They are released daily from the Central Oregon Agricultural Research Center between 10:30 am and 3:30 pm. Releases at potential burn sites allow for more accurate decision-making under marginal conditions. The PIBAL is essential in minimizing adverse smoke impacts on local communities.

The PIBAL program incorporates the weather balloon data into information the Jefferson County Smoke Management Coordinator receives from the Oregon Department of Agriculture (ODA) Weather Center. PIBAL data compiled with Real-Time Weather Data, courtesy of the US Bureau of Reclamation AgriMet Network, can be found on the Jefferson County Smoke Management website. The objective is to provide real time wind patterns, wind speed and wind direction information for the Smoke Management Coordinator to determine whether burning will be allowed.

Materials and Methods

Daily balloon releases occurred on demand throughout the day. The release times and locations were requested by the Smoke Management Coordinator. Air temperature, relative humidity, and surface wind direction and speed are documented at the time of the PIBAL release using the AgriMet weather station at the Central Oregon Agricultural Research Center. Wind directions and speeds are determined at one-minute intervals for a period of ten minutes using an observation Theodolite System and a twenty-six inch diameter helium filled balloon (PIBAL). The PIBAL is used to verify the forecast for the upper level wind direction, speed and mixing height.

The software program, PIBAL Analyzer, developed by the Oregon Department of Agriculture (ODA) analyzes PIBAL information, which includes three components. The first is the PIBAL Sounding, a spreadsheet translating the azimuth (azimuth are angles used to define the apparent position of an object in the sky, relative to a specific observation point) and elevation readings from the wind direction and average wind speed. The second is the Hodograph, which charts the wind direction. The Profile page, the third component, graphs the wind speed. The PIBAL soundings are entered into the PIBAL Analyzer and transmitted to the Jefferson County Smoke Management website for the Smoke Management Program Coordinator. The Coordinator then uses this data in conjunction with the daily aircraft soundings and the ODA Weather Center forecast as well as the ODA's Air Quality Monitor to determine the field burning status for the day.

Results and Discussion

During the 2022 open field-burning season, which began July 25 and ran through September 27, farmers burned a total of 4,924 acres, including 4,033 acres of grass, 642 acres of wheat, and 249 acres of garlic, carrot seed, and other crops (Fig. 1). Multiple, daily balloon releases were performed in the late morning and throughout the day to refine the weather forecast and determining the mixing height for smoke during the optimal burn times. The PIBAL provided the only method to detect the stable air layers, and was particularly helpful on marginal burn days to assist the Smoke Management Coordinator in making the decision whether to allow burning when conditions were either fluctuating or difficult to assess.

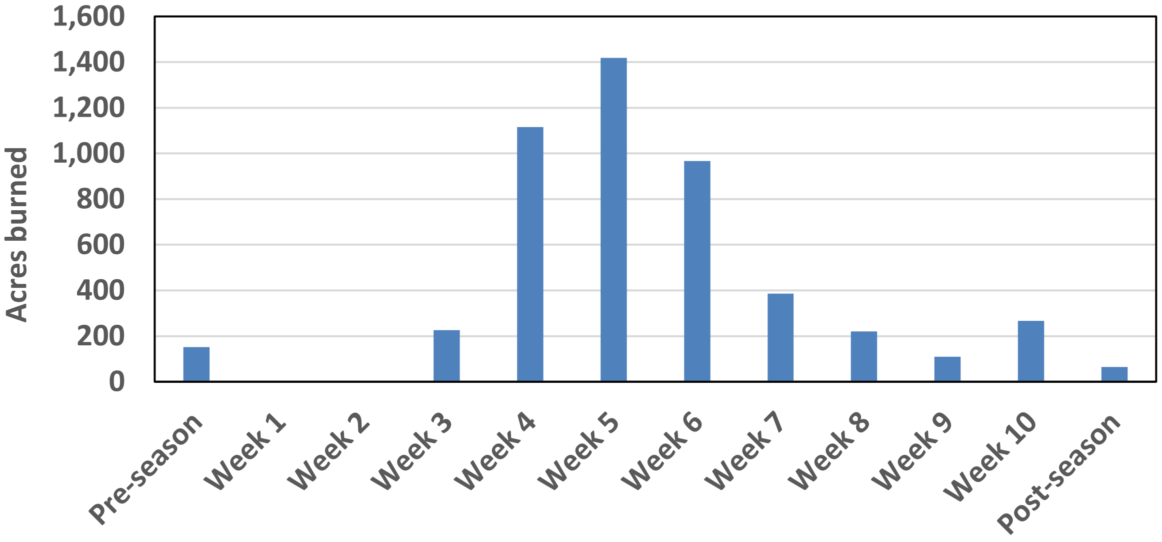


Figure 1. Total acres burned per week during the 2022 open field burning season.