# 2017
# Dryland Field Day Abstracts

## HIGHLIGHTS OF RESEARCH PROGRESS

University of Idaho

Oregon State University

WASHINGTON STATE UNIVERSITY

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*Photo by Karen Sowers*

# *Welcome to our 2017 Field Days!*

# 2017 Dryland Field Day Abstracts:
# Highlights of Research Progress

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WASHINGTON STATE UNIVERSITY,
DEPARTMENT OF CROP AND SOIL SCIENCES
TECHNICAL REPORT 17-1

OREGON STATE UNIVERSITY,
DEPARTMENT OF CROP AND SOIL SCIENCE
TECHNICAL REPORT OSU-FDR-2017

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TECHNICAL REPORT UI-2017-1

Field Days:
OSU Pendleton Field Day—Pendleton, OR, June 13, 2017
OSU Moro Field Day—Moro, OR, June 14, 2017
WSU Lind Field Day—Lind, WA, June 15, 2017
UI Parker Plant Sciences Field Day (morning)—Moscow, ID, June 27, 2017
UI/Limagrain Cereals Field Day (afternoon)—Moscow, ID, June 27, 2017
WSU Wilke Farm Soil Quality Field Day—Davenport, WA, June 28, 2017

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WOCS
WASHINGTON OILSEED CROPPING SYSTEMS
*Part of the Washington State Biofuels Initiative*

USDA
United States Department of Agriculture
Agricultural Research Service

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Photo by Leonardo Hinojosa

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# Part 1. Pathology, Weeds, and Insects

## Identification of Glyphosate Resistance in Russian Thistle in Northeastern Oregon

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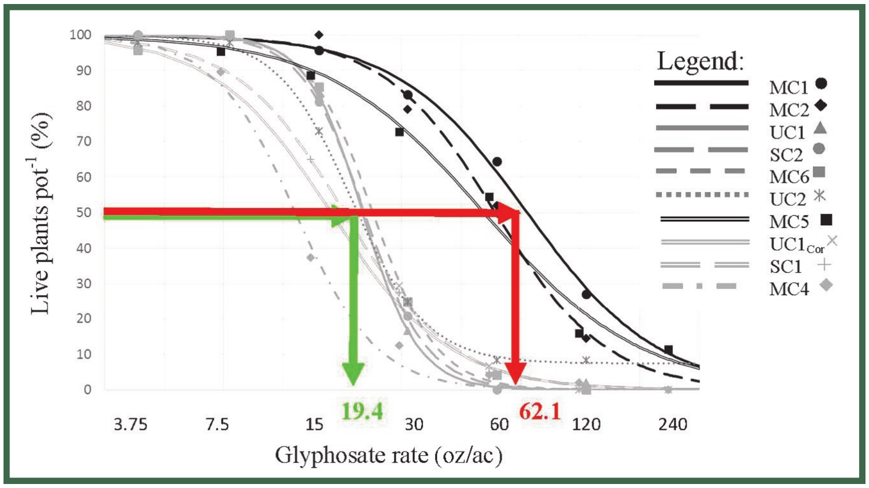

**Figure 1. Dose-response curves of percentage of Russian thistle live plants per pot 3 weeks after treatment. Points indicate mean of the experimental data and lines fitted models. Green and red arrows indicate the average glyphosate rate to kill 50% of the susceptible and resistant populations respectively. UC1 and UC1$_{Cor}$ refer to the same population that was tested in both greenhouses (CBARC and campus) as the control population.**

Farmers in the low-rainfall region of eastern Oregon rely on repeated applications of non-selective herbicides, predominately glyphosate, to control Russian thistle in no-till fallow systems. Reports of poor glyphosate effectiveness have increased in recent years. Reduced efficacy is often attributed to dust, water stress, or generally poor growing conditions during application. Inadequate control also may be the result of the evolution of glyphosate resistance. Therefore, studies were undertaken to determine if glyphosate-resistant Russian thistle populations occur in Oregon. Results from dose response studies confirmed glyphosate resistance in three of ten Oregon Russian thistle populations. The ratio $I_{50Resistant}/I_{50Susceptible}$ from dose-response curves was on average 3.1 for the relative dry biomass per plant and 3.2 for the percent of surviving plants per pot in these three populations. Plant mortality at recommended glyphosate doses for the resistant populations was less than 30% three weeks after treatment. Glyphosate resistance in Russian thistle highlights the imperative need to diversify weed control strategies to preserve the longevity and sustainability of herbicides in semi-arid cropping systems of the Pacific Northwest.

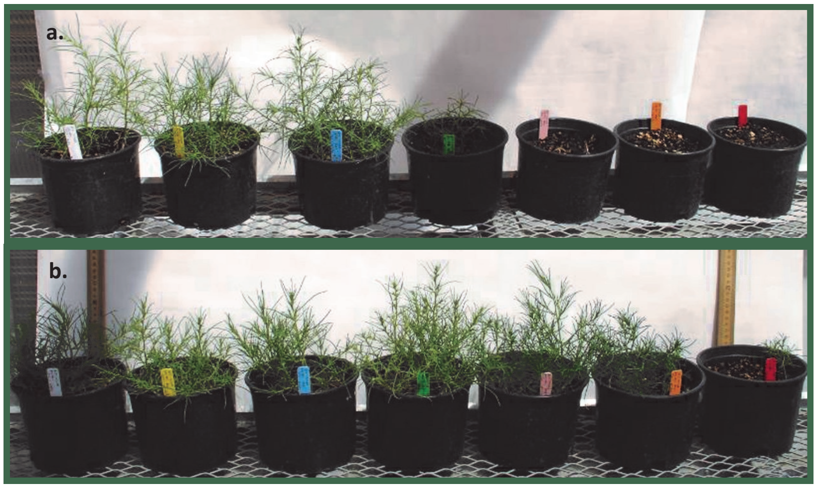

**Figure 2. Photos of the seven treatments 0 oz/ac (white label), 3.75 oz/ac (yellow label), 7.5 oz/ac (blue label), 15 oz/ac (green label), 30 oz/ac (pink label), 60 oz/ac (orange label), and 120 oz/ac (red label) sprayed on a) a susceptible population in Umatilla County and b) a resistant population in Morrow County.**

# Rush Skeletonweed Control in Winter Wheat Following CRP Takeout

Mark Thorne, Henry Wetzel, and Drew Lyon
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Rush skeletonweed is a deep-rooted perennial weed that has become well established on thousands of acres of farmland across eastern Washington while the land was in the Conservation Reserve Program (CRP). Recent changes to the CRP have resulted in land coming back into production and most often without prior skeletonweed control. We applied five different synthetic auxin herbicides to rush skeletonweed infested winter wheat near LaCrosse, WA on November 12, 2015, after the wheat was tillered and again prior to stem jointing on March 17, 2016. The land had been in CRP until October 2013, and the first post-CRP crop was harvested in 2014. In 2015, the field was in summer fallow and was seeded to 'ORCF-102' winter wheat at 60 lb/A on September 11 with a John Deere HZ616 grain drill. Fall-applied Milestone and Stinger resulted in good control by March 8 and maintained effective control through wheat harvest on July 20. Spring-applied Milestone and Stinger resulted in 94 and 100% control, respectively, by June 2, but control declined to 76 and 78%, respectively, by July 20 as a few of the previously dead-appearing rosettes bolted. Control with DPX-MAT28-128, Clarity, and 2,4-D LV6 was weak throughout the trial as rosettes appeared damaged but few actually died and many had bolted by July 20. Wheat yields were variable across the study site but were reduced by DPX-MAT28-128 and 2,4-D LV6 applied in the fall and spring. The spring-applied DPX-MAT28-128 caused kernel abortion and blank heads. In this trial, fall applications of Milestone or Stinger substantially controlled rush skeletonweed without reducing grain yield. The experimental DPX-MAT28-128 and 2,4-D LV6 did not control skeletonweed and appeared to reduce yield. Clarity did not lower yield, but also did not control skeletonweed.

**Poor winter wheat emergence in areas where rush skeletonweed depleted soil moisture during the fallow phase of the rotation. Rush skeletonweed rosettes can easily be seen in areas where wheat failed to emerge.**

**Visually rated control of rush skeletonweed in winter wheat, and wheat yield.[1]**

| Treatments[2] | Rate | Visual control ratings | | | | Wheat yield |
|---|---|---|---|---|---|---|
| | | March 8 | March 31 | June 2 | July 20 | |
| | (oz/A) | -------(% of non-treated check)------- | | | | (bu/A) |
| *Fall-applied herbicides* | | | | | | |
| Non-treated | - | 0 - | 0 - | 0 - | 0 - | 84 ab |
| Milestone | 0.6 | 83 a | 88 a | 98 a | 89 a | 90 a |
| Stinger | 8.0 | 87 a | 92 a | 98 a | 96 a | 87 a |
| DPX-MAT28-128 | 1.7 | 50 a | 10 c | 40 b | 47 b | 76 b |
| Clarity | 4.0 | 63 a | 58 b | 37 b | 45 b | 92 a |
| 2,4-D LV6 | 8.7 | 42 a | 15 c | 48 b | 37 b | 76 b |
| *Spring-applied herbicides* | | | | | | |
| Non-treated | - | 0 - | 0 - | 0 - | 0 - | 79 bc |
| Milestone | 0.6 | 0 - | 6 a | 94 a | 76 a | 87 ab |
| Stinger | 8.0 | 0 - | 10 a | 100 a | 78 a | 90 a |
| DPX-MAT28-128 | 1.7 | 0 - | 3 a | 53 b | 35 b | 48 d |
| Clarity | 4.0 | 0 - | 5 a | 50 b | 32 b | 83 a-c |
| 2,4-D LV6 | 8.7 | 0 - | 5 a | 53 b | 66 a | 76 c |

[1] Means in each column followed by the same letter are not different at $p \leq 0.05$.

[2] DPX-MAT-128 is an experimental formulation of aminocyclopyrachlor.

# Quantifying the Impact of Soil-Borne Wheat Mosaic Virus Under Dryland Conditions

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The incidence of Soil-borne wheat mosaic virus (SBWMV) is on the rise in the Walla Walla Valley this year (14-22 in rainfall zone). Producers who have not previously had SBWMV in their fields have recently tested positive for the virus. Other producers who have previously dealt with SBWMV in patchy, localized areas are now observing symptoms in new fields, and observing widespread symptoms across entire fields.

The increased incidence of SBWMV this year could be due to early moisture in Fall 2016 (which is conducive for infection), the spread of SBWMV within the region, or perhaps a combination of these factors.

SBWMV affects fall-seeded small grains; the infection occurs in fall and first visual evidence of infection expresses in springtime. The mosaic virus is vectored by *Polymyxa graminis,* a soil-borne, fungal-like organism that moves through soil with water. In dryland conditions, patches of infected plants typically occur in low-lying wet swales that are conducive for the swimming spore stage of *P. graminis*. However, in particularly wet years, patches may occur anywhere in the field.

**Photo 1. Characteristic chlorotic patches in winter wheat caused by Soil-borne wheat mosaic virus. March 2017.**

SBWMV symptoms are typically first noticed as chlorotic, yellowish patches (Photo 1). Within the chlorotic patches, plants are often stunted and display a “mosaic” pattern on leaf tissue (Photo 2).

There is no cure for SBWMV, but identification of the virus is very important so that a resistant variety or blend can be planted in problematic fields the following crop year. As springtime temperatures rise, plants may recover or “grow-out” of symptoms; scouting in early spring and collecting suspect plants for analysis before symptoms fade is important.

**Photo 2. Soil-borne wheat mosaic virus resistant cultivar (top leaf) versus susceptible cultivar (bottom leaf). Susceptible leaf displaying characteristic mosaic-like pattern. March 2017.**

With funding from the Oregon Wheat Commission, The Pendleton Cereal Pathology group is working on several objectives this season:

1. Quantify the impact of SBWMV virus on yield under dryland conditions.

2. Evaluate the efficacy of resistant and susceptible variety blends under high SBWMV disease pressure.

# Broadleaf Weed Control and Crop Response with Talinor

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DEPT. PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

Talinor is a premix that will soon be registered in winter wheat to control broadleaf weeds and contains two active ingredients. Bicyclopyrone is a group 27 herbicide that inhibits 4-hydroxyphenyl-pyruvate dioxygenase (HPPD) and is combined with bromoxynil, group 6 herbicide that inhibits photosystem II. Talinor will be used to control group 2 (acetolactate synthase inhibitor) resistant broadleaf weeds, including mayweed chamomile and prickly lettuce.

Studies were initiated in spring 2015 at Culdesac and Genesee, ID in winter wheat to evaluate crop injury and broadleaf weed control. Talinor was applied at 13.7, 16, and 18.2 oz/A compared to Huskie at 11 oz/A and Starane Flex 13.5 oz/A. The experimental design was a randomized complete block with 4 replications and included an untreated check. Crop injury and weed control were evaluated visually where 0% represented no injury or control and 100% represented complete plant death. Grain was harvested at maturity at Genesee.

At Culdesac, no treatment injured winter wheat (data not shown). Talinor at all rates, Huskie, and Starane Flex controlled catchweed bedstraw 84 to 93% (Table 1). All rates of Talinor controlled mayweed chamomile 85 to 94%, but mayweed chamomile was not controlled by Huskie or Starane Flex (66 and 50%). At Genesee, no treatment injured winter wheat (data not shown). All Talinor rates and Huskie controlled common lambsquarters 94 to 99% (Table). Talinor treatments did not control prickly lettuce (42 to 74%). Huskie and Starane Flex controlled prickly lettuce 98%. Grain yield and test weight did not differ among treatments, including the untreated check.

**Table 1. Broadleaf weed control and wheat response with Talinor near Culdesac and Genesee, ID in 2015.**

| | | Culdesac | | Genesee | | | |
|---|---|---|---|---|---|---|---|
| | | Weed control[2] | | Weed control[2] | | Wheat | |
| Treatment[1] | Rate | GALAP | ANTCO | LACSE | CHEAL | Yield | Test weight |
| | oz/A | % | % | % | % | bu/A | lb/bu |
| Talinor | 13.7 | 82 | 92 | 67 | 99 | 104 | 61.2 |
| Talinor | 16 | 93 | 85 | 42 | 95 | 102 | 61.1 |
| Talinor | 18.2 | 84 | 94 | 74 | 94 | 104 | 61.2 |
| Huskie | 11 | 89 | 66 | 98 | 98 | 106 | 61.4 |
| Starane Flex | 13.5 | 89 | 52 | 98 | 60 | 103 | 61.6 |
| Untreated check | -- | -- | -- | -- | -- | 101 | 61.0 |
| LSD (0.05) | | NS | 10 | 31 | 25 | NS | NS |
| Weed density (plants/ft$^2$) | | 0.5 | 5 | 5 | 2 | | |

[1] COC is a crop oil concentrate at 1% v/v and sodium bicarbonate at 0.2 % v/v was applied with Talinor. Ammonium sulfate at 1 lb ai/A and nonionic surfactant at 0.25% v/v was applied with Huskie.

[2] GALAP = catchweed bedstraw, ANTCO = mayweed chamomile, LACSE = prickly lettuce, CHEAL = common lambsquarters.

## Rotational Crops Response to Osprey Xtra Applied to Prior Wheat Crop

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[1]DEPT. PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI; [2]BAYER CROPSCIENCE

Osprey Xtra is a premix that will soon be registered in winter wheat to control grass weeds, including rattail fescue. Currently, few postemergence herbicide options exist or provide effective rattail fescue control. Osprey Xtra will control rattail fescue as a postemergence herbicide. Osprey Xtra is a group 2 herbicide that inhibits acetolactate synthase (ALS) production. Some ALS herbicides used to suppress rattail fescue in wheat can impact rotational crops planted in the following year.

Studies were initiated in spring 2014 at Genesee, ID and Spangle, WA to evaluate rotational crop response in 2015. In 2014, Osprey Xtra was applied at 1X (labeled rate) and 2X rate to wheat, and a 2X rate of Osprey and PowerFlex were included as standards. The experimental design was a randomized split-block with 4 replications. Main plots were the rotational crops and subplots were the herbicide treatments and the untreated check. Rotational crop response was evaluated visually where 0% represented no injury and 100% represented complete crop death. Rotational crops were harvested at maturity.

At Genesee, PowerFlex injured lentil 14% at 45 days after planting, which was the maximum visual injury observed. Chickpea seed yield was greater in plots treated with Osprey Xtra at the 2X rate than the untreated check. Pea, chickpea, lentil and canola visual injury was greater in the PowerFlex treatment than all other herbicides at Spangle at all evaluation times. Chickpea and lentil seed yield tended to be lower for PowerFlex treatments.

The PowerFlex label restricts planting pea, chickpea, and lentil the following year in Pacific Northwest soils. Rotational crops were injured by PowerFlex at both sites but to a higher degree at Spangle. PowerFlex persistence is affected by rainfall and soil pH. A lower pH and less rainfall at Spangle likely caused PowerFlex to persist longer in the soil compared to Genesee. Osprey Xtra did not reduce rotational crop seed yield at either location and should have no rotational crop restrictions for pea, chickpea, lentil and canola.

## Synthetic Wheat Genotypes Improved Yields in a No-Tillage Environment with High Levels of Soil Borne Root Pathogens in the Pacific Northwest

AARON MAHONEY[1], PAT OKUBARA[1,2], TIMOTHY PAULITZ[1,2], AND SCOT HULBERT[1]
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No-tillage (direct-seed) practices are an excellent approach to sustainable agriculture because they prevent soil erosion and improve moisture retention, and organic matter. Consequently, populations of *Rhizoctonia* and *Pythium* spp., necrotrophic root pathogens, can multiply in no-tillage environments causing significant plant stunting and yield losses for direct-seeded wheat. If available, the deployment of genetic resistance would provide a new management approach to these pathogens. Recently, field studies identified five synthetic and synthetic-derived wheat genotypes with minimal stunting when exposed to high levels of these soil borne pathogens. These five lines were crossed into a Pacific Northwest cultivar 'Louise,' which is highly susceptible to *Rhizoctonia* and *Pythium* spp. The progeny of these lines were then subsequently backcrossed to Louise to improve agronomic and phenotypic traits. Populations ($BC_1F_2$) from these crosses were screened in high inoculum field and growth chamber environments for five more generations. Individually selected plants from the $BC_1F_6$ generation were then backcrossed again ($BC_2$) into the recurrent parent Louise so that approximately 85% of their genes are predicted to come from Louise. $BC_2F_2$ populations were then screened in similar high-pathogen environments for five more generations and the most resistant plants were selected and bulked for yield trials. Yield trials were conducted in two farm locations in moderate and high rainfall zones in Davenport, WA and

Pullman, WA in 2016, respectively. To determine differences in yield, multiple fungicides targeting *Rhizoctonia* and *Pythium* spp. were implemented in control plots using treated Louise seed as a check. These plots were compared to the untreated seed of Louise and the $BC_2$ genotypes. Results showed an average of 58 bushels per acre for Louise in the fungicide treated plots, compared to 32 bushels for the untreated seed. This was a reduction of 46% ($P < 0.01$) in the high inoculum environments. The untreated seeds for the $BC_2$ genotypes were not significantly different ($P = 0.09$) with an average of 49.5 bushels per acre. These results suggested beneficial alleles from the synthetic and synthetic-derived genotypes had been transferred into the Louise background and they could improve yields in a high inoculum environment in the Pacific Northwest. Yield data and other agronomic traits will be collected for the second season in 2017.

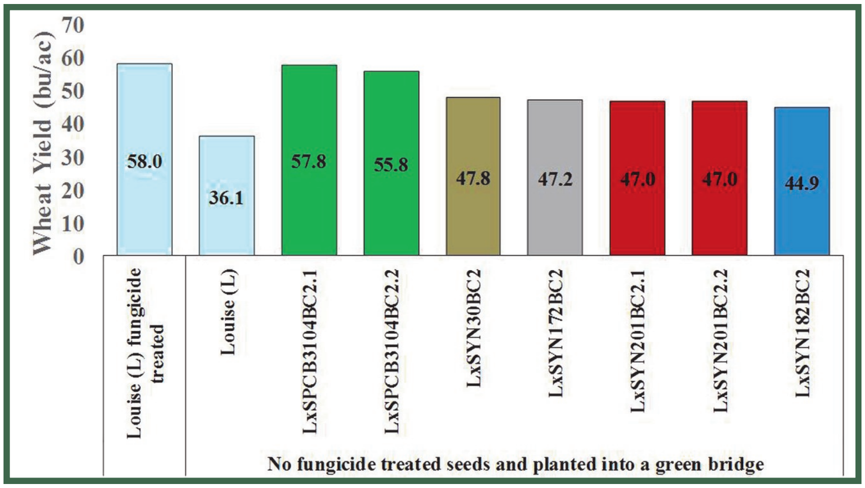

**Figure 1. Yields for wheat genotypes with transferred beneficial alleles from synthetic and synthetic-derived lines into the Louise cultivar background. Yields are averages for the genotypes grown at the Wilke and PCFS farms in high inoculum (green bridge) environments. The different genotypes are colored.**

## Wheat Root Growth and Morphological Variables for Phenotyping Root Rot Resistance

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[1]USDA-ARS, ROOT DISEASE AND BIOLOGICAL CONTROL; [2]MOLECULAR PLANT SCIENCES PROGRAM AND DEPT. OF PLANT PATHOLOGY, WSU; [3]DEPT. OF CROP AND SOIL SCIENCES, WSU

*Rhizoctonia* resistance is a desirable trait in wheat, but can be difficult to screen in the field due to yearly variability in rainfall, soil pathogen populations and other environmental factors. Our standard greenhouse screen is based on total root length measured from digital images of 14-d-old seedlings grown in soil with or without *Rhizoctonia solani* AG-8. To facilitate selection of future resistant lines, we have developed several more rapid, low-cost screens to examine early root growth variables as predictors of *Rhizoctonia* resistance in Pacific Northwest wheat genotypes. For instance, average root growth has been obtained for a population of 30 seedlings in laboratory Petri plates over a 48-96 h period. Additional experiments can be done in soil with or without *R. solani*. Seminal root angles will be quantified from seedlings

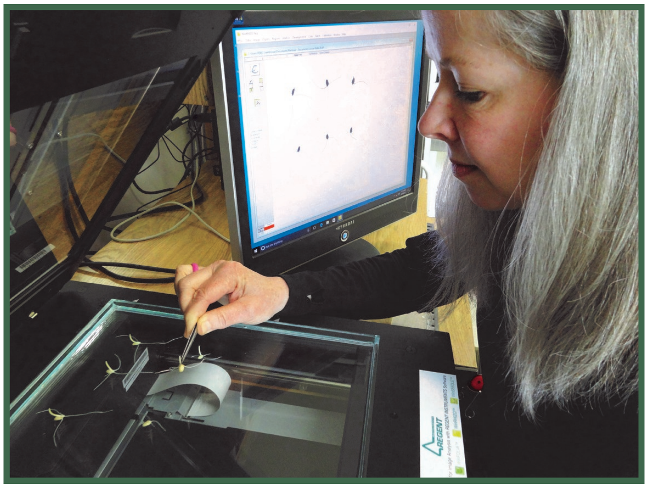

**Photo 1. Technician Karol Marlowe (Okubara laboratory) places young wheat seedlings on a flatbed scanner for root growth imaging.**

**Photo 2. Rachel Dannay, graduate student in the Sanguinet laboratory, examines wheat roots growing in GelZan.**

grown against the walls of transparent pots. More technologically-advanced methods will be used to gather information on the development of post-seedling stage roots. Preliminary experiments indicated that wheat seedling roots grow well in the gellan gum-based clear medium GelZan (Phytotech Labs). When combined with 360° imaging (Ortery Technologies), lateral root size and number, root hair density, root branching pattern, and other architecture traits will be assessed in three dimensions and quantified using DIRT software. Root architecture traits also will be monitored in soil in the absence and presence of the pathogen using the CI-600 *in situ* root imaging system (CID, Inc.). Certain root growth variables differ between the susceptible cultivar Scarlet and its near-isogenic resistant partner Scarlet-Rz1. Recent research has produced two more *Rhizoctonia*-resistant synthetic or synthetic-derived wheat lines showing enhanced growth in the presence of *R. solani* AG-8. These new lines provide additional genetic resources for comparing root growth and morphology in resistant and susceptible wheat. Cooperator: Dr. Tim Paulitz

## Evaluating the Effect of Tillage on Soil-Borne Wheat Pathogens in the Dryland Pacific Northwest

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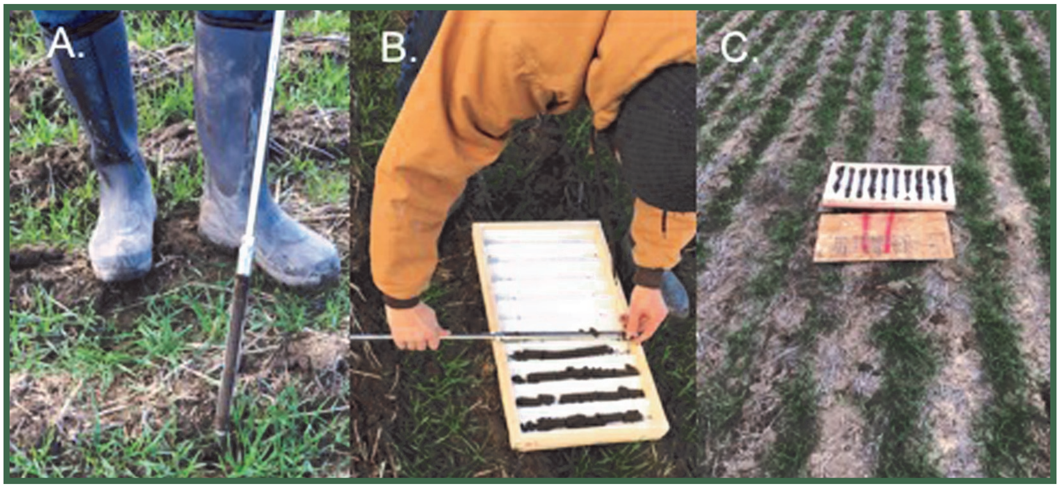
KATHERINE R. MCLAUGHLIN, DUNCAN R. KROESE, AND CHRISTINA H. HAGERTY
OREGON STATE UNIVERSITY

No-till seeding is described as planting directly into the crop stubble from the previous season without use of primary tillage. No-till acreage is increasing in the dryland cereal production region of the Pacific Northwest (PNW). A reduction in tillage can result in positive outcomes, including increased soil water holding capacity and reduced fuel costs. However, no-till management can cause shifts in crop disease profiles. There is conflicting evidence in the literature about whether reduced tillage results in increased diversity of plant pathogens. Similarly, some farms have reported a reduction in disease pressure after converting to no-till; but other farms have reported an increase in disease pressure. The goal of this study is to understand how tillage influences disease dynamics. In Fall 2016, 10 soil samples were collected from each of 30 wheat fields representing a wide



**Soil cores sampled from fields (Photo A), intact cores transported for analysis (Photo B), tillage rated on a 0-10 scale from inversion tillage to no tillage (Photo C).**

range of tillage. Fields were scored on a 0-10 scale from inversion tillage (0) to no-tillage (10). Soil samples are currently being evaluated for three soil-borne pathogen groups: *Fusarium*, *Pythium*, and *Rhizoctonia*. Pathogen abundance will be evaluated as a function of tillage. Additional variables including soil pH, organic matter, and field rainfall zone will be investigated. Cultural disease control recommendations were developed mostly under stubble mulch tillage; this study is part of a long-term goal to develop disease management recommendations for no-till producers of the PNW.

## Stripe Rust Control and Research in 2016

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USDA-ARS WHEAT HEALTH, GENETICS, AND QUALITY RESEARCH UNIT AND DEPT. OF PLANT PATHOLOGY, WSU

In 2016, stripe rust was accurately forecasted using prediction models and monitored in fields throughout the crop season. Rust updates and advises were provided on time to growers for implementing appropriate disease management based on the forecasts and field surveys. Wheat stripe rust started early and developed to a severe epidemic in the Pacific Northwest (PNW). In the PNW, yield losses caused by stripe rust were determined to be more than 70% on the susceptible check and 0-32% on commercial varieties of winter wheat; and 55% on the susceptible check and 0-43% on commercial varieties of spring wheat in our experiment fields near Pullman. The timely application of fungicide in most PNW controlled stripe rust, which saved 18 million bushels of wheat grain, about 75 million dollars at the cost of about 25 million dollars in Washington State alone. Nationally, wheat stripe rust was widespread and caused estimated 5.6% yield loss (about 129 million bushels). Barley stripe rust occurred, but was low. Wheat leaf rust and barley leaf rust occurred in western, but not in eastern Washington. Stem rust of wheat and barley was basically absent in Washington. From stripe rust samples collected throughout the country, we identified 61 races of the wheat stripe rust pathogen and 5 races of the barley stripe rust pathogen. Among these races, 26 were new. In Washington State alone, 33 races of wheat stripe rust pathogen including 10 new races were identified. We completed studies of sequencing several isolates, improving genome sequence assembling and annotation, identifying effectors associated to pathogen virulence, constructing the first map of chromosomes and mapping numerous virulence genes of the stripe rust pathogen. We evaluated 35,000 wheat and 3,000 barley entries for resistance to stripe rust in fields and about 3,000 of them also in the greenhouse, and provided the data to breeding and related programs. Using our stripe rust data, we collaborated with breeders in releasing seven wheat varieties and one barley variety. We registered 29 new wheat germplasm lines that carry either a single or two genes in combination for resistance to stripe rust. We completed studies for mapping five genes for stripe rust resistance in three wheat lines and identified molecular markers. We advanced 40 winter wheat by winter wheat crosses to the $F_3$ generation for identifying and mapping new stripe rust resistance genes. We tested 47 fungicide treatments in fields for control of stripe rust; and 24 winter and 16 spring wheat varieties for their yield loss and fungicide response. The results and resources from our research have been used to develop stripe rust resistant varieties, registering new fungicides, and guiding the control of stripe rust.

## Insects in Fall-Seeded Legumes

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DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

In the Pacific Northwest, fall-planted peas can offer much higher yields, along with other agronomic advantages as compared with spring-sown pea. New varieties of edible fall-planted dry pea are becoming available. Successful integration of fall-planted peas will require assessment of agronomic and plant protection issues that may pertain to these crops. Insect pests limit yield of spring-planted peas. They are also subject to injury from *Pea enation mosaic virus* (PEMV) and *Bean leaf roll virus* (BLRV), transmitted to the crop by pea aphid, *Acyrthosiphon pisu*, migrating to the Palouse from warmer, lower elevation sites in the PNW. Aphids migrating in the fall could infect the plants with virus. In 2004 and 2005, fall planted lentils were sampled for all pests and the communities differed in the number of predators found (Fig.

1). The earlier maturation of fall-sown pea might change vulnerability to pea leaf weevil (*Sitona lineatus*) and pea weevil (*Bruchus pisorum*). How fall-planted peas are affected by these pests and diseases has not been assessed.

Starting in 2016, we are assessing the abundance and injury of insect pests and the prevalence of aphid-transmitted viruses in experimental and commercial plantings of fall-sown pea. Aphids were trapped after emergence at the locations shown on the map below (Fig. 2), at the Lind Dryland Research Station, and in plots near Dayton WA being operated by USDA-ARS geneticist, Rebecca McGee. In the fall of 2016, only three aphids were captured in pan traps and none were carrying virus. However, plant tissue collected from across all sites detected BLRV predominantly in western sites and some PEMV in eastern sites. This indicates that fall planted peas can be infected prior to the main growing season. We will continue to monitor viruses and pests in fall-planted pea over the next several years.

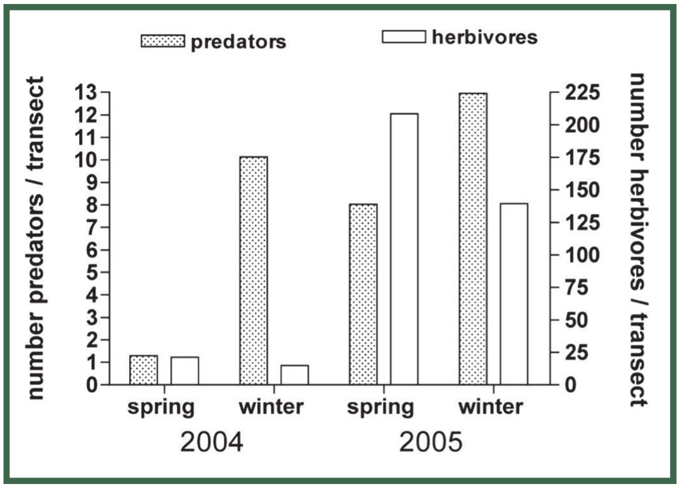

**Figure 1. Abundance of predatory insects and herbivores (pests) in fall planted lentil in 2004 and 2005. Differences suggest similar patterns might occur in pea. The greater abundance of predators could be an advantage that producers can exploit.**

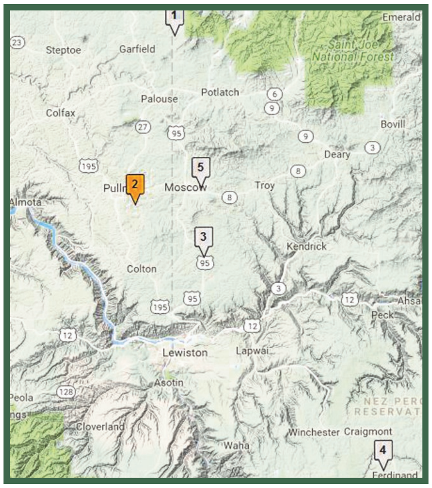

**Figure 2. Map showing sites with fall planted pea currently being monitored for insects and viruses (not shown on this map is a site at the Lind Dryland Research Station and another site near Dayton, WA).**

## Fungi and Oomycetes in Herbicide-Killed Roots: Who Are the Players in the Greenbridge?

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Growers have known for years that root pathogens such as *Rhizoctonia* and Pythium can be carried over in the "greenbridge" after proliferating on dying roots killed by herbicides such as Roundup (glyphosate). If growers do not spray out weeds and volunteer 2-3 weeks before planting in the spring to allow microbial populations to outcompete pathogens, these diseases can increase. What fungi are in the roots, and how does this community change after roots are killed? We conducted a greenhouse experiment with field soil, where plants were killed with glyphosate, SelectMax (clethodim) or left alive and used next-generation DNA sequencing (MiSeq) to characterize fungal and oomycete community dynamics as roots die. The dynamics of these communities differed among treatments. *Pythium volutum* and *Lagena radicola* were the dominant oomycetes in roots, but as the roots were dying, *P. volutum* increased for two weeks, but *L. radicola* declined in freshly killed roots (Fig. 1). This *Pythium* species is difficult to isolate, has been reported in Washington, but has not been recognized as a major player in root diseases. *Lagena* has often been observed in roots, but is an obligate parasite, and its impact on roots and wheat is unknown. *Myrmecridium* sp was the most dominant fungus in roots, and as the roots died, other saprophytes, such as *Cadophora*, started to displace the pathogens in the killed roots (Fig. 2). These findings offer insight into how microbial communities change after roots are killed and shed light on the key players that compete with pathogen populations. Moreover, the presence of under-recognized species in roots suggest that there are still new fungi to be discovered in roots with molecular techniques that play important roles in plant health, despite 50 years of traditional research.

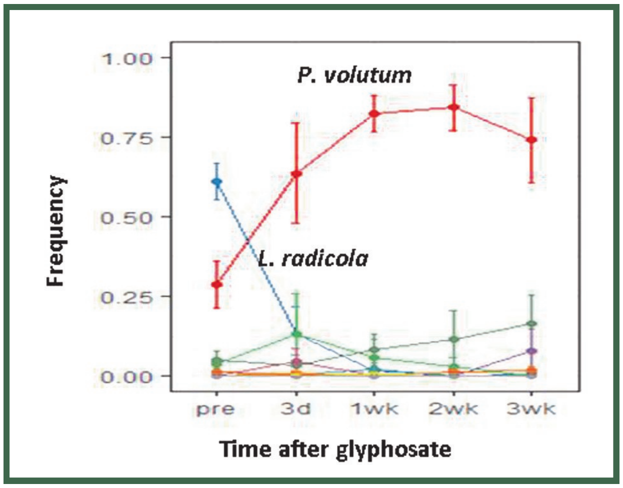

**Figure 1. Oomycetes**

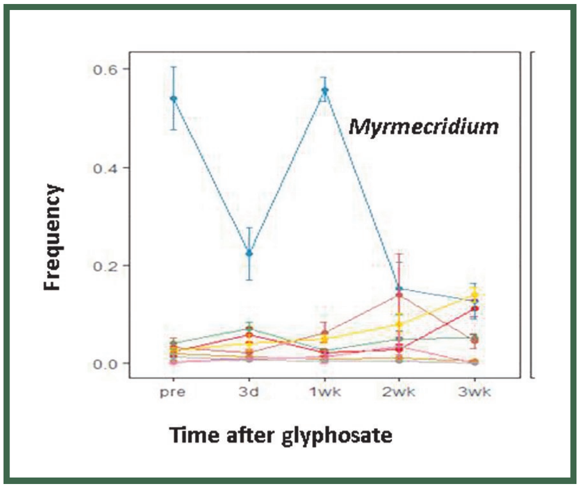

**Figure 2. Fungi**

## Assessment of Soil Acidity on Soil-Borne Pathogens, Weed Spectrum, Herbicide Activity, and Yield on Dryland Wheat Production

CHRISTINA H. HAGERTY[1], JUDIT BARROSO[1], STEPHEN MACHADO[1], DON WYSOCKI[1], KURT SCHROEDER[2], GARY WEGNER[3], PAUL CARTER[4], TIM MURRAY[4], AND STEPHEN VAN VLEET[4]
[1]OREGON STATE UNIVERSITY; [2]UNIVERSITY OF IDAHO; [3]COLUMBIA RIVER CARBONATES; [4]WASHINGTON STATE UNIVERSITY

Synthetic Nitrogen (N) inputs have been used in the inland Pacific Northwest (IPNW) dryland wheat production region since the early 1900s. The resulting eight decades of N inputs has acidified soils in the IPNW. In many commercial wheat fields of the region, soil pH in the top 6 inches has dropped below 5.5, the critical pH for wheat. Nitrogen continues to be added annually, further perpetuating soil acidification. Agricultural lime can mitigate the acidifying effects of nitrogenous fertilizers, but has been generally thought of as an uneconomical solution for low-input, dryland wheat producers. This situation is problematic for economic, environmental, and agronomic reasons. There is evidence that some yield-limiting soil-borne pathogens such as *Cephalosporium* and *Fusarium* thrive under acidic conditions. There is also evidence that some noxious weeds thrive under acidic conditions while herbicide efficacy can be reduced. The pathology and weed dynamics in low pH soils are further compounded as overall crop heath declines simultaneously in acidic conditions. As soils of the Columbia Basin become more acidic with each cropping cycle, it is crucial to evaluate of the impact of soil acidity in our local production system. A field experiment will be conducted in three different rainfall zones (Moro, Pendleton, and Pullman) to understand the complex effect of soil acidity on soil-borne pathogens, weed spectrum, herbicide activity and yield. We have assembled a tristate team of scientists from Washington State University, Oregon State University, and University of Idaho as soil acidity is a yield limitation across all three states. The scientists involved in this project have expertise in the fields of agronomy, cropping systems, plant pathology, soil science, and weed science –

**Photo 1. Photo of replicated plots in Moro, Oregon treated with $CaCO_3$ at 600lbs./acre, 1200lbs./acre, 2400 lbs./acre, and untreated control plots. Photo taken in October 2016 by C.H. Hagerty.**

this will allow us to implement the project and interpret the results with a synergistic approach to gain the most amount of information from a single experiment.

## Eyespot, Cephalosporium Stripe, and Snow Mold Diseases of Winter Wheat

TIM MURRAY AND HONGYAN SHENG
DEPT. OF PLANT PATHOLOGY, WSU

Eyespot (strawbreaker foot rot) and Cephalosporium stripe diseases are most common in the high-rainfall regions of Washington, but also occur in the low- and intermediate-rainfall wheat-producing areas and have potential to cause loss in grain yield up to 50% for eyespot and 80% or more for Cephalosporium stripe. In contrast, snow mold diseases historically have been a problem in the north-central wheat-producing area of Washington near the Waterville Plateau and can cause complete yield loss when a susceptible variety is grown and disease is severe.

Planting a resistant variety is the best control for all of these diseases. In addition, fungicide application in spring is an option for eyespot control in some areas. Our research has focused on identifying new and effective resistance genes to these three diseases. Over the past 10 years, we have tested new varieties and advanced breeding lines for eyespot and Cephalosporium stripe resistance in inoculated field trials and used that information to provide variety ratings. Several varieties with effective eyespot resistance and Cephalosporium stripe tolerance are available; check the small grains team website listed below for more information. Five fungicide treatments are now registered for eyespot control: Tilt 3.6EC + Topsin-M 4.5FL; Alto 100SL + Topsin-M 4.5FL; Priaxor 4.16SC; Quilt Xcel 2.2SE + Topsin-M 4.5FL; and, Nexicor EC. Results of our field trials with variety ratings and fungicide trials are available on the WSU Wheat and Small Grains website (http://smallgrains.wsu.edu/disease-resources/research-reports/).

The winter of 2016-17 will be remembered for being cold and snowy across most of the eastern Washington wheat-producing area. Snow fell and persisted beginning in early December in most areas and stayed for 60 to over 100 days. Pink snow mold was found in some areas of the state (e.g. Prescott; photo above) where it had not been seen for many years, and it was severe enough to kill wheat in parts of some fields. As this is being written, snow cover is still present in some areas of Douglas County and it is anticipated that both Speckled and pink snow molds will be present when the snow melts. Planting a resistant variety early is still the best control for the snow molds. In conjunction with the WSU Winter Wheat Breeding program and University of Idaho Extension Plant Pathology program in Idaho Falls, ID, we are working with new sources of disease resistance to understand their potential value in our area, and testing current and new varieties for snow mold resistance in field plots near Mansfield and Waterville, WA, and Tetonia, ID.

## Update on the New Cereal Aphid in the Pacific Northwest

Sanford D. Eigenbrode and Ying Wu
Dept. of Plant, Soil, and Entomological Sciences, UI

**Figure 1. Feeding damage by wheat grass aphid on Stephens wheat.**

*Metopolophium festucae* ssp. *cerealium M.f.c.* is a European cereal aphid that was introduced to the United States in 1994 at Oregon. It has no official common name but we call it the wheat grass aphid because it attacks wheat and many other common wild and cultivated grasses (but not corn). It is prevalent in the region based on samples of winter wheat throughout the Palouse, in central Washington, and northern Oregon. It is not a vector of Barley yellow dwarf virus, but, it can cause substantial direct injury by its feeding. Feeding by aphids, especially the nymphs, causes a red staining and chlorosis, presumably due to an unknown toxin or toxins in their saliva. This staining is associated with greater damage per aphid than is caused by other species. Shown here are the typical staining lesions (Fig. 1) , a picture of the aphids from our laboratory colonies established from collections on the Palouse (Fig 2.), and data showing the amount of reduction in chlorophyll (based on readings taken by Minolta SPAD chlorophyll meter) after 7 days of feeding by single aphids of each species (Fig 3.). Wheat grass aphid damage is significantly greater than damage by bird cherry-oat aphid or Russian wheat aphid. Individual nymphs, although smaller, cause more damage than individual adults. Varieties may differ in susceptibility.

**Figure 2. Adult and nymphs of wheat grass aphid.**

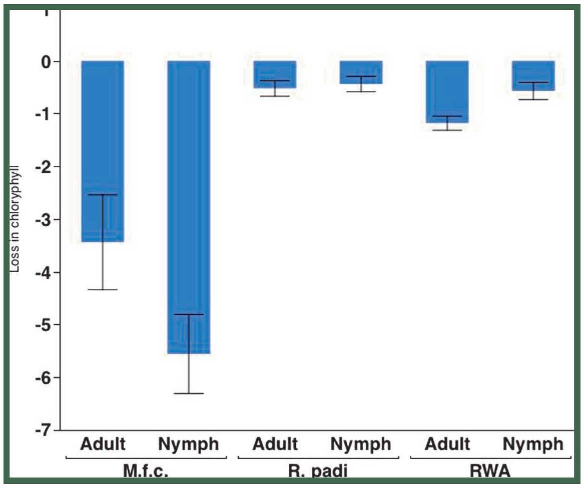

**Figure 3. Reduction in chlorophyll produced by wheat grass aphid (*M.f.c.*), bird cherry-oat aphid (*R. padi*) and Russian wheat aphid (RWA).**

## Identifying Weed Infestations with Optical Data at Harvest

Judit Barroso[1], John McCallum[2], and Dan Long[2]
[1]CBARC, OSU; [2]USDA-ARS, CPCRC

Kochia (*Kochia scoparia* L.), Russian thistle (*Salsola* ssp.), and prickly lettuce (*Lactuca serriola*) are economically important weeds infesting dryland wheat (*Triticum aestivum* L.) production systems in the western United States. Their late maturing nature means that they may still be green and growing well after the wheat crop is physiologically mature.

When the crop is harvested, the weedy plant matter that does not completely separate will be contained in the grain stream. The objectives of this study were to determine the ability of an optical sensor, installed for on-the-go measurement of grain protein concentration, to detect the presence of green plant matter in flowing grain and assess the potential usefulness of this information for mapping weeds at harvest. An in-line optical sensor with sensitivity in the visible and NIR wavelengths (500-1100 nm) was mounted on the clean grain filling auger of a combine harvester. Spectra of the grain stream were recorded continuously at a rate of 0.33 Hz during harvest of an 18 ac wheat field. All readings were georeferenced using a GPS receiver with 1 m positional accuracy. Chlorophyll of green plant matter was detectable in the red (670 nm) waveband. A map of the chlorophyll signal showed a good relationship (78% agreement on average) with the reference map constructed prior to harvest of the three green weed species. This information on weed distributions at harvest is useful to optimize the post-harvest control of these species by using site-specific herbicide applications. Kochia, Russian thistle, and prickly lettuce produce most of their seeds post-harvest, their control at that time reduces the amount of seeds that, otherwise, would become part of the seed bank.

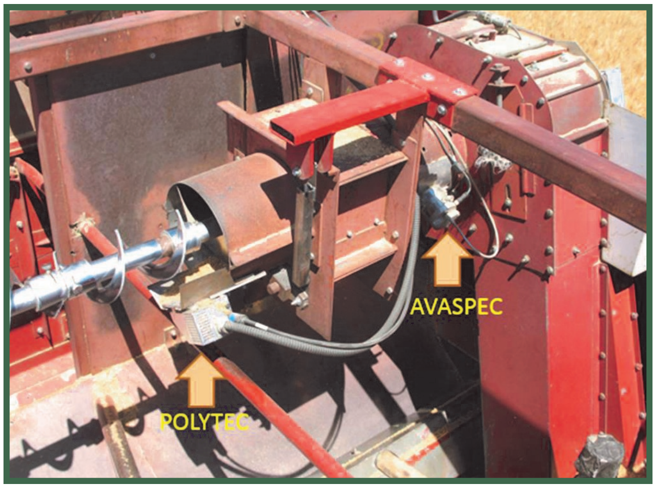

**Figure 1. An Avaspec model 2048 optical sensor was mounted to the combine's grain bin filling auger to measure grain protein and detect plant material in the harvested grain.**

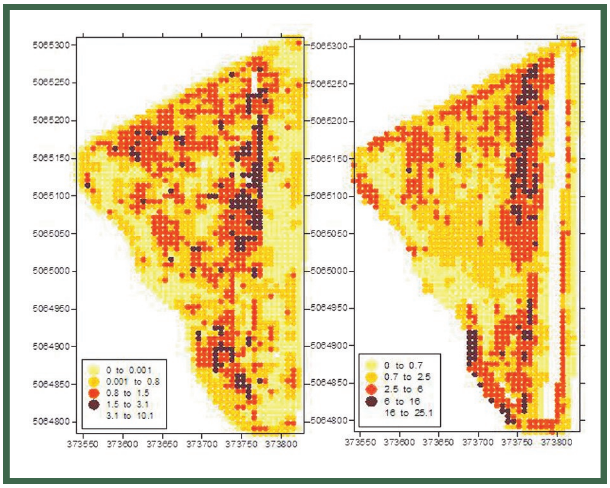

**Figure 2. Weed infestation maps a) ground truth and b) sensor**

**Table 1. Comparison between the weed reference map (ground truth) and the weed map from the sensor.**

| | | | | Ground truth | | |
|---|---|---|---|---|---|---|
| Zero weed tolerance | Threshold | Infested (%) | Sensor | TRUE | FALSE | Agreement |
| Ground truth | 0.0 | 77.0 | TRUE | 65.4 | 12.5 | 75.80% |
| Sensor | 0.7 | 78.0 | FALSE | 11.7 | 10.4 | |
| Low weed infestation | | | | | | |
| Ground truth | 0.8 | 36.3 | TRUE | 20.1 | 16.2 | 67.50% |
| Sensor | 2.5 | 36.5 | FALSE | 16.3 | 47.4 | |
| Moderate weed infestation | | | | | | |
| Ground truth | 1.5 | 7.7 | TRUE | 1.7 | 4.8 | 89.20% |
| Sensor | 6.0 | 6.7 | FALSE | 6.0 | 87.5 | |

# Part 2. Breeding, Genetic Improvement, and Variety Evaluation

## The Low Falling Number Problem of Wheat: Applying Knowledge about Seed Biology to a Real-World Issue

STEPHANIE SJOBERG[1], CAMILLE STEBER[2], KIMBERLY GARLAND-CAMPBELL[2], AND ARRON CARTER[1]
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The Hagberg-Perten Falling Number (FN) test is used by the wheat industry to measure starch degradation caused by alpha (α)-amylase enzyme activity in flour. Grain with too much α-amylase activity (resulting in an FN below 300) must be sold at a severe discount because it results in poor quality baked goods. Low FN/high α-amylase can result from two independent genetic causes, preharvest sprouting and late maturity alpha-amylase. Preharvest sprouting is the germination of mature grain on the mother plant when cool, rainy conditions occur before harvest. Alpha-amylase can be produced early in the germination process, before seedling growth is obvious. Late maturing α-amylase (LMA) expression occurs in susceptible individuals in response to a cold or high temperature shock during the late maturation phase of grain development. The FN of 92 varieties were determined at 21 locations in 2013 and 2014 in collaboration with the Washington State University Cereal Variety trials (http://smallgrains.wsu.edu/variety/). These data were posted on the web to make the information available to farmers and breeders (http://steberlab.org/project7599.php). When the data were analyzed as a whole, the low heritability (0.16) of FN suggested that genetics explained only a small part of the FN problem. We hypothesized that genetics would have a stronger impact (higher heritability of FN) if we could account for the multiple genetic and environmental factors involved, including PHS, LMA, and grain starch and protein characteristics. If so, then using weather data to separate FN data into the mega-environments (ME), PHS, LMA, and "No Event" locations, should improve apparent heritability. Consistent with this notion, we found the mean ± SE of heritability across the 6 MEs to be 0.26 ± 0.037 (Fig. 1). Broad Sense Heritability was highest in the "No Event" environment where FN was not impacted weather conditions causing PHS or LMA. When calculated across an entire year or both years, heritability is generally lower than when split into these MEs. The one exception to our hypothesis was the 2014 PHS environment where only 11% of phenotypic variation was due to the genetic variation (H2 = 0.11). This suggests that FN in some of these locations that experienced rain were impacted by other factors besides sprouting. For example, some locations may have experienced both sprouting and LMA.

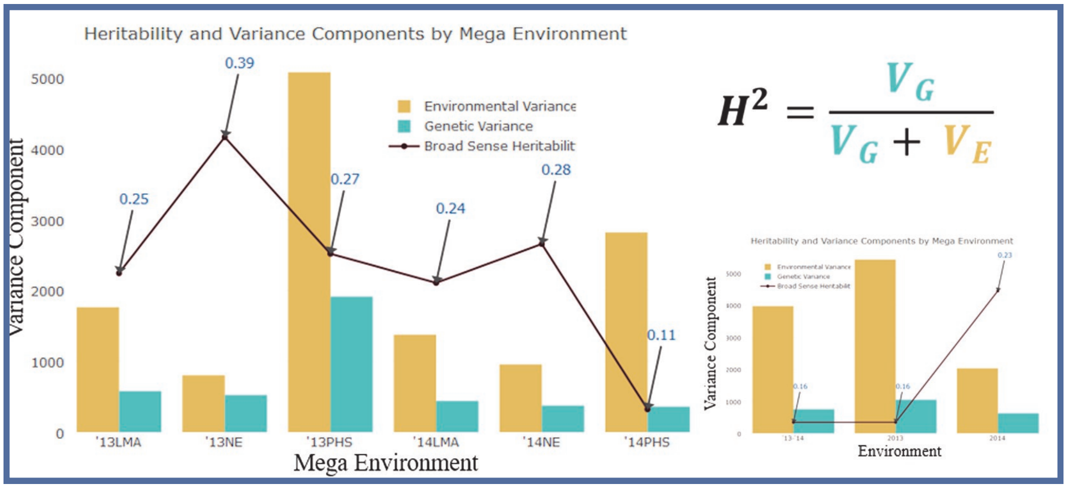

**Figure 1. Variance components (Genetic and Environmental) and Broad Sense Heritability of the FN trait as calculated per Mega Environment (ME) as defined in Fig. 2 (PHS = Preharvest Sprouting, LMA = Late Maturity α-Amylase, and NE = No Event). The same values were also calculated per year separately and combined (2013, 2014, and '13-'14) with all MEs included.**

# Breeding to Address Future Needs for Wheat Production in the Pacific Northwest

R.S. ZEMETRA[1], M. LARSON[1], A. HEESACKER[1], T. HARRAN[1], H. GUNN[1], C. MUNDT[2], AND A. ROSS[1]
[1]DEPT. OF CROP AND SOIL SCIENCE, OSU, [2]DEPT. OF BOTANY AND PLANT PATHOLOGY, OSU

One of the challenges in breeding wheat is the time it takes to develop a new variety. It takes on average ten years from the first cross to having a variety ready for a farmer to plant. So to address a future need a breeder sometimes has to guess if there is a problem that is going to occur in the future and start working on the solution today. An example of this is the growing need for wheat cultivars in the intermediate to high rainfall wheat growing areas with resistance to soil-borne wheat mosaic virus (sbWMV). This disease is found in soil and since it is a virus there are no chemical controls to reduce the impact of the disease. Once it is in the soil it can't be eradicated and will slowly spread with time. The only way to prevent yield loss is through adding a gene for resistance to sbWMV. The disease was identified in an eastern Washington field around 2008 and can now be found on farms in both eastern Washington and eastern Oregon. Work started in 2009 to transfer sbWMV resistance into varieties adapted to growing in the Pacific Northwest. Using a combination of conventional breeding methods to transfer the resistance gene and molecular techniques to identify individual plants that carry the gene, new soft white winter wheat varieties are being developed carrying resistance to sbWMV. The final test is to evaluate the breeding line under disease pressure (Fig. 1). While transferring a single gene for resistance is not difficult, the challenge is having not only sbWMV resistance but also having the variety be high yielding, carry resistance to other diseases such as stripe rust, and maintain the high level of end-use quality expected of wheat produced in the Pacific Northwest. Want to know what genes need to be introduced today to address the needs of the future? Just ask a plant breeder what parents they are using in their crossing block this year.

**Figure 1. 2017 screening nursery for sbWMV resistance showing resistant (green) and susceptible (yellow green) breeding lines.**

# Washington Extension Cereal Variety Testing Program

RYAN HIGGINBOTHAM[1], VADIM JITKOV[2], AND ANDREW HORTON[2]
[1]WSU EXTENSION; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

The WSU Extension Cereal Variety Testing Program provides growers, the agribusiness industry, university researchers, and other interested clientele with comprehensive, objective information on the adaptation and performance of wheat and barley cultivars across the various climatic regions of eastern Washington. The Cereal Variety Testing Program conducts comparisons using scientifically sound methodology, produces independent results, disseminates all data to clientele, and uses uniform testing procedures across common locations. The evaluation trials are conducted at many locations: 24 for soft white winter and 17 for hard winter wheat; 18 for soft white and hard spring wheat; and 12 for spring barley. Trial results are available in printed form in *Wheat Life* and the Cereal Variety Testing Annual Report.

Comprehensive results for last year and previous years can be found on the Variety Testing Website (http://smallgrains.wsu.edu/variety). Variety performance data is provided within days after harvest via the program website and an email list-serve. Oral presentations, field days, and industry and extension meetings are other means used for delivering research results. Growers and interested parties are welcome to visit the testing sites whenever they'd like. Plot maps are available on the program website and can also be found attached to the large Variety Testing sign at most trial locations.

An additional method that growers may use to access data generated by the Variety Testing program is through the Variety Selection Tool, located on the small grains website (http://smallgrains.wsu.edu). The small grains website was launched in early 2014 by our small grains Extension team and aims to provide growers with a one-stop place to find current information about small grain production in the region. The Variety Selection Tool is based on two years of results of variety performance data from the variety trials along with other variety characteristics from multiple sources. Users are able to select a market class of grain, along with a precipitation zone, and an interactive table is populated with varieties and their performance within that precipitation zone. Information available includes yield, test weight, protein, plant height, disease ratings, maturity and more!

## iPat: Intelligent Prediction and Association Tool for Genomic Research

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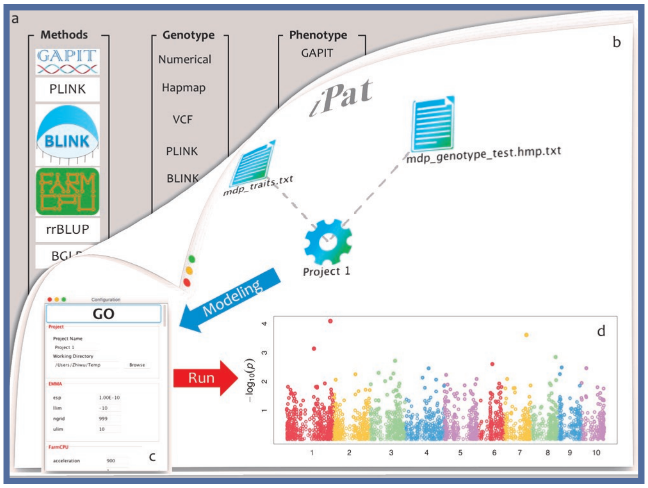
DEPT. OF CROP AND SOIL SCIENCES, WSU

The ultimate goal of genomic research is to effectively predict the phenotypes from genotypes so that medical management can be employed to improve human health and molecular breeding can be exercised to increase agricultural production. Before all the genes being identified, genomic prediction plays the critical role to be complimentary to genome wide association studies, the primary method to identify genes underlying phenotypes. Unfortunately, most computing tools hardly perform data analyses for both. Furthermore, a majority of these tools are executed through command line interface (CLI) that not only eliminate users without programming skills, but also result in a low learning curve due to zero tolerance to input parameters and keywords. This study demonstrated the development of a friendly graphic user interface (GUI) software package, iPat (intelligent prediction and association tool) to address these problems. Users can perform all the analyses by simply dragging and clicking mouse to specify input data files and choose parameters and models. iPat was written in Java to enhance GUI and communication with CLI tools, including GAPIT, Plink, FarmCPU, BLINK, rrBLUP and BGLR. iPat was also featured with flexibility to adapt multiple genotype formats, including hapmap, numerical, VCF and Plink. In addition to the three genomic prediction methods in GAPIT, a GWAS assisted genomic prediction method was implemented to perform genomic prediction by using any of the GWAS methods, including compressed mixed linear model and FarmCPU. The executable file of iPat can be downloaded for free on http://ZZLab.Net/iPat. The website also contains a user manual, tutorials and demonstration dataset.



Project
Project Name
Project 1
Working Directory
/Users/Zhiwu/Temp
EMMA
esp 1.00E-10
llim -10
ngrid 999
ulim 10
FarmCPU
acceleration 900

**Figure 1. Design of intelligent prediction and association tool (iPat). The tool provides users the ability to access incorporated packages and data inputs (a) by using graphic user interface (GUI). The GUI (b) allows users to control all the processes, including modeling (c) and displaying results (d). The current incorporated packages include GAPIT, PLINK, FarmCPU, BLINK, rrBLUP, and BGLR. The input genotype data can be any of the formats: numerical hapmap, VCF, PLINK, and BLINK. The input phenotype data can be either with (GAPIT) or with (FarmCPU) individual identifications. The GUI allows users to drag any type data files into the interface and create project icons to link data files, manage analyses, and display results.**

## USDA-ARS Club Wheat Breeding

KIM GARLAND-CAMPBELL[1], PATRICIA DEMACON[2], EMILY KLARQUIST[2], AND NUAN WEN[2]
[1]USDA-ARS; [2]DEPT. OF CROP AND SOIL SCIENCES, WSU

The focus of the USDA program is to develop high quality club wheat and soft white cultivars, and to incorporate germplasm for disease resistance into soft and hard PNW-adapted lines. The program has yield trials in 11 locations across eastern Washington, Idaho, and Oregon, which allows us to test our cultivars in a variety of different climates and leads to production of better varieties for specific PNW climates.

Figure 1. USDA-ARS Club Wheat summer field crew after hand harvesting head rows.

**Pritchett** is the latest variety released by the USDA-ARS. It is a soft white winter club developed by both WSU and the USDA-ARS. Pritchett is targeted to the traditional low-intermediate rainfall club wheat growing region. It has excellent emergence from deep sowing, excellent club wheat quality, and excellent resistance to stripe rust and Cephalosporium stripe disease. Pritchett should replace Bruehl in low rainfall areas due to superior yield, test weight, milling quality, eyespot tolerance, earlier maturity, similar winter survival and moderate snow mold resistance. Current data are limited but Pritchett has been intermediate to Bruehl and ARS Crescent for tolerance to low falling numbers. Grain of Pritchett grades as club wheat more consistently than Bruehl.

The top goals for 2017-2018 are to; 1) incorporate a new gene for pre-harvest sprouting tolerance into Washington wheat to prevent low falling number scores at harvest; 2) improve the current Fusarium greenhouse screenings so more lines can be reliably screened year round; 3) purchase a second freeze chamber to increase our capacities for testing lines tolerant to freezing temperatures; 4) continue our collaborations with other breeding programs for the stripe introgression crossing block which seeks to incorporate new (yet to be identified) stripe rust resistance into adapted wheat varieties all over the United States; 5) continue the screening for cereal cyst nematode (CCN) resistant wheat varieties and the extensive survey for CCN distribution which has been conducted each year since 2013 to delineate the extent of infestation.

## Development of Wheat Mutant Populations Using Fast Neutrons and Gamma Ray

CHAOZHONG ZHANG[1,2], JINGZHENG WU[1,2], DAVID HOADLEY[3], YUEGUANG WANG[1], AND DAOLIN FU[1]
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Mutant populations are valuable genetic resources for fundamental research and applied studies in cereal crops. In wheat, mutant populations have been prepared using chemical agents (e.g. ethyl methanesulfonate and sodium azide) and physical irradiations (e.g. gamma ray and fast neutron). Here, we studied the effect of fast neutron (FN) and gamma ray (GR) on hexaploid wheat (*Triticum aestivum* cultivar 'Brundage' and line 'IDN01-10704A'). We aim to generate thousands of mutants in Brundage and IDN01-10704A. Desirable mutant will be used for specific trait improvement in Brundage, IDN01-10704A, and other wheat cultivars in the Pacific Northwest.

For FN treatment, mature seeds were treated in the McClellan Nuclear Research Center (McClellan, CA) using the FN radiation doses from 7 to 49 gray (Gy; an irradiation unit, 1 Gy = 100 rad) with an increment of 7 Gy per treatment. Based on germination test, FN irradiation significantly repressed the germination of shoots and roots; FN doses applied had a negative correlation with the seedling size. Seedlings from the 7 to 21 Gy range survived, of which the 7 Gy treatment had on effect on plant sizes and leaf numbers, the 14 Gy treatment significantly repressed plant sizes but not on leaf numbers, while the 21 Gy treatment significantly repressed plant sizes and leaf numbers. Most seedlings from higher doses (≥ 28 Gy) did not survive. For GR treatment, mature seeds were treated in the JL Shepherd & Associates (San Fernando, CA) using a center line dose of 275 Gy. Similar to the FN test, GR irradiation significantly repressed the germination of shoots and roots. Both FN and GR-based mutant populations are currently grown in the Parker Farm, Moscow, ID.

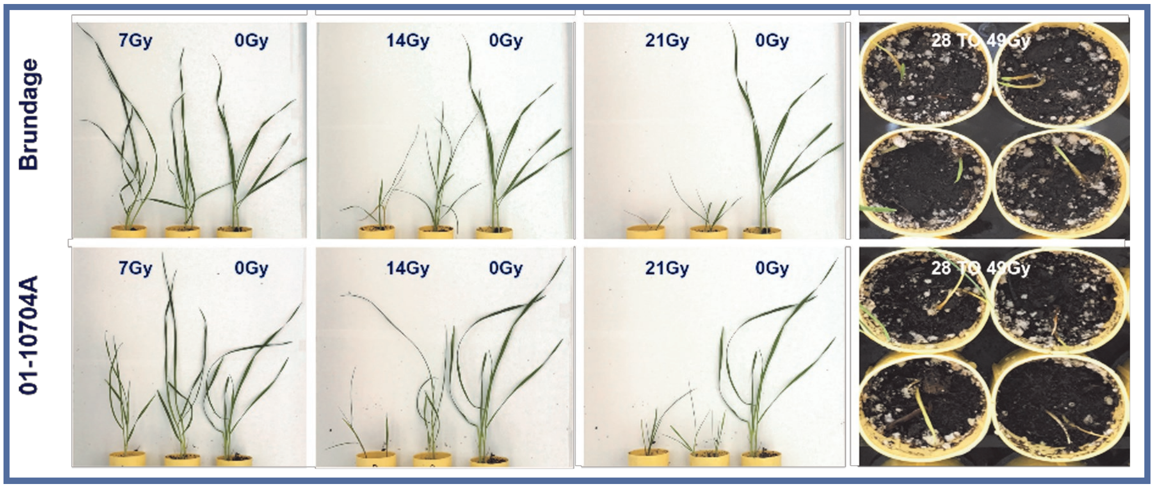

**Figure 1. Fast neutron-treated seedlings in greenhouse. Photos were taken three weeks post germination (or two weeks post transplanting). Empty cones represented lethal doses. For non-lethal doses, two survived seedlings per dose were displayed together with one non-treated control (0Gy).**

# 'Celiac-safe' Wheat Genotypes: A Target Not Too Far

Sachin Rustgi[1,2], Diter von Wettstein[2], Nii Ankrah[2,3], Richa Gemini[2], Patrick Reisenauer[2], and Richard Koenig[2]
[1]Dept. of Plant and Environmental Sciences, Clemson University; [2]Dept. of Crop and Soil Sciences, WSU; [3]School of Biological Sciences, WSU

Prolamins dubbed as gluten represent the major seed storage proteins in wheat grains, and cherish the glory of being one of the most consumed dietary proteins in the world. In addition, gluten was also found responsible for a variety of dietary disorders in the susceptible individuals. According to an estimate about 7.5% of the U.S. population is affected by the 'gluten syndrome'. The only effective therapy known so far is lifelong adherence to abstinent diet, which is difficult to practice if not impossible. In recent years, wheat sales have suffered a setback due to the increasing public awareness about the gluten-induced disorders and reliance on misconceptions or rumors. On the other hand, the market for gluten -free commodities is constantly strengthening and projected to touch a $7.59 billion mark by 2020. Based on our findings and the parallel research conducted elsewhere, we hypothesize that it is possible to develop a general dietary therapy for gluten syndrome by eliminating or detoxifying the cause of these disorders. We tested our hypothesis by - i) tissue-specific silencing of the wheat *DEMETER* and *Alarm Clock 4* genes, which respectively encode a DNA glycosylase and a Fe-S cluster biogenesis protein. These genes collectively control transcriptional activation of 100 different prolamins, except high molecular weight glutenins. ii) Ectopic expression of a glutamine specific endoprotease from barley and a post-proline cleaving endopeptidase from *Flavobacterium* in wheat grains. The combination of 'glutenases' was earlier tested by others and us to completely detoxify gluten proteins to non-immunogenic peptides. Endosperm-specific silencing of the wheat *DEMETER* and *Alarm Clock 4* genes will be respectively achieved by a TALE (transcription activator-like effector) repressor and an RNA-guided Cas9 (CRISPR associated protein 9) nuclease. These site-directed mutagenesis procedures are being used in a combination to pyramid the effect of wheat *DEMETER* and *Alarm Clock 4* gene silencing in a single genotype. So far wheat genotypes exhibiting up to 76% reduction in immunogenic prolamins were identified and efforts to obtain genotypes with >90% suppression in gluten content are underway. Similarly, wheat genotypes expressing two 'glutenases' in their endosperms were obtained and their detailed biochemical characterization is in progress.

The major outcomes of this research will be the development of wheat genotypes with near complete elimination/detoxification of immunogenic prolamins, high lysine content and enhanced bioavailability of prolamins to the consumers. Moreover, these wheat genotypes will serve as the first prophylactic dietary therapy available to the gluten intolerant, sensitive and allergenic individuals.

## The USDA-ARS Western Wheat Quality Laboratory

CRAIG F. MORRIS, DIRECTOR AND DOUG ENGLE
USDA-ARS WESTERN WHEAT QUALITY LABORATORY

The mission of the USDA-ARS Western Wheat Quality Lab is two-fold: conduct milling, baking, and end-use quality evaluations on wheat breeding lines, and conduct research on wheat grain quality and utilization. Our web site: http://wwql.wsu.edu/ provides great access to our research. Our research publications are readily available on our web site.

Our current research projects include soft durum wheat, grain hardness, arabinoxylans, puroindolines, polyphenol oxidase (PPO), waxy wheat, and quinoa. Our recent publications include the identification of genetic markers of wheat associated with flavor preference using the laboratory mouse model published in the Journal of Cereal Science. A study on the effect of soft kernel texture on the milling properties of soft durum wheat was published in Cereal Chemistry.

Research on wheat grain consumption and selection by inbred and outbred strains of mice was published in Physiology & Behavior. A study on how puroindoline genes introduced into durum wheat reduce milling energy and change milling behavior similar to soft common wheats was published in the Journal of Cereal Science. Research on quinoa seed quality response to sodium chloride and sodium sulfate salinity was published in Frontiers in Plant Science. A study on the rheology and pasting properties of soft-textured durum wheat and hard-textured common wheat was published in the Journal of Cereal Science. Currently the lab is working on grant-funded research aimed at removing the culinary constraints of soft kernel durum wheat, a genetically rich cereal species. Recent wheat varieties that have been developed in collaboration with WSU, OSU and USDA-ARS scientists include Otto, Puma, Sprinter, Pritchett, Dayn, Glee, Sequoia, and Earl.

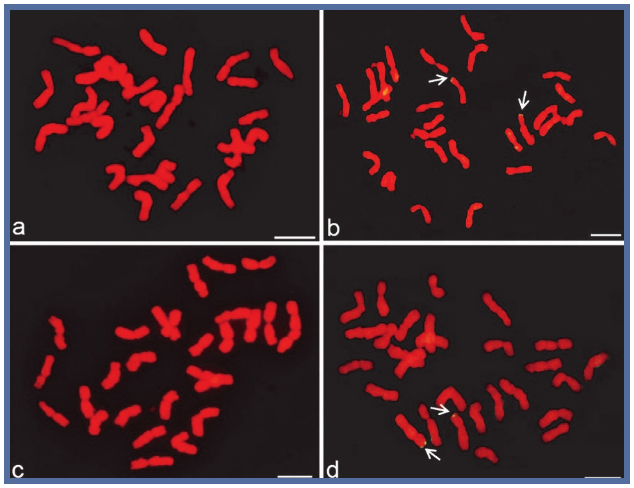

**Figure 1. 5DS-5BS chromosome translocation conferring soft kernel texture in durum wheat (courtesy X. Cai and M. Zhang).**

# Identification of a Locus Corresponding to the Preharvest Sprouting Tolerance Gene *ERA8* in Wheat (*Triticum aestivum* L.)

Shantel A. Martinez[1,3], Samantha R. Beck[4], Daniel Z. Skinner[2,3], Deven See[2,3], Arron H. Carter[1,3], Kimberly A. Garland Campbell[1,2,3], and Camille M. Steber[1,2,3]
[1]Molecular Plant Sciences, WSU; [2]USDA-ARS; [3]Dept. of Crop and Soil Sciences, WSU; [4]Integrated Plant Sciences, WSU

Preharvest sprouting (PHS) is the germination of mature wheat grain on the mother plant when cool and wet conditions occur before harvest. PHS causes severe losses for wheat growers. Lack of seed dormancy accounts for 60-80% of PHS susceptibility. The *ERA*8 mutation was selected for increased sensitivity to the dormancy hormone ABA, resulting in increased seed dormancy and PHS tolerance. This gene is effective in the soft white spring background, Zak, and represents a new source of PHS tolerance for PNW wheat. The goal of this project was to identify *ERA*8-linked molecular markers for genomic selection during breeding. We mapped the *ERA8* gene using both traditional QTL analysis and using a next-generation sequence-based approach. Using both methods we localized *ERA8* to a region of chromosome 4A. Figure 1 illustrates the fine mapping of *ERA8* in the Louise/Zak*ERA8* RIL population down to a 4.9 cM region using single nucleotide polymorphisms (SNP). A SNP is a change in a single DNA nucleotide that is detected by sequencing. *ERA8* is currently being crossed into wheat breeding lines to increase preharvest sprouting tolerance. The *ERA8* SNP markers identified by this project are currently being used for rapid genomic selection in breeding lines. Identification of additional recombinants to fine map the region even more is currently underway.

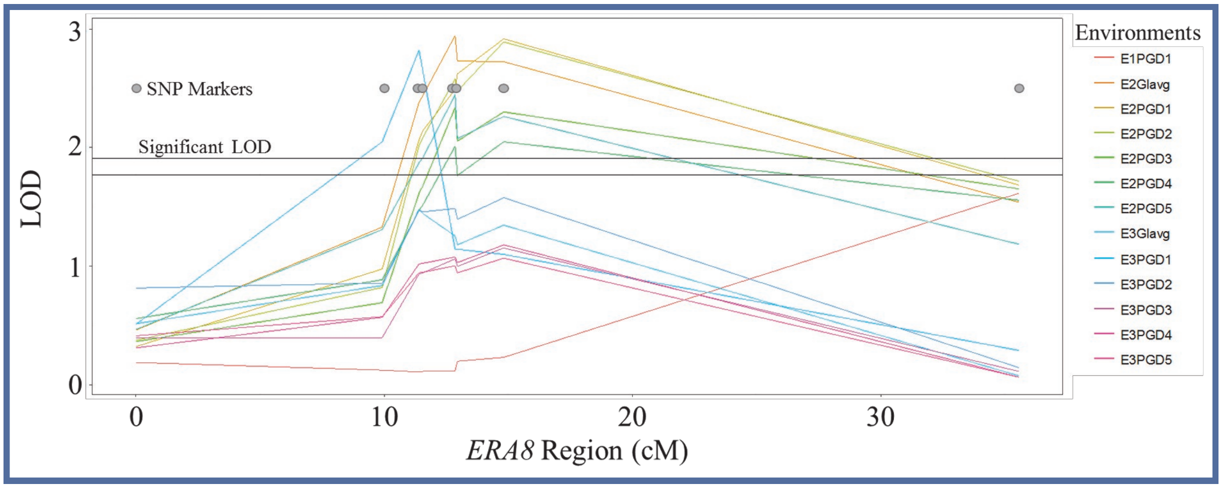

**Figure 1. Fine mapping of *ERA*8 in the Louise/Zak*ERA8* population. Each colored line represents seeds harvested from a different environment. Each environment has a different significant LOD threshold, and the black horizontal lines represent the range ($p<0.05$). The large grey dots represent the SNP markers used for mapping. Future work will increase the definition using additional markers.**

# Creating Options for Wheat Producers in the Pacific Northwest

K. Brandt[1], S. Trittinger[1], M. Larson[1], A. Heesacker[1], T. Harran[1], C. Mundt[2], A. Ross[1], and R.S. Zemetra[1]
[1]Dept. of Crop and Soil Science, OSU; [2]Dept. of Botany and Plant Pathology, OSU

The climate in the Pacific Northwest (PNW) is becoming more variable, trending to warmer winters and lower rainfall in May and June. This can have a significant impact on wheat producers in low to intermediate rainfall production zones. Two ways to address this problem are: one, breed for traits that minimize the impact of the environmental changes, and two, create new market class options for the wheat producers in the low to intermediate rainfall zones.

Facultative Breeding Project: The rapidly changing climate has already had an effect on the PNW, where we have experienced fewer frost days on average, with this trend only expected to become more pronounced in the years to come. Winter wheat requires gradually decreasing, sustained cold temperatures in order to vernalize and flower in the spring. Warmer winters could delay flowering leading to problems if rain does not occur in late May or June. A solution to this problem is the development of facultative wheat lines that can survive our typical, freezing winters as well as our future unpredictable winters. To do this, molecular markers associated with traits that allow winter wheat to be productive regardless of winter temperatures need to be developed. Using lines developed from a cross between Skiles and Goetze, two winter varieties that differ for vernalization response and photoperiod, field trials have been planted in three Oregon locations in 2016/2017. These lines are now being assessed for response to winter field conditions, and will also be assessed for the ability to grow with reduced or no vernalization in the future. Information generated from this study will be used in the breeding program to develop new varieties that are adapted to the new environmental realities of the PNW.

High Quality Hard Wheat for the PNW: One approach to overcoming low rainfall induced poor wheat quality is to change the market class of wheat to one that is less negatively impacted if rain does not occur when expected. Such a market class is hard winter wheat. But there is a problem switching to hard winter wheat. Wheat grown in the Pacific Northwest often produces high grain yield but low percent grain protein. To achieve the higher percent grain protein high nitrogen input is usually required which raises environmental and economic concerns. High grain protein (12% or higher) is needed to provide an adequate level of gluten for bread quality. Glutenins are a group of gluten proteins and are important for dough elasticity. Bx7 is one of the high-molecular-weight glutenin subunits. The objective of this study is to evaluate whether a modified gluten composition caused by an over-expression (oe) of the Bx7 gene improves the bread-making quality in hard wheat at sub-optimal levels of grain protein. Sixty lines with and without the Bx7oe allele were selected and planted over two years at two locations at two fertility (nitrogen fertilizer) levels. Results from this study will determine if bread-quality hard winter wheat can be produced in traditional soft white winter production areas.

# Part 3. Agronomy and Soils

## Advances in Dryland Farming in the Pacific Northwest

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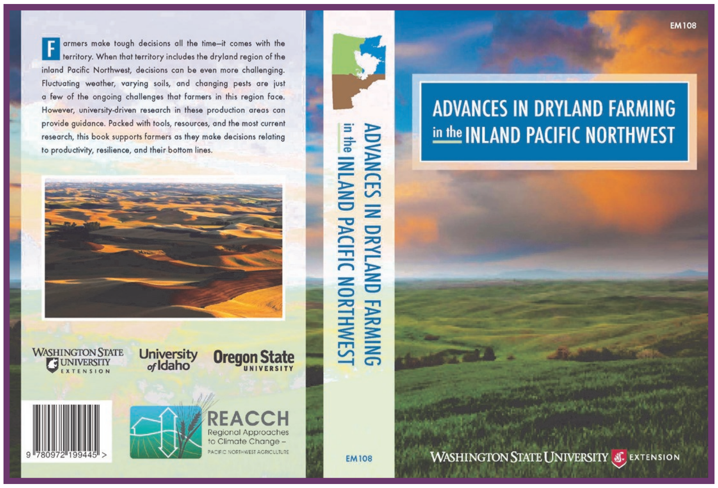
Georgine Yorgey[1], Chad Kruger[1], Stephen Machado[2], Kristy Borrelli[3], Elizabeth Kirby[1], Rakesh Awale[2], Elizabeth Allen[1], Prakriti Bista[2], Ian Burke[4], Laurie Houston[5], Haiying Tao[4], Bertie Weddell[1], and Sanford Eigenbrode[1]
[1]Center for Sustaining Agriculture and Natural Resources, WSU; [2]Columbia Basin Agricultural Research Center, OSU; [3]Penn State University Extension; [4]Dept. of Crop and Soil Sciences, WSU; [5]Applied Economics, OSU; [6]Dept. of Entomology, Plant Pathology, and Nematology, UI

Fluctuating weather, varying soils, and changing pest pressures are just a few of the ongoing challenges that farmers in the inland Pacific Northwest face. University-driven research in these production areas can provide guidance. A new book, *Advances in Dryland Farming in the Inland Pacific Northwest,* represents a joint effort over a three-year period by a multi-disciplinary group of research and Extension scientists from across the region. Together they compiled and synthesized recent research advances as well as economic and other practical considerations to support farmers as they make decisions relating to productivity, resilience, and their bottom lines.



Farmers make tough decisions all the time—it comes with the territory. When that territory includes the dryland region of the inland Pacific Northwest, decisions can be even more challenging. Fluctuating weather, varying soils, and changing pests are just a few of the ongoing challenges that farmers in this region face. However, university-driven research in these production areas can provide guidance. Packed with tools, resources, and the most current research, this book supports farmers as they make decisions relating to productivity, resilience, and their bottom lines.

The book has 12 chapters: Climate Considerations, Soil Health, Conservation Tillage Systems, Crop Residue Management, Rotational Diversification and Intensification, Soil Fertility Management, Soil Amendments, Precision Agriculture, Integrated Weed Management, Disease Management for Wheat and Barley, Insect Management Strategies, and Farm Policies and the Role for Decision Support Tools.

The book will be available electronically via the WSU Extension Learning Library, the OSU Extension Catalog, or UI Extension/CALS Publications Catalog, as well as on reacchpna.org. Physical copies can also be ordered through the Extension Publications Stores.

## Nitrogen Removal Estimation in Winter Wheat Using Normalized Difference Red-Edge Index and Proximal Protein Sensors

RACHEL BRESLAUER, HAIYING TAO, AND DAVID BROWN
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Proper Nitrogen (N) management is critical in winter wheat for farmers to maximize the value of their grain at harvest by achieving optimal grain protein (Hard Red >14%, Soft White <12%). The Palouse's uniquely hilly topography makes it a challenging place to achieve optimal protein levels across a field because ideal N management varies with field conditions.

Being able to estimate N removal in a previous crop is an important component of constructing appropriate variable N prescription rates for the coming year. Two promising tools for estimating crop N removal are i) on-the-go protein sensors that estimate grain protein at harvest and ii) normalized difference red-edge indices (NDRE) calculated from RapidEye satellite imagery.

In spring 2017 six monitoring sites located on collaborator's farms in Adams and Whitman counties in Washington and Latah county in Idaho. Monitoring plots within fields were chosen using an unsupervised image classification of on high resolution (15 ft.) RapidEye imagery from 2009-2017. Each location will be monitored for spring plant available N, harvested grain N, and biomass N at harvest time and will be harvested with a combine mounted with a proximal protein sensor. This project aims to assess the accuracy of each tool in estimating grain and biomass N in a harvested crop and their suitability for being used in constructing N recommendations in the Palouse.

**Figure 1. Grouping results for a field in Adams county Washington. Rapideye imagery was used to classify variability in fields. Random monitoring location were chosen within each group.**

More information about how the RapidEye red edge band can be found at https://apollomapping.com/wp-content/user_uploads/2012/07/RapidEye-Red-Edge-White-Paper.pdf.

## Labile Soil Organic Carbon Pools as Early Indicators for Soil Organic Matter Changes Under Different Tillage Practices

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Soil organic matter (SOM) is essential for soil fertility, water retention, and maintaining crop productivity. Soil storage of organic matter also reduces $CO_2$ levels in atmosphere and mitigate climate change. In soils, changes in SOM occur due to imbalance between SOM addition (primarily through crop residues) and its biological decomposition. Intensive soil mixing increases soil-residue contact and accelerates microbial decay of SOM, whereas low soil disturbances leaves residues on soil surface and favor SOM accumulation. In addition, tillage can also enhance SOM decomposition by breaking soil aggregates, increasing soil aeration, and raising soil temperature.

However, due to large inherent spatial variability and its recalcitrant nature, changes in SOM with response to agronomic practices are slow and show years later when it is too late for adjustments in management. Alternatively, labile pools of soil organic carbon (SOC, proxy for SOM), such as particulate organic matter carbon, permanganate oxidizable carbon, water extractable organic carbon, microbial biomass carbon, mineralizable carbon, have rapid turnover rates of weeks to months or few years compared with bulk SOM pools (SOC and total N). To this end, identifying early indicators of SOM dynamics will allow early management decisions and quick remedial actions necessary to build SOM stocks.

This study evaluated SOM pools across four tillage systems (no-till, disk/chisel, spring plow, and fall plow) in a wheat-pea long-term experiment (WPLTE) and under an undisturbed grass pasture (Table 1). All the tillage systems within WPLTE decreased SOC and total N relative to grass pasture. Also, labile SOC pools were higher under grass pasture than cultivated soils. Within WPLTE, neither SOC nor total N differed significantly among tillage systems. On the contrary, low disturbance tillage systems (no-till and disk/chisel) increased the labile SOC pools than fall plow or spring plow. The labile SOC pools were strongly correlated with bulk SOC and total N. Under wheat-pea rotation, low disturbance tillage systems (no-till and disk/chisel) have a potential to maintain or increase SOM, which can be assessed early through its physical (POMC), chemical (POXC, WEOC), and microbiological (MBC, Cmin) indicators. Microbiological pools were the most sensitive indicators of tillage induced changes in SOM dynamics.

**Table 1. Tillage effects on SOM pools in top 6-inch Walla Walla silt loam near Pendleton, OR in 2016.**

| Treatments | Bulk SOM Pools | | Labile SOC Pools | | | | |
|---|---|---|---|---|---|---|---|
| | SOC g/kg | TN g/kg | POMC g/kg | POXC mg/kg | WEOC mg/kg | MBC mg/kg | Cmin mg/kg |
| Grass pasture | $24.2^{a}$ | $1.78^{a}$ | $4.85^{a}$ | $706^{a}$ | $223^{a}$ | $678^{a}$ | $796^{a}$ |
| No-till | $17.9^{b}$ | $1.33^{b}$ | $4.48^{a}$ | $676^{b}$ | $181^{b}$ | $531^{b}$ | $565^{bc}$ |
| Disk/chisel | $18.2^{b}$ | $1.36^{b}$ | $4.56^{a}$ | $659^{bc}$ | $183^{b}$ | $570^{b}$ | $661^{b}$ |
| Spring plow | $17.2^{b}$ | $1.33^{b}$ | $3.67^{b}$ | $648^{cd}$ | $159^{c}$ | $509^{bc}$ | $612^{b}$ |
| Fall plow | $16.3^{b}$ | $1.26^{b}$ | $3.72^{b}$ | $633^{d}$ | $153^{c}$ | $418^{c}$ | $472^{c}$ |

Values within a column followed by the same letter are not significantly different ($P = 0.05$). SOC = soil organic carbon, TN = total nitrogen, POMC = particulate organic matter carbon, POXC = potassium permanganate oxidizable carbon, WEOC = water extractable organic carbon, MBC= microbial biomass carbon, Cmin = carbon mineralized in 30 days.

## Can We Manage Nitrogen Deficiencies of Waterlogged, Dryland Winter Wheat?

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The undulating landscape of the Palouse leads to differences in soil water storage patterns in the spring. Many soils in the region contain dense, clay layers that restrict water drainage leading to seasonally perched water tables, especially in the low-lying draws and flats. Winter wheat often exhibits nitrogen deficiency symptoms, such as yellowing, in these poorly drained areas at the tillering stage of growth. In 2016, we detected and monitored plant and soil conditions of waterlogged winter wheat from spring until harvest. A variety of crop, soil and root sensing instruments were installed to make continuous measurements at the WSU Cook Agronomy Farm (Pullman, WA) with episodic measurements in saturated areas at four other wheat fields in the Palouse region of eastern Washington and northern Idaho. One field location was lost due to Italian ryegrass pressure. In waterlogged wheat, fluctuations of the water table within the first foot of soil reduced biomass, number of tillers, plant height, chlorophyll concentration, and rooting depth (as measured by soil coring). The waterlogged soils also had 18 lb less N ac$^{-1}$ in the 4-ft profile than adjacent well-drained soils, with relatively more ammonium and less nitrate N. In the first week of May, the water table at Cook Farm receded below the first foot and the soil began drying out, but the waterlogged winter wheat did not “green-up” until the end of May/beginning of June. Across all sites, waterlogging penalized yields by 10% and N uptake by 17%, and reduced grain protein concentrations. We found that a spring top-dress application of urea, ammonium, or nitrate-based fertilizers allowed waterlogged wheat to “green-up” by the first week of May (Fig. 1), and increased the Normalized Difference Vegetation Index (NDVI), Normalized Difference Red Edge (NDRE), chlorophyll concentration, leaf area index, and yields of waterlogged wheat to similar levels of adjacent plants that were not top-dressed with fertilizer but were aerated and green at the tillering stage (Zadocks 2). We diagnosed the yellowing of winter wheat in waterlogged soils as a soil nitrogen deficiency that was caused by a combination of shallower roots and less plant available N under waterlogged conditions. Importantly, top-dressing also increased yields of neighboring well-drained, green wheat. Therefore, the results of this study have wider implications for split or tactical application of fertilizer. While there is potential to manage waterlogged with spring N applications, there are concerns of reduced nitrogen use efficiency and water quality in these vulnerable landscape positions due to potential run-off of fertilizer to streams.

**Figure 1. Response of waterlogged winter wheat to 50 lb of N topdressed ac$^{-1}$ in a flat near Palouse, WA, taken on May 3, 2016.**

# Simulating Field-Scale Variability and Precision Management with a 3D Hydrologic Cropping Systems Model

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Effective variable-rate nitrogen (N) management requires an understanding of variability between years and across a field (for example, lateral redistribution of water and nitrogen). We can improve our understanding of how to manage field-scale variability by using cropping systems models alongside field data. CropSyst-Microbasin (CS-MB) is a fully distributed, 3-dimensional hydrologic cropping systems model that simulates small (10’s of hectares) heterogeneous agricultural watersheds with complex terrain. This study used an intensively sampled 27-acre watershed, in the Inland Pacific Northwest, USA, to: (1) assess the accuracy of CS-MB simulations of field-scale variability in water transport and crop yield in comparison to observed field data, and (2) quantify differences in simulated yield and farm profitability between variable-rate and uniform fertilizer applications in low, average and high precipitation years. During water years 2012 and 2013 (a ‘‘water year’’ refers to October 1st through the following September 30th, where a given water year is named for the calendar year on September 30th), the model simulated surface runoff, soil water content, and crop yield with acceptable accuracy. During the low precipitation year, there was no difference in model-predicted yield under uniform or variable-rate management. In the high precipitation year, the model predicted that uniform N management resulted in less than a bushel per acre increase in field average yield in comparison to variable-rate management. The savings in fertilizer costs under variable-rate N management resulted in $9 to $13 per acre greater field average returns to risk. The savings in fertilizer cost while maintaining yield can offset start-up costs for variable rate in roughly 3 years, using costs reported from local growers using variable-rate N management and modeled yield increases in high precipitation years. This study was published in Precision Agriculture and is available online at http://link.springer.com/article/10.1007/s11119-017-9517-6/fulltext.html.

## Regional Growers Continue to Try New Strategies

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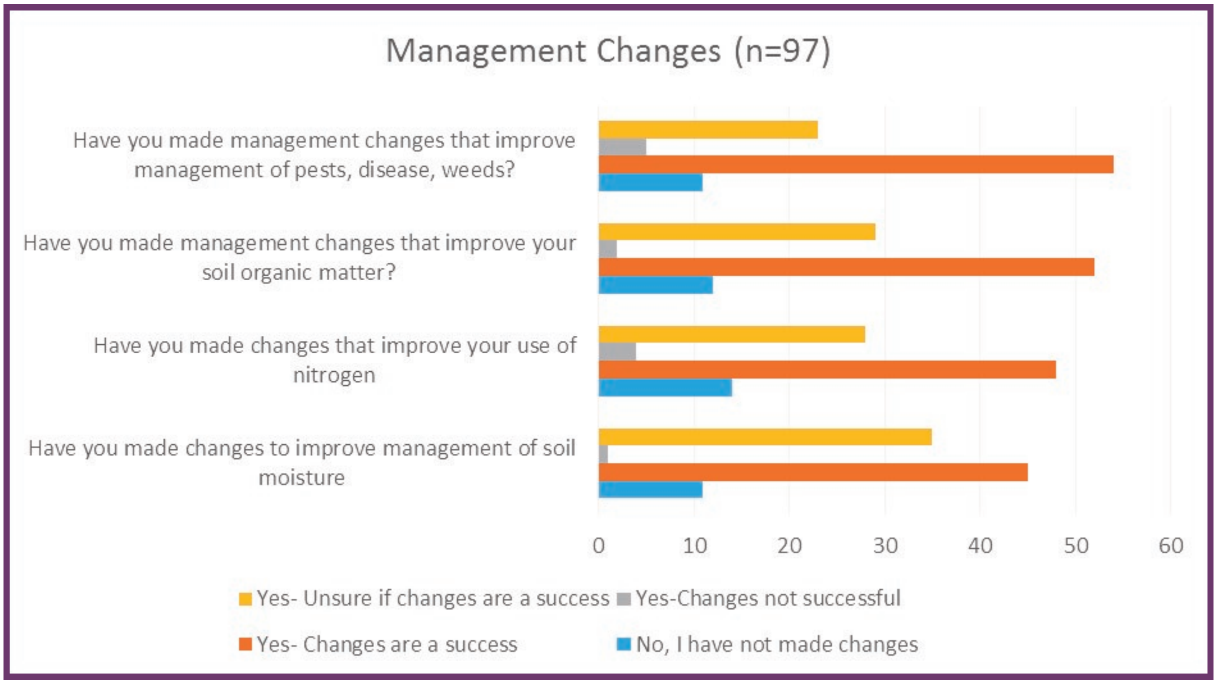
In summer 2016, growers who attended field days across the inland Pacific Northwest were asked whether they had gained new knowledge or made management changes in the last five years. The majority of surveyed growers had made changes to address a variety of issues (see figure below). Among those who made changes, most said their changes were a success, while a sizeable group was unsure of whether their changes were successful or not. Changes included reducing or eliminating tillage, eliminating burning, growing new crops, changing cropping sequences, experimenting with cover crops or soil amendments, conserving residue, using new precision nitrogen management tools, adding nitrogen testing, or using a stripper header.



## Wind Erosion Potential and Soil Characteristics Influenced by Tillage Practices in the Horse Heaven Hills

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The Horse Heaven Hills (HHH) is the driest rainfed wheat growing region in the world. Low precipitation, high winds, poorly aggregated soils, sparse residue cover, and a tillage-based winter wheat-summer fallow often combine to create surface conditions highly susceptible to wind erosion. We measured wind erosion, PM10 (particulate matter ≤ 10 µm in aerodynamic diameter) emissions, and soil properties of no-tillage summer fallow (NTF), undercutter-tillage summer fallow (UTF) and traditional- tillage summer fallow (TTF) after spring tillage and planting winter wheat in a winter wheat – summer fallow rotation at two sites in the HHH. A portable wind tunnel was used to measure wind erosion and PM10 emissions while soil characteristics were measured outside of and adjacent to the wind tunnel. Windblown soil and PM10 loss were generally lowest for NTF and lower for UTF than TTF, especially at the eastern HHH site. Soil characteristics influenced soil and PM10 loss as NTF retained larger surface aggregates and more surface residue than TTF. We encourage the continued adoption of conservation-tillage or no-tillage summer fallow management in the HHH as these practices retain more residue and/or larger aggregates on the soil surface in this highly erosive region. A full report of this study is available at: Singh, P., B. Sharratt, and W.F. Schillinger. 2012. Wind erosion and PM10 emission affected by tillage systems in the world's driest rainfed wheat region. *Soil & Tillage Research* 124:219-225.

**Wind erosion potential from summer fallow tillage treatments in the Horse Heaven Hills using a portable wind tunnel. The left image is traditional-tillage fallow after primary spring tillage at the eastern site and the right image is undercutter-tillage fallow taken after planting winter wheat at the western site.**

## Customizing Nitrogen Fertilizer and Seeding Rates in Soft White Winter Wheat

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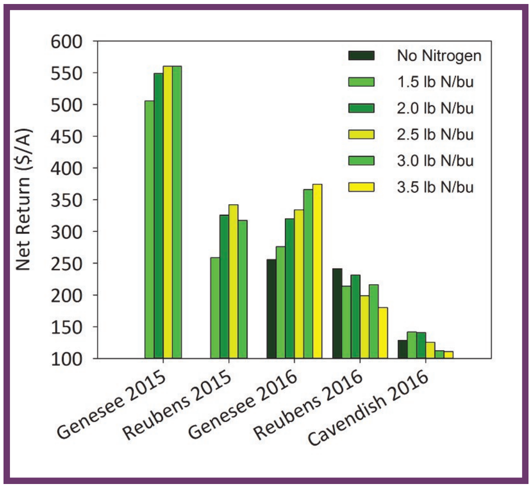
New varieties of soft white winter wheat are being continually developed and released. With the large number of public and private entities releasing new varieties, there are no shortage of choices. While these cultivars often feature higher yields, superior disease resistance and improved end-use quality compared to the older varieties, will they respond similarly to inputs such as seeding rate and nitrogen fertilizer? Current fertilizer guides are a useful resource. However, as the cost of inputs increase, improved optimization is valuable.

Field trials were established at three locations in northern Idaho (Cavendish, Genesee, Reubens) to examine six newer cultivars or advanced lines of soft white winter wheat in combination with nitrogen and seeding rates. These cultivars include: UI-WSU Huffman, IDN01-10704A, IDN02-29001A, SY-Ovation, LCS Artdeco, and LCS Drive. Included in this study were six nitrogen rates (no nitrogen, 1.5, 2.0, 2.5, 3.0 and 3.5 lb N/bu expected yield) and three seeding rates (0.6, 0.8 and 1 million/A). In 2015 average yields were 105 and 76 bu/A for Genesee and Reubens, respectively. With increasing nitrogen rate, there was a corresponding increase in yield with a range of 97 to 121 bu/A for Genesee and 62 to 84 bu/A for Reubens. Yields in 2016 were typically higher with a range of 61 to 95 bu/A for Cavendish, 79 to 110 bu/A for Genesee and 64 to 86 bu/A for Reubens. While seeding rate occasionally influenced yield, the impact was minimal.



Seasonable and environmental variability greatly impacts identifying the optimal nitrogen rates. Returns were higher in 2015 due to a premium for low protein and higher wheat prices. In most cases, a moderate to high nitrogen rate resulted in the greatest economic return with the exception of Reubens and Cavendish in 2016. Looking across all five site/years, the optimal nitrogen rate ranged from 78 to 116% of the average nitrogen requirement of 2.5 lb nitrogen per bushel of expected yield. While there were differences between locations and years, varieties such as LCS Drive and SY Ovation produced greater returns at higher seeding rates while varieties such as LCS Artdeco produced the greatest return at lower than average nitrogen rates. However, those varieties that had a high optimal nitrogen rate were not necessarily the most economical in the study. This data suggests that based on the economic outcome, variety specific recommendations may warrant further investigation.

**Table 1. Optimal nitrogen rate for cultivar based on net economic return in Northern Idaho.**

| | Nitrogen Rate (%) | | | | | |
|---|---|---|---|---|---|---|
| | Genesee | Peck | Cavendish | Genesee | Peck | Average |
| Cultivar | 2015 | 2015 | 2016 | 2016 | 2016 | |
| IDN01-10704A | 108 | 108 | 88 | 140 | 60 | 101 |
| IDN02-29001A | 108 | 116 | 88 | 140 | 60 | 104 |
| LCS Artdeco | 84 | 120 | 68 | 88 | 60 | 78 |
| LCS Drive | 120 | 120 | 68 | 92 | 60 | 111 |
| SY Ovation | 120 | 120 | 68 | 140 | 84 | 116 |
| UI-WSU Huffman | 84 | 116 | 76 | 120 | 82 | 96 |

Nitrogen rate percentage based on average rate of 100% = 2.5 lb N/bu wheat.

## Long-Term Biosolids Experiment at Lind

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Biosolids produced from municipal wastewater treatment plants are applied to many agricultural fields around the world as a source of nitrogen, phosphorus, and other plant nutrients. Biosolids also provide stable soil organic carbon (SOC) and, therefore, can replenish some of the SOC lost to oxidation and wind erosion during the past 135 years of dryland farming in the wheat-fallow region of the Pacific Northwest.

An 8-year biosolids field experiment was initiated at Lind in April 2011. We used a split-block experimental design with tillage method (either traditional double disk or conservation undercutter) for main plot treatments and subplot treatments were fertilizer type (either chemical fertilizer or biosolids). We have two sets of plots to allow for data collection every year in the 2-year wheat-fallow rotation. Biosolids were applied with a manure spreader at a rate of 2.8 dry tons/acre to meet the nutrient requirements for two winter wheat crop years (2012-2015). Biosolids were reapplied to both sets of plots at the same rate for the 2016-2019 crop years. The chemical fertilizer treatment receives 50 lbs N and 10 lbs S/acre as aqua + thiosol for every wheat crop.

Results from the first five years show equal winter wheat grain yield between tillage treatment and fertilizer treatment combinations (Table 1). More spikes are produced with biosolids but this is offset by greater kernel weight in the chemical fertilizer treatment. These yield component differences primarily occur during the first crop after biosolids application when relatively more nitrogen is released compared to the second crop cycle. Significantly more wheat straw is produced with biosolids compared to chemical fertilizer (Table 1). There have been no differences to date in any of the yield components or in straw production between the tillage treatments. However, undercutter primary tillage retains significantly ($p<0.001$) more surface residue through the fallow cycle compared to double disk primary tillage.

**Table 1. Winter wheat grain yield, grain yield components, straw production, and surface residue after planting winter wheat after fallow during five years (2012-2016) at Lind.**

| | | Yield Components | | | | |
|---|---|---|---|---|---|---|
| | Surface residue (%)* | Spikes ($m^2$) | Kernels / Spike | 1000 Grain wt. (g) | Grain yield (bu/A) | Straw wt. (lbs/A) |
| Application | | | | | | |
| Chemical fertilizer | 24 | 220 | 35 | 39 | 40 | 3220 |
| Biosolids | 24 | 262 | 35 | 35 | 41 | 3910 |
| Significance (*p*-value) | ns | 0.02 | ns | 0.002 | ns | 0.007 |
| Tillage implement | | | | | | |
| Undercutter | 29 | 238 | 35 | 37 | 40 | 3500 |
| Double disk | 19 | 244 | 35 | 37 | 40 | 3630 |
| Significance (*p*-value) | < 0.001 | ns | ns | ns | ns | 0.03 |

*Percent surface residue cover remaining after planting with deep-furrow drills.

# The Agriculture Climate Network: A New Model for Climate Change Extension

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Emerging climate change impacts pose challenges for dryland agricultural production in the Northwest. Decision-makers need accessible news and information to support a deeper understanding of both weather *and* climate variability, for both the near and far future. The website AgClimate.net is designed to be a platform for discussion about agriculture and climate issues in the Northwest while serving as a one-stop-shop for updates on relevant and current research initiatives. Our multi-institutional team provides links to specific decision-making tools, and discusses appropriate uses and applications. We encourage readers to submit questions about projected impacts, new technologies, and emerging challenges and opportunities for regional agriculture. We recruit experts to contribute science-based blog articles about their areas of expertise. In this way, the Agriculture Climate Network supports a community of practice that includes Northwest producers, policy-makers, agricultural professionals and researchers working together on climate and agriculture issues.

Spring wheat near Steptoe Butte, Washington State. By Sathish J. CC BY NC 2.0.

Topics covered at AgClimate.net reflect the diversity of production systems in the Pacific Northwest. We frequently share news and tools that relate specifically to dryland agriculture. Recent articles that will be of particular relevance to dryland decision-makers include: an exploration of research on new wheat pests, Keep an eye on those pests! Vigilance and adaptability to climate change (or go to www.agclimate.net and type the title of the article or key words in the Search box). a discussion of innovative approaches to build soil carbon storage enhance resilience in the face of climate change, Flex Cropping – Storing More Carbon Under Challenging Environmental Conditions; and a summary of what current climate projections suggest about the future of drought and storm events in our region, Parched and drenched – we can expect both in the Northwest. Producers, researchers and other stakeholders are encouraged to sign up for the Agriculture Climate Network newsletter and to consider contributing articles.

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Agriculture and Climate Change Research in the Pacific Northwest

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# Alkaline Biochar Amendment Increased Soil pH, Carbon, and Wheat-Pea Yields

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Stephen Machado, Larry Pritchett, Karl Rhinhart, and Rakesh Awale
Columbia Basin Agricultural Research Center, OSU

Agricultural soils in the inland Pacific Northwest (PNW) have been acidifying mainly because of the use of ammonium-based nitrogen fertilizers. In soils, these N-fertilizers produce acidity ($H^+$ ion) and decrease soil pH while they convert into nitrate-N ($NO_3^-$) form. Low soil pH (<5.5) can limit the availability of essential plant nutrients (N, P, K, Ca, B, etc.), reduce fertilizer use efficiency, increase solubility of plant toxic metals such as Al and Mn, increase incidence of winter kill and disease, and thereby reduce crop yields.

Alkaline biochar amendment to arable soils has been proposed as one effective countermeasure to increase soil pH, improve soil fertility and water retention, increase soil organic carbon stock, and enhance crop productivity. However, there is limited information on the integrated effects of biochar amendments in combination with chemical N-fertilizer in cropping systems of the PNW. In 2013, a biochar experiment was initiated at the Columbia Basin Agricultural Research Center using direct seeded winter wheat - spring pea crop rotation. One-time application of three rates of alkaline biochar, derived from forest wood waste, was made at the onset of the experiment, and each crop received fertilizer-N every year (Table 1). Grain yields of both phases were determined every year, while soils were tested in the fall of 2016 (Fig. 1).

**Table 1. Biochar and fertilizer-N applied in the study.**

| Treatment | Biochar | Fertilizer-N (lb/ac) | |
|---|---|---|---|
| | tons/ac | Wheat | Pea |
| Trt1 | 0 | 16 | 0 |
| Trt2 | 0 | 84 | 16 |
| Trt3 | 5 | 84 | 16 |
| Trt4 | 10 | 84 | 16 |
| Trt5 | 20 | 84 | 16 |

Without biochar, higher N-rate application (Trt2) slightly declined surface 4-inch soil pH than lower N-rate (Trt1). On the contrary, addition of biochar increased (Trt3, Trt4, & Trt5) soil pH as well as soil carbon over the fertilizer-N alone treatments (Trt1 & Trt2). The soil pH and carbon increments in biochar treatments increased with biochar rate. Mean (2014-2016) grain yields of both wheat and pea were higher with biochar treatments than fertilizer-N alone treatments. Pea yields were similar across biochar rates, whereas wheat yields were higher with 10 ton than either 5 ton or 20 ton biochar rates. Overall, the study showed that alkaline biochar has potential to increase crop yields through its positive effect on soil health.

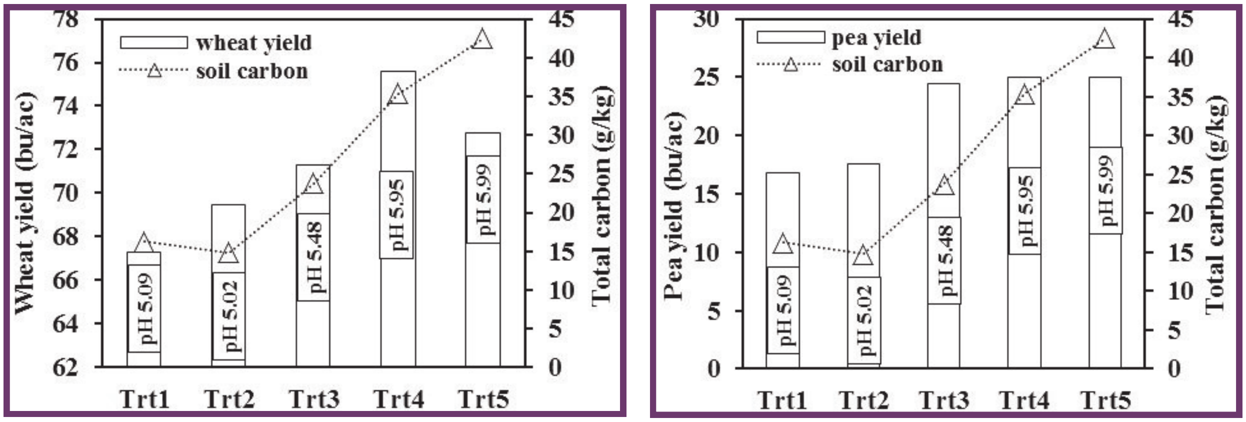

**Figure 1. Mean (2014-2016) crop yields, and surface 4-inch soil pH and carbon in treatments.**

## Tracing Nitrogen Mineralization Under Earthworm Presence in a Simulated Palouse Agroecosystem

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Shane Stoner[1], Jodi Johnson-Maynard[1], Dave Huggins[2], Dan Strawn[1], Ian Leslie[2], and Kendall Kahl[1]
[1]Dept. Plant, Soil, and Entomological Sciences, UI; [2]USDA-ARS

Greater adoption of conservation practices has resulted in increases in earthworm population density in Inland Pacific Northwest agroecosystems. Organic matter incorporation into the soil profile during earthworm foraging and burrowing activity has been shown to significantly increase nitrogen (N) mineralization in agricultural soils. Additional decomposition and organic N transformation occurs in the earthworm gut, producing plant-available inorganic N forms which are deposited in the soil as labile forms in casts and middens. Microbial activity has also been shown to increase in the presence of earthworms, stimulating nitrification. The influence of earthworm species on the fate of litter-derived N from surface deposition to decomposition was proposed for study. A 13-week mesocom study was conducted to characterize N mineralization and nitrogen-15 (N15) response through soil N pools. N15 labelled wheat straw was applied to mesocosms containing the endogeic earthworm *Aporrectodea trapezoides* (AT) and the anecic earthworm *Lumbricus terrestris* (LT), separately and combined (B). Mesocosms were destructively sampled on weeks 1, 2, 4, 7, 10, and 13. Total carbon, nitrogen and the N14/N15 ratios of bulk soil, casts, earthworms, and microbial biomass were measured at two soil depths (0-10 and 10-20 cm).

At the end of the study (Week 13), total soil N in the 0-10 cm depth was 11% greater in earthworm treatments (AT, LT, and B) with earthworms as compared to the controls. In the 10-20 cm depth, AT treatments yielded the greatest increase (~17% greater than controls) compared to LT and B treatments (~7% greater). Similar trends were observed in total soil C. Mean $NO_3^-$ concentration in the 0-10 cm depth of LT (19.0 mg/kg) treatments at week 13 were greater than that measured in AT treatments (12.3 mg/kg). Conversely, AT produced the greatest week 1 ammonium concentrations across all treatments. Nitrate and ammonium trends strongly indicate the occurrence of nitrification and net mineralization. Species-specific results are currently undergoing analysis. Isotope data from earthworms, casts, and inorganic N are forthcoming and may shed light on the fate of litter-derived N. Current data suggest species-dependent effects on N mineralization rates, and future analysis should reveal N sources and fluxes in biotic and abiotic pools over time.

## Can a Grazed Cover Crop Compete Economically with Dryland Grain Production?

KATHLEEN PAINTER, KEN HART, DOUG FINKELNBURG, AND JIM CHURCH
NORTHERN DISTRICT, UI EXTENSION

Benefits to the land from planting and grazing cover crops are hard to estimate and may not be realized in the short run. However, rotational and soil quality benefits can be expected. A comparison of costs and returns for predominant dryland crops with a grazed cover crop shows that in times of low commodity prices, a grazed cover crop can be less unprofitable than other options. Two different cover crop mixtures planted in May and grazed for three months are compared to 2016 returns for direct seeded crops in the higher rainfall dryland cropping region (Fig. 1). Assuming that cover crops can provide 4 AUMS per acre and an AUM is valued at $18, net returns for a grazed cover crop option were about $30 per acre less unprofitable than winter wheat production. In 2016, economic returns were estimated at -$75 per acre for winter wheat, typically the main cash crop in this region, compared to -$43 per acre for a 4-way grazed cover crop or -$48 per acre for a 6-way grazed cover crop (Figs. 2 and 3).

**Figure 1. Oats, turnips, buckwheat, and peas in cover crop mix.**

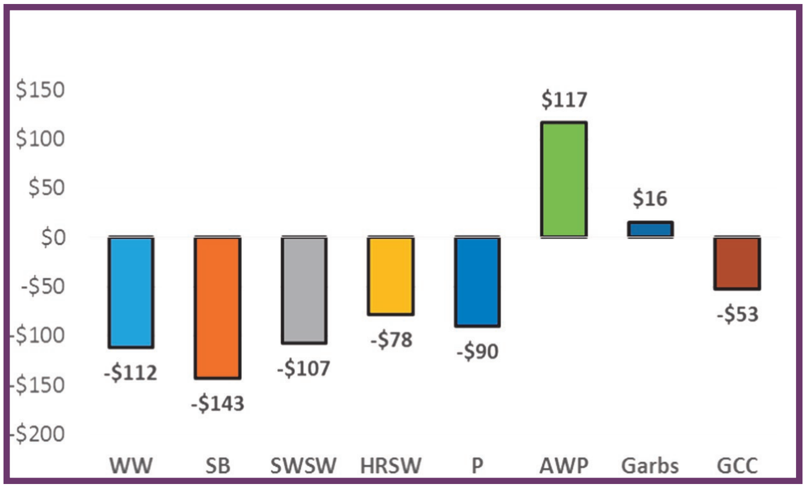
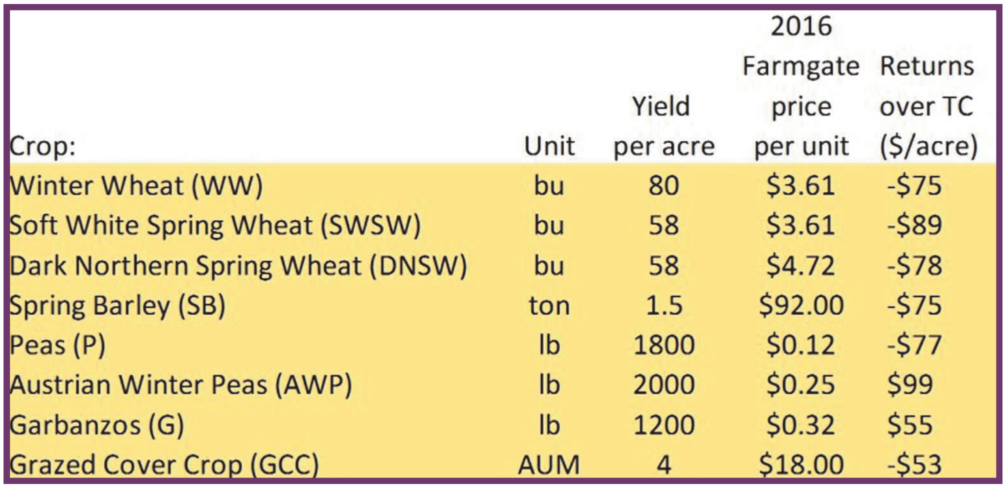


**Figure 2. Net returns over total costs estimates for direct-seeded crops in North Idaho ($/acre/year), based on price and yield assumptions in Figure 3.**



| Crop: | Unit | Yield per acre | 2016 Farmgate price per unit | Returns over TC ($/acre) |
|---|---|---|---|---|
| Winter Wheat (WW) | bu | 80 | $3.61 | -$75 |
| Soft White Spring Wheat (SWSW) | bu | 58 | $3.61 | -$89 |
| Dark Northern Spring Wheat (DNSW) | bu | 58 | $4.72 | -$78 |
| Spring Barley (SB) | ton | 1.5 | $92.00 | -$75 |
| Peas (P) | lb | 1800 | $0.12 | -$77 |
| Austrian Winter Peas (AWP) | lb | 2000 | $0.25 | $99 |
| Garbanzos (G) | lb | 1200 | $0.32 | $55 |
| Grazed Cover Crop (GCC) | AUM | 4 | $18.00 | -$53 |

**Figure 3. Yield, 2016 farmgate price assumptions, and net returns over total costs for direct-seeded crops in North Idaho ( $/ac/year).**

# Effects of Spring and Fall Planted Cover Crops on Dryland Direct-Seed Rotation in North-Central Idaho

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DOUGLAS FINKELNBURG, KENNETH HART, AND JAMES CHURCH
UI EXTENSION, NORTHERN DISTRICT

Dryland small grains, grain legumes and oilseeds farmers in the Pacific Northwest are interested in sustainable and profitable methods of improving soil quality. This ongoing study seeks to demonstrate the effects on soil and crop production of using cover crop mixes to augment a winter wheat, spring barley, spring pea direct-seeded rotation. Winter wheat yields were depressed following two spring planted cover crop mixes (5-way & 12-way) when compared to chemical fallow in the drought year of 2015. Spring barley yields were unaffected by fall planted mixes vs chemical fallow in 2016. Yields were analyzed using a generalized linear mixed model.

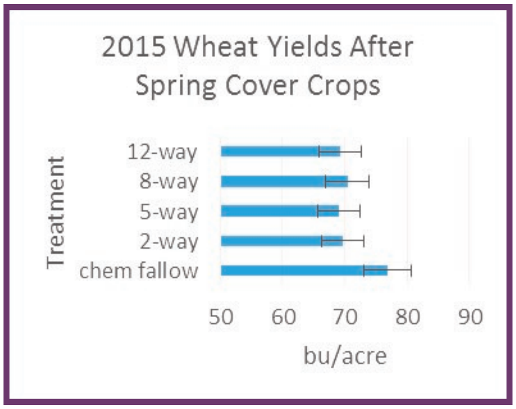
**Cover Crop Mixes**

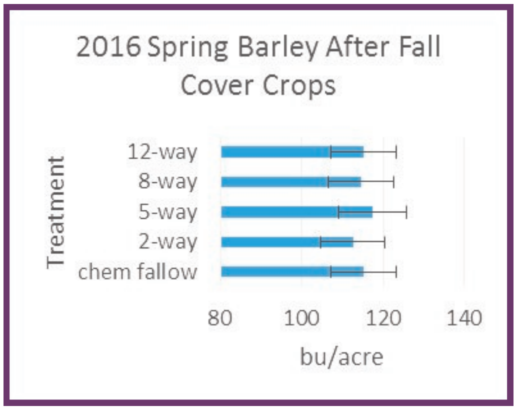
| **Spring Planted** | **2-Way** | **5-Way** | **8-Way** | **12-Way** |
|---|---|---|---|---|
| | | | **lbs/acre** | |
| Forage Pea | 32 | 14 | 8 | 6 |
| Bob Oat | 25 | 10 | 5.5 | 4 |
| Daikon Radish | | 2.5 | 1.5 | 1 |
| Sorghum Sudan Grass | | 7 | 4 | 3 |
| Soybean | | 9 | 5 | 3.5 |
| Buckwheat | | | 4 | 3 |
| Appin Turnip | | | 1 | 1 |
| Brown Flax | | | 3 | 2 |
| Manta Millit | | | | 1 |
| Crimson Clover | | | | 1 |
| Sunflower | | | | 1 |
| Lentil | | | | 1 |

| **Fall Planted** | **2-Way** | **5-Way** | **8-Way** | **12-Way** |
|---|---|---|---|---|
| | | | **lbs/acre** | |
| Austrian Winter Pea | 32 | 14 | 8 | 6 |
| Everleaf Oat | 25 | 10 | 5.5 | 4 |
| Daikon Radish | | 2.5 | 1.5 | 1 |
| Sorghum Sudan Grass | | 7 | 4 | 3 |
| Hairy Vetch | | 7 | 4 | 3 |
| Rapeseed | | | 1.5 | 1 |
| Appin Turnip | | | 1 | 1 |
| Brown Flax | | | 3 | 2 |
| Manta Millit | | | | 1 |
| Crimson Clover | | | | 1 |
| Sunflower | | | | 1 |
| Winter Lentil | | | | 1 |

**Rotation Plan**

2014 – Spring Cover Crops
2015 – Winter Wheat, Fall Cover Crops
2016 – Spring Barley, Fall Cover Crops
2017 – Spring Peas
2018 - Winter Wheat





# Wheat Prices, at a 15-Year Low, Affecting Regional Returns from Agriculture

KATHLEEN PAINTER
NORTHERN DISTRICT, UI EXTENSION

Net returns for soft white winter wheat, a major cash crop for the entire dryland Pacific Northwest region, are estimated at -$82 per acre using 2016 crop and input prices (Fig. 1). Soft white winter wheat crop is grown on over 40% of all acreage in the dryland crop producing region of the inland Pacific Northwest (USDA-NASS). While some of the non-grain crops were profitable, such as peas ($50 per acre) and chickpeas ($40 per acre), average returns per acre were negative for all crop rotations, with a rotation of hard red winter wheat, hard red spring wheat, and peas being the least negative, at -$27 per acre.

Prices for No. 1 soft white winter wheat at the port of Portland, OR, averaged just $4.86 per bu from August through December of 2016 (USDA-AMS). Average marketing year wheat prices in Portland have fluctuated considerably over the past 36 years (Fig. 2). Adjusted for inflation, wheat prices were highest in the early 1980s, falling from a high for the whole series of $11.68 per bu in 1980 and declining throughout the 1990s. The lowest prices of the series hovered around $4 per bu in 2000 and 2001 (2017 dollars). In 2008, wheat prices spiked to $11.28 per bu (2017 dollars), then hovered around $6.80 per bu in 2014 and 2015, before falling by nearly 30% to their current levels. Note that these Portland prices do not reflect transportation expenses that farmers must pay to market their grain.

**Figure 1. Net returns over total costs by crop for the annual cropping region of the dryland Pacific Northwest, 2016 farmgate prices.**

| **LEGEND:** | **Crop Prices** |
|---|---|
| Soft White Winter Wheat (SWWW) | $3.61 |
| Hard Red Winter Wheat (HRWW) | $4.60 |
| Soft White Spring Wheat (SWSW) | $3.61 |
| Hard Red Spring Wheat (HRSW) | $4.72 |
| Spring Barley (SB) | $92.00 |
| Lentils (L) | $0.30 |
| Peas (P) | $0.12 |
| Chickpeas (CP) | $0.32 |
| Spring Canola (SC) | $0.16 |

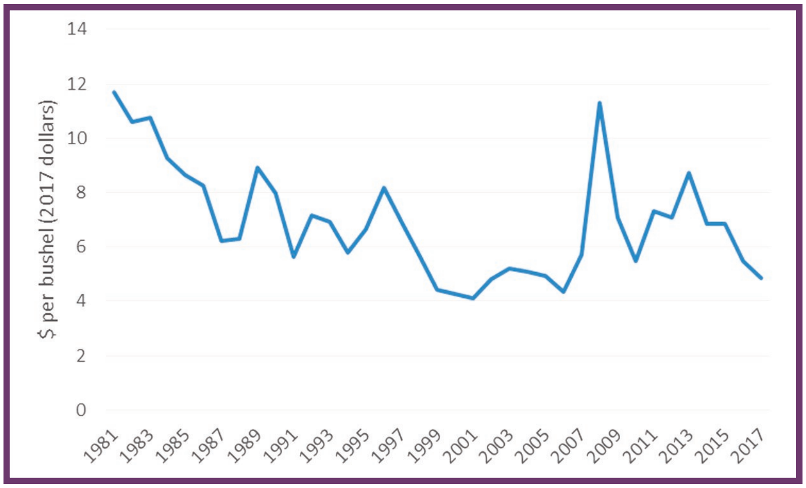


**Figure 2. Soft white winter wheat prices at Portland, OR, expressed in 2017 dollars($/bu).**

# Laboratory Method to Evaluate Wheat Seedling Emergence from Deep Planting Depths

BILL SCHILLINGER, STEVE SCHOFSTOLL, TIM SMITH, AND JOHN JACOBSEN
DEPT. OF CROP AND SOIL SCIENCES, WSU LIND

Planting depth effect on seedling emergence is an important concern for many crops grown around the world. Farmers in the low-precipitation (less than 12 inch annual) winter wheat (WW) production region of the Inland Pacific Northwest plant seed as deep as 7 inches below the surface of summer-fallowed soils with deep-furrow drills to reach adequate seed-zone moisture. Seedlings need to emerge through 3-5 inches of soil cover, most often under marginal seed-zone moisture conditions. We developed a laboratory method to accurately assess WW emergence from deep planting depths in pots. To test the methodology, we first conducted a 4-year field experiment to measure emergence of four WW varieties having either standard-height (Moro and Buchanan) or semi-dwarf (Eltan and Xerpha) growth habit. Depth of soil cover over the seed was 5.5 inches and seed-zone water content over the four years ranged from very dry to wet. Next, a factorial laboratory pot experiment was conducted using the same WW varieties and soil seed-zone water potentials similar to those during the four years in the field. Statistical comparison between field and laboratory emergence data showed a strong correlation ($r = 0.71$, $p < 0.01$) for median time to emerge. In Figure 1, we visually present the "layering approach" for conducting a laboratory pot experiment to measure WW emergence from deep planting depths under a wide range of water potentials.

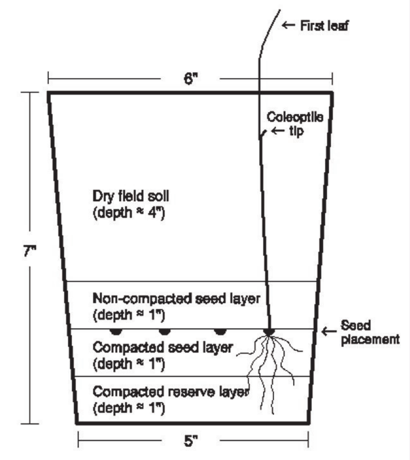


**Figure 1. Cross-section illustration of a prepared pot for measuring wheat seedling emergence in the laboratory. Four distinct soil layers as required: a) compacted reserve layer; b) compacted seed layer; c) non-compacted layer on top of the seed; and d) thick layer of loose, dry soil that extends to the top of the pot.**

# The WSU Wilke Research and Extension Farm Long-Term Rotation Summary

AARON ESSER AND DEREK APPEL
WSU EXTENSION

**Diversified crop rotation at the WSU Wilke Research and Extension Farm.**

The WSU Wilke Research and Extension Farm is located on the eastern edge of Davenport, WA. Washington State University maintains and operates this facility. The farm is in a direct seed cropping system utilizing no-till fallow, winter wheat, spring cereals and broadleaf crops. Broadleaf crops are incorporated when weed pressures and market prices create opportunities for profitable production. The predominant cropping system practiced by farmers in this region is a 3-year rotation, which includes summer fallow, winter wheat, and spring cereals. Farmers are interested in intensifying rotations to reduce fallow years and increase crop diversity to improve long-term agronomic and economic stability.

The south side of the farm is divided into seven plots; three plots are in a more traditional 3-year crop rotation, and four plots are in an intensified 4-year crop rotation. The north side of the farm remains in an intensified rotation that forgoes summer fallow and is in a continuous cereal grain production. Economic return over input costs (seed, fertilizer, pesticides) is analyzed in three year averages to help remove some of the year-to year variability (Fig. 1). Fixed cost associated with the farm are not included because of the variability from farm to farm across the region. Overall no significant difference in economic return over input costs has been detected between the 4-year and 3-year rotation at $150 and $146/ac. The continuous crop rotation has been significantly less at only $105/ac. More information and reports can be found at http://wilkefarm.wsu.edu/.

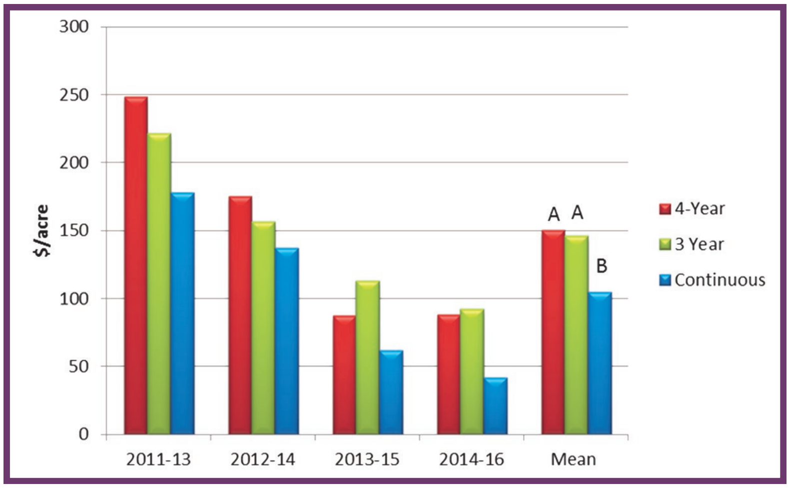


**Figure 1. Three-year average economic return over input costs of 3-year, 4-year, and continuous cropping systems at the WSU Wilke Farm. Costs do not include fixed costs associated with the farm. Means within columns assigned different case letter are significantly different (P<0.10).**

## Building a Framework for Big Data and Open Science to Model Soil Organic Carbon in the Northwestern United States

EDWARD FLATHERS AND PAUL E. GESSLER
COLLEGE OF NATURAL RESOURCES, UI

Soil Organic Carbon (SOC) is primarily associated with soil organic matter and relates to many soil properties that influence resiliency and soil health for agriculture. It is also a critical base product for understanding soil-atmospheric carbon flux, which is a significant part of the overall carbon budget of the Earth. Maps of the distribution of SOC across the landscape could be used to support further analysis of soil-atmospheric interactions, agricultural crop modeling and decision-making, and long-term monitoring of soil carbon content. Soil surveys often measure SOC during soil sampling, and we have access to published observations to begin mapping SOC levels across the landscape. In order to develop a continuous map of SOC, we need to interpolate values between sample locations using a modeling process that takes into account the environmental variables that influence the dynamic carbon system within the soil.

The *scorpan* technique for modeling soil properties uses seven categories of environmental input data to make predictions: soil classes, climatic values, organisms present, relief, parent material, age, and spatial location. We gather data representing these categories from sources within the United States Department of Agriculture (USDA), United States Geologic Survey (USGS), and the University of Idaho. Collating these data is challenging because the data tend to be large and varied in format. Because the volume and variety of data is high, we treat this as a Big Data project, using approaches like Extract, Transform, and Load to collect data from remote providers, transform the data to compatible formats, and load the transformed data into a database where we can proceed with modeling.

The primary goal of this project is to demonstrate a repeatable, re-usable framework for applying a *scorpan* model for mapping SOC in the northwest. This will be an initial step toward developing an accurate spatially explicit soil carbon map with the expectation that although the map is likely inaccurate in many ways, explicitly publishing the data and methods used in production provides a foundation and framework upon which to refine the modeling process and improve the output products. The focus is to develop and demonstrate the concepts of open science and a re-usable and modifiable framework that can be improved upon or applied in other spatial and temporal contexts and scales. All modeling components including input data, metadata, computer code, and output products are made freely available under an explicit open source license. In this way, reproducibility is explicitly supported; the methods and code released are available to be re-used by other researchers; and the research products are plainly open to critical review and improvement.

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under award number 2011-68002-30191.

## The Wheat Root System: Opportunity for Crop Improvement in Dryland Farming Systems

Bikash Ghimire[1], Scot H. Hulbert[1,2], and Karen A. Sanguinet[1]
[1]Dept. of Crop and Soil Sciences, WSU; [2]Dept. of Plant Pathology, WSU

The understanding of root system architecture (RSA) has been recently touted as an untapped source for crop improvement since roots are actively involved in the uptake of water and essential nutrients in addition to their phenotypic plasticity to respond to heterogeneous soil environments. Several studies have shown that root system architecture (RSA) of specific crop species can be altered to improve desirable agronomic traits such as yield, drought tolerance, and resistance to diseases and nutrient deficiencies. Dryland farming communities are at a high risk of drought. For example, the 'snowpack' drought in 2015/16 caused economic losses of $212 million associated with non-irrigated dryland wheat production (USDA). We have initiated a project on the study of the RSA of both young seedlings as well as the adult root system of spring wheat from climate controlled laboratory growth chambers, greenhouses and native dryland fields. Hollis—a hard red spring wheat with excellent milling and end-use attributes for the Pacific Northwest (PNW) and Drysdale—a hard white spring wheat with increase water use efficiency and improved drought tolerance in Australia were included in the study. Gel-based plate assays and a minirhizotron system were used to examine the seedling or adult root systems in the greenhouse and in a field-based study at the Lind Dryland Research Station. We were able to detect quantifiable differences in root traits between the cultivars, which will be useful to test to what extent the root traits are heritable from one growth environment to the another and from year to year. Above all, the knowledge gained from the dynamic root system and the associated traits can be leveraged to expedite current breeding efforts toward the development of drought-resilient wheat cultivars with enhanced grain yield.

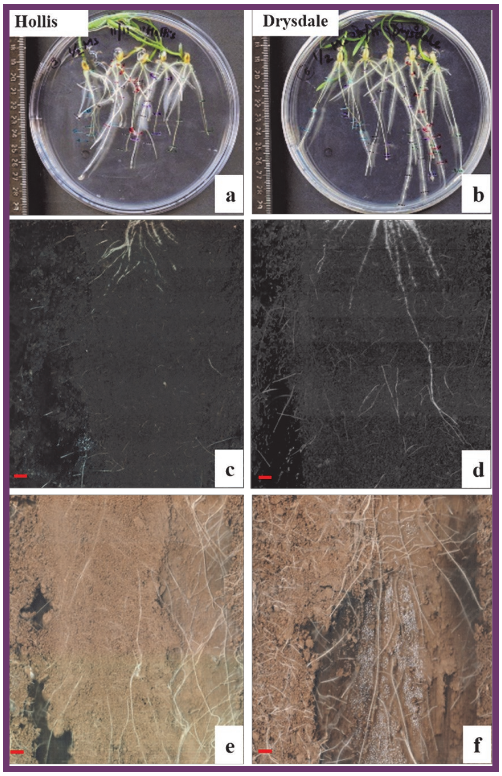


**Figure 1. Comparison of root growth between Hollis and Drysdale cultivars. a-b, 5-day old seedlings; c-d, images taken by CI-600 in situ root imager in the greenhouse at the heading stage of Hollis (52 DAP) and Drysdale (58 DAP); e-f, images field-based study at the Lind Dryland Research Station during the heading stage of Hollis (81 DAS) and Drysdale (79 DAS) at 86.4-108.0 cm (vertical depth~ 74.8-93.5 cm). Scale bar equals 1 cm.**

# Impact of Liming on Fusarium Crown Rot

ANDREW LEGGETT AND KURTIS SCHROEDER
DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

Fusarium crown rot is a common root disease of wheat and barley worldwide. In the dryland wheat producing areas of northern Idaho and eastern Washington, Fusarium crown rot is caused by the soilborne pathogens *Fusarium culmorum* and *F. pseudograminearum.* Previous research suggests a possible correlation between decreasing soil pH and decreasing incidence of Fusarium crown rot. This current study investigates the impact of soil pH and liming on Fusarium crown rot.

Greenhouse studies were established to examine the impact of soil pH using Babe spring wheat and soil limed from pH 4 to 5, 6, or 7. At planting, each soil treatment received one of three inoculation treatments which included no inoculum, low (15 ppg) or high (150 ppg). After 3 weeks in a growth chamber at 59°F plants were destructively harvested and disease severity measured. Preliminary results suggest Fusarium crown rot is most favored by a soil pH of 5 to 7 with an optimum around 6 (Fig. 1), contrary to previous research.

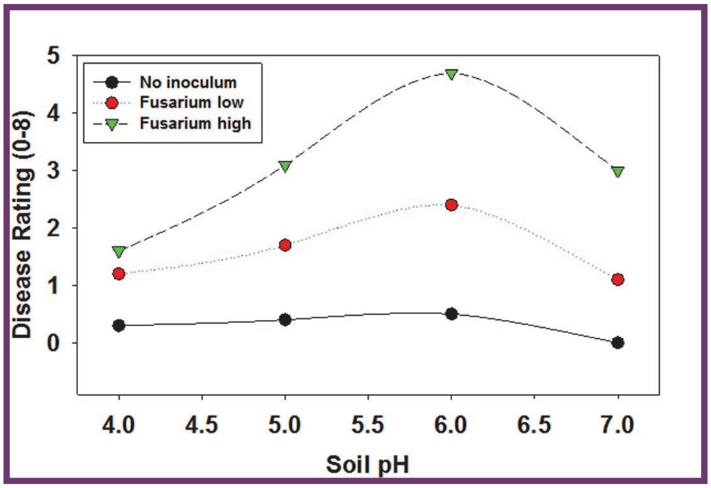


**Figure 1. Fusarium crown rot rating.**

Field trials were established in a low pH (4.2 in the top six inches) field at the University of Idaho Parker Farm in the spring of 2016. Ten weeks after seeding, the pH of soils in the limed plots was 5.4 in the top 0 to 3 inches and 4.9 in the 3 to 6 inch depth. Two hard spring wheat varieties, Glee and WB-Hartline, were selected to represent varieties common in the region, but also more susceptible to Fusarium crown rot. Treatments included inoculated and non-inoculated plots as well as limed and non-limed plots. After harvest, stems were collected and rated for disease. No significant difference was observed in disease or yield between limed and non-limed inoculated plots for either Glee or WB-Hartline (Table 1). Despite an effect of the inoculum, good growing conditions and timely rains resulted in low plant stress and mild symptoms expression. This trial is being repeated at two locations in 2017.

**Table 1. Yield and disease severity of spring wheat seeded into a low pH field in northern Idaho.**

| Variety | Fusarium Inoculum | Limed | Yield (bu/A) | Test Weight (lb/bu) | Disease Severity (0-3) |
|---|---|---|---|---|---|
| Glee | N | N | 44 | 62 | 0.2 |
| Glee | N | Y | 42 | 62 | 0.1 |
| Glee | Y | N | 39 | 62 | 0.7 |
| Glee | Y | Y | 41 | 62 | 0.7 |
| WB-Hartline | N | N | 54 | 60 | 0.3 |
| WB-Hartline | N | Y | 56 | 60 | 0.3 |
| WB-Hartline | Y | N | 49 | 59 | 1.0 |
| WB-Hartline | Y | Y | 53 | 59 | 0.9 |

# Beneficial Endophytes of Winter Wheat

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[1]PLANT PATHOLOGY AND SYMBIOSIS, FOREST, RANGELAND, AND FIRE SCIENCES, UI; [2]DEPT. OF PLANT, SOIL, AND ENTOMOLOGICAL SCIENCES, UI

Endophytic microbes function symbiotically within plants and may provide a number of benefits to their hosts, including disease, insect, and abiotic stress resistance. Microbes that endophytically colonize seed can be transmitted to the developing plant and likely play critical roles in plant health and development. In laboratory and greenhouse studies, fungi antagonized economically important wheat pathogens and improved yield in drought-stressed, diseased plants; however, the strongest functional effects against pathogens were observed in response to seed colonists. Fungi and bacteria colonizing winter wheat seed reduced the severity of leaf rust in developing seedlings by 50% compared to seed lacking colonists (Fig 1.) and reduced mortality in plants infected with crown rot. Because early or primary seed colonists determine microbiome assembly, natural seed colonization leads to confounding variability in responses to artificially introduced microbes in field trials designed to test the effects of biological in crops, a problem we saw with our 2016 field trials. Treating winter wheat seed with promising microbes prior to sowing could mimic natural seed colonization, outcompete early seed colonists, and provide emergent seedlings and developing plants with symbiotic benefits and improved pathogen resistance—potentially with less confounding variation across field trials. Our 2017 UI Kambitsch Farm field trial tests this concept. We encapsulated seed sown in this trial with a polymer carrying fungal endophytes that antagonized and inhibited Fusarium crown rot and leaf and stripe rusts in laboratory and greenhouse assays. Four fungal treatments are being tested in the hard red winter wheat variety UI SRG against Fusarium crown rot and four more in the soft white winter wheat variety Stephens against stripe rust.

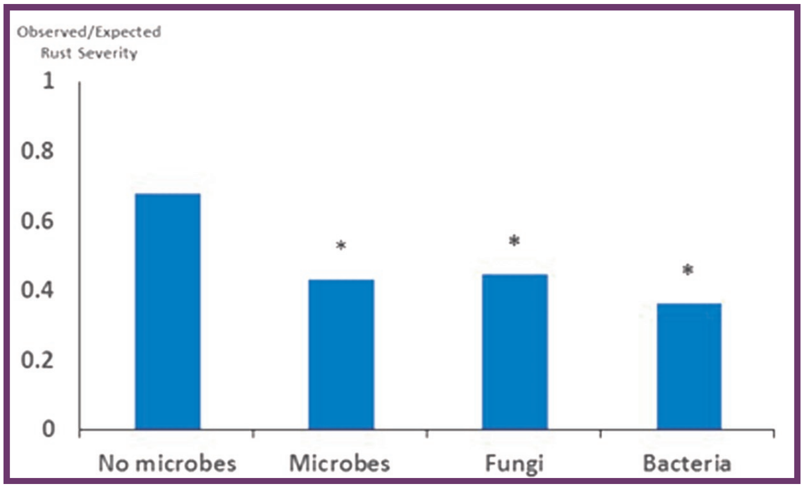


**Figure 1. Stars indicate a significant difference in averages compared to seeds with no microbes.**

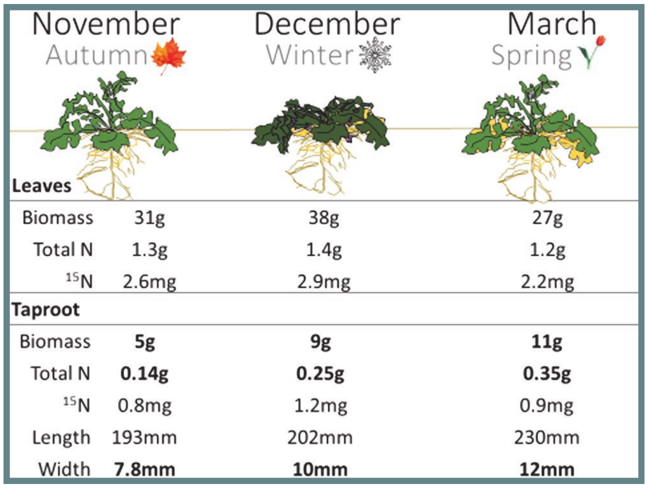
# Part 4. Oilseeds and Other Alternative Crops

## Overwinter Nitrogen Cycling in Winter Canola

TAI MCCLELLAN MAAZ[1], FRANK L. YOUNG[2], AND WILLIAM L PAN[1]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]USDA-ARS

Winter canola minimizes nitrogen (N) losses associated with leaf die-off by mineralizing of nitrogen from leaves dropped in the winter during spring regrowth and storing proteins in the taproot. Previous studies examining the N recovery following freezing temperatures have typically been conducted after stem elongation in the spring, and the role of overwinter N storage in the taproot at the rosette stage has largely been ignored. In 2016, an $^{15}N$ tracer study was conducted in Davenport, WA, where the cotton-wick method was used to inject $^{15}N$-labeled urea into winter canola plants at two to three day intervals beginning with the six leaf stage and prior to the onset of freezing air temperatures in order to track the fate of leaf N. Plants were harvested prior to freezing, after five consecutive days of subfreezing temperatures, and at stem elongation during the spring. Plant growth was not affected by the labeling procedure; however, during a freezing period, root weight and width increased while above-ground biomass, crown height, and root length remained the same. Freezing did not affect the quantity of the tracer recovered in the shoots and roots, but a greater portion of the nitrogen tracer was stored in the roots and crown after freezing and early spring, which may indicate overwinter nitrogen storage in the taproot. On average, the overwinter recovery of the nitrogen tracer was high, and 75% of the N tracer added to winter canola plants in the fall remained in the plant or was recycled in the spring. Some of the tracer was also recovered in neighboring plants due to recycling of the leaf N in the soil. We recommend that growers account for winter vegetative nitrogen when making spring top-dressing recommendations.

**Table 1. Biomass, total N, and $^{15}N$ tracer recovery by leaves and roots, root length, and root width of winter canola plants in November, December, and March in Davenport, WA.**



| | November<br>Autumn | December<br>Winter | March<br>Spring |
|---|---|---|---|
| **Leaves** | | | |
| Biomass | 31g | 38g | 27g |
| Total N | 1.3g | 1.4g | 1.2g |
| $^{15}N$ | 2.6mg | 2.9mg | 2.2mg |
| **Taproot** | | | |
| Biomass | **5g** | **9g** | **11g** |
| Total N | **0.14g** | **0.25g** | **0.35g** |
| $^{15}N$ | 0.8mg | 1.2mg | 0.9mg |
| Length | 193mm | 202mm | 230mm |
| Width | **7.8mm** | **10mm** | **12mm** |

## Large-Scale Spring Canola Variety Trials in Eastern Washington – 2016 Results

KAREN SOWERS[1], AARON ESSER[2], DEREK APPEL[2], DENNIS ROE[1], BILL PAN[1], AND DANIEL STENBAKKEN[3]
[1]DEPT. OF CROP AND SOIL SCIENCES, WSU; [2]WSU EXTENSION; [3]VITERRA, INC.

Spring canola has proven to be a viable rotation crop in eastern Washington (WA), yet many producers remain hesitant it will work on their farm, and make a difference economically. With funding from Viterra, the WOCS team established on-farm spring canola variety trials in Spring 2016 at three locations in eastern Washington to evaluate performance in different rainfall, soil pH and soil types, and to provide producers an opportunity to see the varieties on a farm-scale. Yield and economic results are shown in Table 1. With a mean yield of 1,818 lbs/acre at Davenport, 2,235 lbs/acre at St. John, and 2,552 lbs/acre at Fairfield; a strong local market at Warden, WA, and wheat markets low, the opportunity to gain agronomic benefits from spring canola in rotation in eastern WA is worth consideration.

The complete report for the 2016 On-farm Spring Canola Variety Trials can be found at the WOCS website www.css.wsu.edu/oilseeds.

Winter canola trials were established in late summer 2016 at St. John, Ralston, Hartline, and Odessa (irrigated). Spring canola variety trials will be established at Almira, Fairfield, Pullman, and Walla Walla. Watch our website and your email for tour dates of the trials this May and June!

**Table 1. Mean yield of each cultivar, and economic return over costs with the assumption that seed cost and herbicide costs are the primary costs, and all other costs are equal at each location.**

| **Treatment** | **Mean Yield** | | **Seed Costs** | **Herbicide Costs** | **Total Costs** | **ROI Costs** | |
|---|---|---|---|---|---|---|---|
| | lbs/acre | | ------------------ | $/acre | ------------------ | | |
| NCC101S[1] | 2420 | a | 46 | 15 | 61 | 380 | a |
| HyCLASS 930[2] | 2368 | ab | 51 | 7 | 58 | 338 | abc |
| LL140P[3] | 2272 | abc | 59 | 19 | 78 | 301 | C |
| BY 5535CL[4] | 2181 | bc | 37 | 16 | 53 | 345 | ab |
| Nexera 2020CL[4,5] | 2081 | cd | 37 | 16 | 53 | 358 | a |
| Early One[1,6] | 1887 | d | 18 | 15 | 33 | 311 | bc |
| Mean | 2202 | | | | | | |
| Significance | 0.001 | | | | | 0.001 | |
| Tukey HSD $_{(0.05)}$ | 235 | | | | | 42 | |

[1]Non-GMO hybrid; [2]Roundup Ready; [3]Liberty Link; [4]Clearfield tolerant; [5]High-oleic; [6]*B. Rapa*

Many thanks to our 2016 cooperators: Randy Emtman, Fairfield; Kye & Tracy Eriksen, St. John; Derek Appel/WSU Wilke Research & Extension Farm, Davenport.

Seed provided by Bayer CropScience, BrettYoung, Caldbeck Consulting, Croplan by Winfield, Dow, and Spectrum Crop Development.

Funding provided by Viterra, Inc. and the WOCS Project.

# Rhizosphere Soil Microbial Communities of Winter Canola and Winter Wheat at Six Paired Field Sites in Eastern Washington

Jeremy Hansen[1], Bill Schillinger[2], Tarah Sullivan[2], and Tim Paulitz[1]
[1]USDA-ARS; [2]Dept. of Crop and Soil Sciences, WSU

With increasing acreage of canola in the Inland Pacific Northwest, it becomes necessary to investigate the effect of this relatively new rotational crop on soil microbial communities and the performance of subsequent crops. Canola plants contain glucosinolates (GSLs), which upon cell rupture and during the decay of residue hydrolyze to produce isothiocyanates (ITCs). The production of ITCs is the mechanism responsible for the "biofumigation effect." The biofumigation effect is generally considered positive; however, the non-selectivity of ITCs has potential to impact beneficial soil organisms. Canola root GSLs and ITCs often have greater concentration and toxicity in the root. Toxicity and proximity of ITCs to soil microorganisms would potentially create changes in the rhizosphere soil microbial community. Results from a related field study near Reardan, WA suggest that winter canola influenced the bulk soil microbial community as a whole. Suppression of fungal members of the microbial community including mycorrhizae was observed. The objective of this research is to determine the differences and similarities in the rhizosphere microbial communities of canola and wheat. Canola and wheat rhizosphere soil (Fig. 1A) was collected from six farms in Adams and Douglas Counties. Each farm is a paired site with winter canola and winter wheat grown in adjacent fields having similar soil properties and crop history. Each sample was a composite of rhizosphere soil of five plants at two landscape positions. Fall samples were collected in November of 2015 and another spring sampling in March 2016. Samples from the farms of Derek Schafer, Rob Dewald, and Curtis Hennings near Ritzville, WA and Doug Poole, Tom Poole, and Denver Black near Mansfield, WA were collected. Rhizosphere microbial community composition was determined using phospholipid fatty acid (PLFA) analysis. PLFA data showed differences in the microbial community associated with landscape position and no significant differences between crops at the fall sampling. PLFA data from spring samples showed significant differences in the microbial communities between the canola and wheat treatments (Fig. 1B) while the differences associated with landscape became negligible. These data suggest that initial microbial communities were similar and only varied with expected differences in landscape. As the crops develop, microbial communities shift and the influence on the rhizosphere becomes apparent. Given the importance of microbially-mediated soil processes, any decline in members of the community or the community as a whole could potentially impact the performance of subsequent crops.

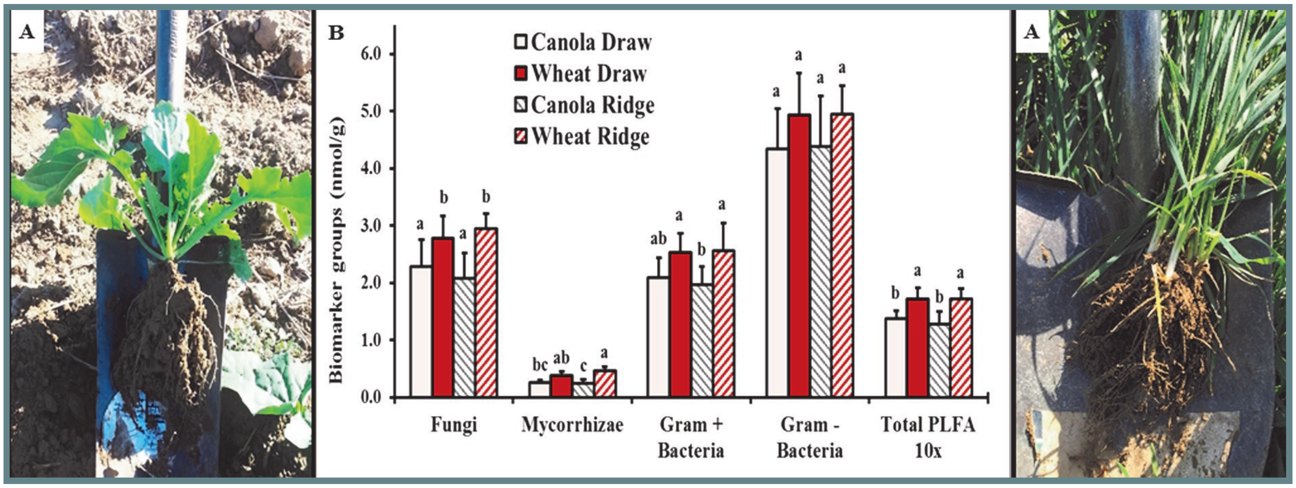


**Figure 1. Differences in microbial community groups as determined by PLFA biomarkers. Pictures show the collection of canola and wheat rhizosphere samples. Rhizosphere soil is defined here as soil adhering to canola or wheat roots after extraction.**

# Spring Canola Nitrogen Supply Recommendations for the Pacific Northwest

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Canola integration into wheat dominated cropping systems of the Pacific Northwest (PNW) will improve the agronomic and economic sustainability of the region, similar to other semi-arid wheat regions of the world. Nitrogen management strategies are required to fit the unique PNW soils and environments.

**Spring canola N rate.** Physiological and morphological differences between wheat and canola dictate different N management strategies are needed in transitioning from wheat to canola fertilizer management. In the inland Pacific Northwest, the total N supply requirement of spring canola in semi-arid systems is determined by multiplying yield potential by the unit N requirement. The unit N requirement (UNR=lb N supply/100 lb grain) is the amount of N supply needed to yield 100 lb grain, which is the inverse of NUE (grain yield/total N supply) at economically optimal yields. A survey of western states canola fertilizer guides revealed a range of UNRs partly due to differences in factors used in estimating non-fertilizer N supply, including soil nitrate sampling depth, factoring N mineralization from organic matter, and previous crop straw credits. Variable UNRs are also a function of yield, which in turn is a function of water supply (Fig. 1). A yield component analysis of improved Nitrogen Use Efficiency (NUE= lb grain/lb N supply) with increasing water-driven yield potentials demonstrates that increasing water supply increases both N uptake efficiency (bigger, deeper root systems) and N utilization efficiency (more pods, seeds) contributions to the increases in NUE and corresponding decreased UNR at economic optimal yields (Fig. 2). While N and S rates had little impact on spring canola oil content and quality, water and temperature played a larger role.

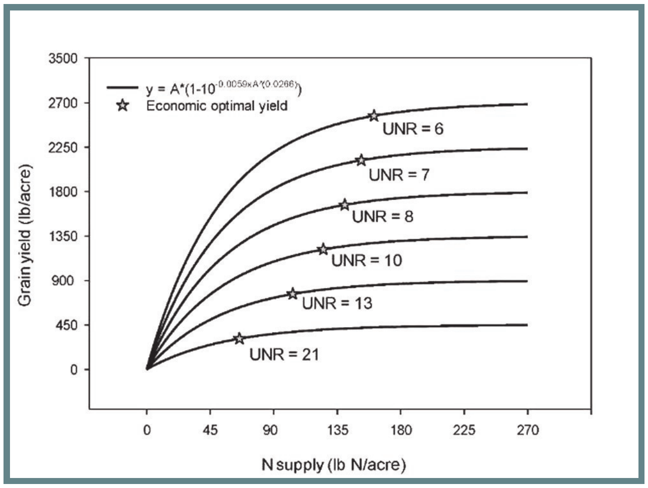

**Figure 1. Unit N requirement decreases as water driven yield potential and crop N efficiencies increase.**

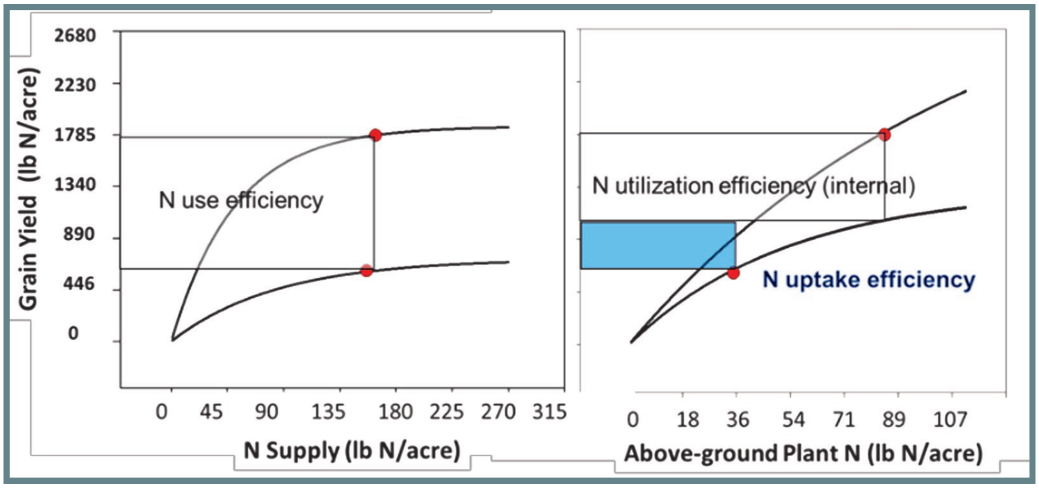

**Figure 2. Improved N utilization efficiency (use of plant N to make grain) and N uptake efficiency (proportion of total N supply absorbed by the plant) both contribute to increased NUE with more water and yield potential.**

**Spring canola N timing.** In field studies, Hammac found that fall N application at high rates (120 and 160 lb/ac) and fall-spring split N application at low rates (40-40 lb/ac) outperformed split application with high spring rates and single rate spring application. Declines in grain and oil yield may have resulted from damage to taproot growth and development as observed by Pan. Spring timed application may be ideal to minimize N loss in terms of 4R nutrient management, but placement and source will need to consider ammonia exposure to maximize seedling health and overall productivity. In drier winter locations, fall N fertilization has effectively spread the N fertilization of spring wheat, while achieving better distribution of soil nitrate throughout the 4 ft root zone.

## Selecting Nitrogen Source to Minimize Damage Caused by Free Ammonia

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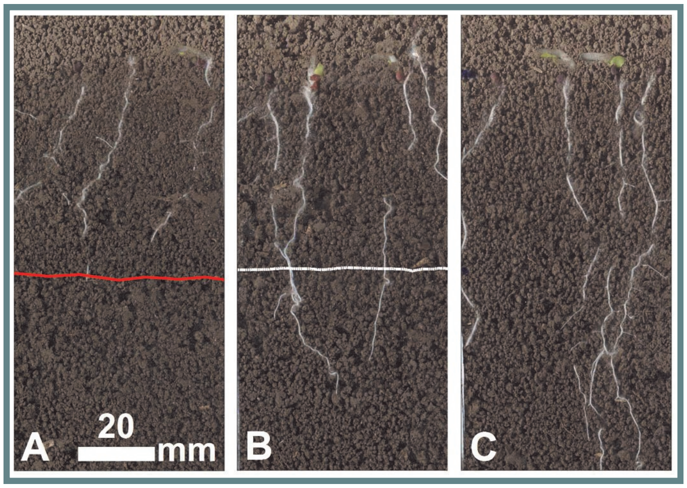
When planning Nitrogen (N) fertilizer application the source of the fertilizer should be considered in order to optimize nutrient availability as well as to avoid damaging seedling root systems. Canola root systems have been shown to be sensitive to urea banded below the seeds. The two primary considerations when choosing a safe source of N fertilizer are the salt toxicity and ammonia/ammonium toxicity. The conversion of ammonium to free ammonia is primarily controlled by the initial pH of the fertilizer reaction. A high pH will lead to more free ammonia than ammonium. Free ammonia has been shown to be extremely toxic to plant cells. Therefore fertilizers with a high pH would be expected to release more free ammonia and consequently have a higher level of toxicity. Urea, Anhydrous Ammonia, and Aqua Ammonia all have pH greater than 8 in solution. Fertilizers with a pH lower than 8 are Ammonium Sulfate, Mono-Ammonium Phosphate, and Di-Ammonium Phosphate. In this study we compared the application of ammonium sulfate (AS) (pH = 5-6, partial salt index = 3.52) to urea (pH = 8.5-9.5, partial salt index = 1.618). Urea (Fig. 1.A) and AS (Fig. 1.B) were banded at a rate of 0.016 oz N ft$^{-1}$ (43 lbs/A at a 6” row spacing) were compared with a control 0 oz N ft$^{-1}$ (Fig. 1.C). Both the AS and the Urea were seen to retard tap root growth. However, the urea was seen to completely prevent root passage through the fertilizer band, whereas the roots exposed to AS were seen to pass through the band.



**Take away points:** It was determined that canola roots are more sensitive to urea than ammonium sulfate. This is likely because urea would produce higher levels of free ammonia following dissolution.

## Effects of Mowing Early Planted Winter Canola on Yield, Survival, and Moisture Use

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A major constraint on the adoption of winter canola in the winter wheat/fallow zone of Washington is the ability to establish a uniform stand of the crop in the hot, dry growing conditions associated with the recommended seeding date of mid-to-late August. Seeding canola earlier in the summer (early-to mid-July) increases the chance for uniform stand because temperatures are cooler and soil moisture more readily available. However, large plants are less likely to survive the winter, due to exhaustion of soil moisture reserves or occurrence of stem elongation before the frost.

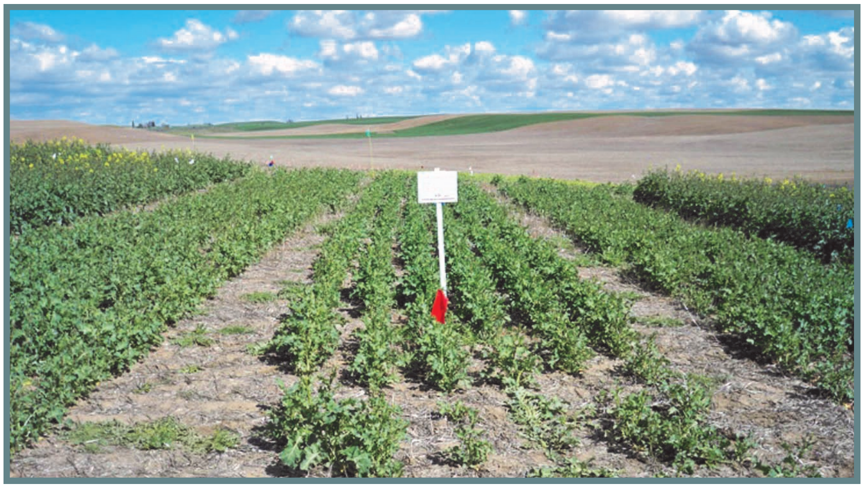

Figure 1. Different plant heights in Spring 2016.

Research conducted at the University of Idaho investigated early planting of winter canola with one to three harvests of the biomass for "canolage" (canola silage) in an irrigated system and research conducted in Australia evaluated spring and winter varieties for grazing. Canopy management with fungicides or defoliation with a mower has been recommended for growers in the UK if the leaf area of their winter canola plants is too large. However, these strategies need to be evaluated for winter wheat/fallow region in Washington because the climate condition are different from where previous studies conducted.

Figure 2. Mowing July planted canola in Fall 2015.

A study was conducted for two growing seasons in 2015-2017 to evaluate seeding date and mowing winter canola on water use and canola yield. In this study, glyphosate resistant winter canola was planted July 21, August 4, and September 14, 2015. Within the July planning, designated plots were mowed September 21, October 21, and both dates and no-mowing treatment was also included. Mowing height was set as not to damage the crown of the plant (6 to 10 inches).

The preliminary data shown that winter survival ranged from 62% to 97% in all plots. Mowing had no significant effect on winter survival when compared to the July-planted non-mowed canola. The highest yield (2825 lbs/A) was reached when canola was planted in August. Slightly lower yields (≈2700 lbs/A) were realized from canola planted in July and mowed once either in September or October. When canola was mowed twice, yield was almost 500 lbs/A less than the August planting date. There was plenty of snow cover at Davenport to protect the small plants in the September planting and survival and yield was excellent considering the planting date.

**Ongoing Research:** This study has been repeated for the 2016-2017 year with Haiying Tao taking over the research.

**Table 1.** Effect of planting and mowing date on winter canola yield and survival at Davenport, WA 2016.

| Treatment date | | Yield (lbs/A) | Survival (%) |
|---|---|---|---|
| Planting | Mowing | | |
| 7/21/2015 | none | 2675 | 75 |
| 7/21/2015 | 9/21/2015 | 2705 | 63 |
| 7/21/2015 | 10/21/2015 | 2700 | 72 |
| 7/21/2015 | both | 2345 | 74 |
| 8/4/2016 | NA | 2825 | 62 |
| 9/14/2016 | NA | 2560 | 97 |

# WSU-HT1, a Group Two Herbicide Tolerant Camelina Cultivar

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One of the limitations of camelina as an oilseed rotation crop in the PNW is the paucity of herbicides labeled for the crop and its sensitivity to residual amounts of herbicides commonly used in wheat production. Specifically, Group 2 herbicides that inhibit acetolactate synthase (ALS), like sulfonylureas and imidazolinones, are particular problems because of their long residual activities. Imidazolinones include Beyond®, a herbicide popularly used in Clearfield wheat varieties. A breeding project was initiated to develop a camelina variety adapted to dryland region of the PNW that is resistant/tolerant to group 2 herbicides. Mutagenized camelina seed was sown at a very high density, allowed to germinate and establish, and then treated with Beyond herbicide. Several mutants were identified with partial resistance to the herbicides. One line in particular carried a mutation that provided partial resistance to both imidazolinones and sulfonylureas. Crosses between this line and other camelina varieties were made to create a breeding population from which WSU-HT1 was selected.

These breeding lines carrying the mutant gene showed no herbicide injury and high yields when planted into soils where the herbicide Beyond was applied at four times the recommended rate the previous season. WSU-HT1 had the highest yield and oil content of the breeding lines and is being released for commercial production. Yield and oil content are competitive with, or better than, other varieties that have been grown commercially in the region.

**Table 1. Performance of WSU-HT1 and other cultivars**

| Variety | 2014 | | 2015 | | 2016 | |
|---|---|---|---|---|---|---|
| | Yield[1] | % Oil | Yield | % Oil | Yield | % Oil |
| WSU-HT1 | 858 ab | 33.7 ab | 983 a | 34.8 a | 1951 a | 35.3 a |
| Blaine Cr. | 597 b | 31.2 b | 780 a | 34.6 a | 1207 c | 35.3 a |
| Calena | 980 a | 34.5 a | 840 a | 35.2 a | 1943 ab | 36.0 a |
| Suneson | 690 ab | 32.3 ab | 864 a | 36.0 a | 1266 bc | 35.2 a |
| Midas | n.t | n.t | 806 a | 33.7 a | 1242 c | 34.8 a |

[1]lbs/acre

**Other traits targeted for improvement:**

Another problem with camelina production has been the lack of suitable markets and corresponding low prices. A recent decision by the FDA provides GRAS status to camelina oil as a food ingredient if erucic acid is less than 2% of the oil content. While current varieties exceed this limit, we have developed lines with less than 0.5% erucic acid. Although these lines currently do not perform well agronomically, we have crossed them to lines like WSU-HT1 to improve their performance. If successful, these breeding lines will greatly expand the current marketability of camelina, thereby increasing farmer profitability. Past efforts to encourage commercial camelina production with only the promise of future fuel markets have failed. In contrast, the canola food oil and feed meal markets have ensured markets for canola producers, even during times of wavering canola biofuel markets and prices. This food + fuel history of canola integration into the PNW should provide a model pathway for successful camelina integration.

## *Brassica Rapa* Type Winter Canola Varieties in East-Central Washington

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The drylands of east-central Washington often present a high-stress environment for winter crops, including winter canola, due to dry seed-zone conditions for planting in late summer, cold winters, meager precipitation, and frequent early onset of high temperatures in late spring. The *Brassica napus* type of winter canola has high yield potential and is generally considered the most promising domestically-produced oilseed feedstock for biodiesel production in the Inland Pacific Northwest. Most breeding and agronomy research has been conducted for *B. napus* varieties. Another type of winter canola, *Brassica rapa*, was bred in Sweden for tolerance to cold and other abiotic stresses. The downside to *B. rapa* winter canola is lower yield potential compared to *B. napus* types. However, "optimum" yield potential is often not realized in east-central Washington due to the above-mentioned stresses. The upside to *B. Rapa* winter canola is excellent winter hardiness, early maturity to better avoid high temperatures during flowering, and limited pod shatter. Also, deer do not eat *B. rapa* canola. We are growing the *B. Rapa* winter canola variety "Largo" in a long-term cropping systems study at the Ron Jirava farm near Ritzville, WA.

**Largo winter canola in a large-scale cropping systems experiment near Ritzville, WA in 2016. Flowers were initiating on April 5 (left) and the crop was in full flower on April 28 (right). The site received 14.56 inches of crop-year precipitation in 2016 (average is 11.5 inches) and the canola grew to a height of nearly six feet. Some lodging occurred. Seed yield of this crop was 2,120 lbs/acre whereas seed yield of *B. napus* varieties in neighboring fields was more than 3,000 lbs/acre.**

## A Survey of Blackleg Disease of Canola Caused by *Leptosphaeria maculans* in Northern Idaho

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Blackleg (also known as stem canker, or Phoma stem canker) is the most damaging disease of *Brassica* crops and causes annual yield losses of more than $900 million in Europe, North America, and Australia. Blackleg can cause yield losses of up to 80%; therefore, resistance to blackleg disease has been one of the major objectives of many *Brassica* breeding programs.

The causal agent of blackleg is the fungal pathogen *Leptosphaeria maculans* (anamorph *Phoma lingam*). Blackleg infects rapeseed and mustard crops beginning at the seedling stage and under the proper conditions can progressively damage the crop by creating stem cankers that restrict vascular flow of water and nutrients to the upper plant. Blackleg symptoms are characterized by dull-white lesions on leaves with small dark spots (pycnidia). As the disease progresses deep brown lesions with a dark margin may be seen at the base of stems and these cankers can result in lodging. Severe blackleg infection can spread through the entire plant, creating the potential for seed infection and future transmission through planting infected seeds.

Blackleg is most severe in regions with warm, humid conditions and summer rains. While canola crops have been grown in the PNW for many years, many believe that the region's prevailing warm and dry conditions combined with little summer rainfall are not conducive to the disease blackleg. However, blackleg disease was discovered in northern Idaho near Bonners Ferry in 2011. Blackleg disease poses a major threat to canola production in the PNW region and virtually no selection has been carried out to identify resistance genes or cultivars suitable for the region.

A preliminary survey in 2015 found blackleg infected canola across several counties in northern Idaho. In 2016, leaf and stubble samples were collected from 40 locations across Latah, Nez Perce, Lewis, and Idaho counties. Included in the survey were fields of winter canola, spring canola, mustard, and a variety of Brassicaceae weeds. *Leptosphaeria maculans* was found at 14 locations. A less virulent blackleg pathogen, *L. biglobosa*, also was found at two locations. In total, 67 *L. maculans* isolates and 6 *L. biglobosa* isolates were collected. The majority of the isolates found have been confirmed to be pathogenic on blackleg susceptible canola cultivar Westar.

Isolates are currently being characterized to identify the race structure among the population already found to exist in northern Idaho. This information will be used by the University of Idaho's Canola Breeding Program to screen for resistance in current cultivars and develop new canola cultivars with superior resistance to blackleg.

## Manipulating the *AT-hook Motif Nuclear Localized* (*AHL*) Gene Family for Bigger Seeds with Improved Stand Establishment

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In low rainfall dryland-cropping areas of eastern Washington, stand establishment can have a major impact on yields of camelina and canola. During dry years these seeds need to be planted in deep furrows so that the developing seedling has access to water in the soil. One approach to facilitate stand establishment is to develop varieties with larger seeds and longer hypocotyls as seedlings while maintaining normal stature as adults. Few mechanisms, however, have been identified that uncouple adult stature from seedling height. The Neff lab has identified an approach to improve stand establishment by uncoupling seedling and adult phenotypes through the manipulation of members of the *AHL* family. When these genes are over-expressed, the result is seedlings with shorter hypocotyls. When the activity of multiple genes is disrupted, the result is seedlings with taller hypocotyls, demonstrating that these genes control seedling height in a redundant manner. In the Brassica *Arabidopsis thaliana,* we have identified a unique allele (*sob3-6*) for one of these genes, *SOB3/AHL29*, that over-expresses a protein with a disrupted DNA-binding domain and a normal protein/protein interaction domain. In *Arabidopsis*, this mutation confers normal adult plants that produce larger seeds and seedlings with hypocotyl stems that can be more than twice as long as the wild type. The goal of this project is to enhance camelina and canola seedling emergence when they are planted deeply in low-rainfall dryland-cropping regions (generally less than 12"/year) or in wheat stubble. This can be achieved by manipulating *AHL* gene family members to develop varieties that have long hypocotyls as seedlings yet maintain normal growth characteristics as adult. The current aims for this project are: 1) Analyze seed size of *AHL* mutations in *Arabidopsis*; 2) Identify, clone and characterize *AHL* gene family members from camelina and canola; 3) Generate transgenic camelina and canola expressing *AHL* genes; 4) Use CRISPR/Cas9-based genome editing to modify *AHL* genes. During this funding period, the Neff Lab has used a combination of molecular, genetic, biochemical, and biotechnological approaches to understand the role of *AHL* genes in plant growth and development. Our primary goal has been to characterize *AHL* genes from *Arabidopsis* and camelina, while also establishing a canola transformation system. Using transgenic *Arabidopsis* we have characterized seed size in all of the *AHL* gene dominant-negative mutations that we have identified. Surprisingly, though each mutation leads to longer hypocotyls, only the *sob3-6-like* mutants created larger seeds. We have also generated putative transgenic canola expressing *Atsob3-6*, though these still need to be verified. Because of problems with transgene silencing, we have generated additional transgenic camelina expressing *Atsob3-6,* for seed size and emergence analysis. We have also generated camelina CRISPR/Cas9 lines targeting, *sob3-like* genes, some of which may be exhibiting longer hypocotyls. Using *Arabidopsis AHL* mutants, we have now demonstrated that the long hypocotyl seedling phenotypes are regulated by plant hormones including the auxins and brassinosteroids. This work was part of David Favero's Ph.D. dissertation and was published in two peer-reviewed manuscripts, one in Plant Journal and the other in Plant Physiology. Using *Arabidopsis AHL* mutants we have shown that clade A and clade B AHLs have opposite roles in flowering time. We have also shown that clade A and clade B AHLs only interact with members of their own clade. Using CRISPR/Cas9 to target four clade B AHLS, our preliminary results suggest that mutations in this family leads to larger plants. These need to be verified by gene sequencing.

## Winter Canola Nitrogen Supply and Timing Recommendations for the Pacific Northwest

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**Biomass and Nitrogen (N) accumulation/requirements.** Winter canola planted before late August should be managed as a two-season crop. First, Nitrogen (N) fertilization strategies are required to cover planting to winter freeze. Second, coming out of winter freezing requiring shoot regrowth, the canola N requirements will align with Unit N Requirements (UNRs) established for spring canola. Studies across eastern Oregon and Washington have shown early seeded winter canola can accumulate up to 3,000 lb dry biomass/acre and 135 lb N/acre between emergence and winter, which offers opportunities for animal grazing or silage production if mixed with high fiber straw. Late seeded winter canola may only accumulate <100 lb biomass and <5 lb plant N. If leaves don't dieback during mild winter temperatures or snow cover, the biomass N will be used during subsequent crop development and grain filling. However, if above ground biomass dies due to freezing or water stress, then perhaps plants will only recycle ~1/3 of the shoot N to support grain production. Cautionary management should consider the prospect of having too lush growth and water use stimulated by initial high N fertilization, which can lead to induced water stress and greater susceptibility to winter-kill. Coming out of the winter thaw, the N requirements are similar to spring canola. A 3,000 lb grain/acre winter canola crop will produce more than 17,000 lb/acre total dry matter and accumulate more than 225 lb N/acre. This translates to a total N supply need of 300 to 450 lb total (fertilizer + soil) N supply for a crop that is 75 to 50% efficient at accumulating the total N supply.

**N timing.** Davis observed that broadcast tilling all urea and ammonium phosphate fertilizer at planting of winter canola reduced yields and winter survival compared to 25% at planting with the remainder applied later as split fall: spring topdress applications. Mechanisms could include seedling damage or too lush of growth. Similarly, Wysocki also found that applying all 140 lb N/acre at winter canola planting as urea resulted in yields similar to the 0 N control, while 0 to 25% of the total N fertilizer applied at planting resulted in higher yields. Esser showed a reduction in final grain yield by placing up to 30 lb urea-N/A near the seed. Collectively, these field studies align with root studies that caution against the application of high ammonia-based fertilizers at canola planting, particularly when placed with and below the seed. Unless there is sufficient spacing between the seedling and fertilizer row, ammonia based fertilizers should be applied preplant during fallow, or as fall- and spring post-plant topdressing. Ongoing studies conducted by Dr. H. Tao will verify this hypothesis. These research results and principles were presented at three 2017 WOCS winter workshops. Fertility recommendations will be published in a forthcoming PNW nutrient management guide.

**Table 1. Seed yield and survival at Moscow, ID in 2014, 2015 as affected by Nitrogen rate and timing.**

| | Seed Yield | | | |
|---|---|---|---|---|
| Fertilizer Timing Treatment | 2014 | 2015 | Mean | Winter Survival |
| | ———————— | *lbs. per acre* | ———————— | ——score[1]—— |
| Reduced N at Planting Only | 1680 a[2] | 2695 a | 2154 a | 6.5 b |
| All at Planting | 1978 b | 2405 a | 2178 a | 5.4 a |
| None at Planting 50% in Fall, 50% in Spring | 2346 c | 3775 b | 3038 b | 6.9 b |
| 25% at Planting, 25% in Fall, 50% in Spring | 2306 c | 3594 b | 2929 b | 6.7 b |
| 25% at Planting, 75% in spring | 2360 c | 3257 b | 2794 b | 6.8 b |

[1] Scored on a scale of 1 to 9 with one equaling no survival and nine equaling complete survival.

[2] Means within columns with different letters are significantly ($P<0.05$) different.

## Effects of Increasing Seeding Rates on Spring Canola Yields

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Canola seed, particularly transgenic seed, is expensive. Canola is also hard-seeded, and germination of seed can be ~50%. Increased canola seed rates could offer increased crop establishment, resulting in crop and weed competiveness, and productivity by maximizing above ground growth and yield potential. A study was established near Pullman, WA, to evaluate a range of seeding rates. Spring canola variety Hyclass 930 was planted on April 20th, 2016 using a Monosem planter calibrated to deliver seeding rate treatments detailed in Table 1, on an10 inch row spacing. The study was conducted as a randomized complete block design with 3 replications of 10 by 75 ft plots. The entire study was fertilized with 20 lb of sulfur and 80 lb of nitrogen, and glyphosate was spilt applied at 0.387 lb ai $A^{-1}$, with 0.124 lb ai $A^{-1}$ of cloypralid added in the later application timing. Crop stand counts were recorded 62 days after treatment. The study was harvested using a plot combine with a 5 foot header on September 20, 2016. All data were subjected to an analysis of variance using the statistical package built into the Agricultural Research Manager software system (ARM 8.5.0, Gylling Data Management). Spring canola stand counts significantly increased as the seeding rate increased, with 10 plants $m^{-1}$

for the 26 seed m$^{-1}$ treatment (4 lb A$^{-1}$) and 31 plants m$^{-1}$ for the 79 plants m$^{-1}$ seeding rate (12 lb A$^{-1}$). Based on intended seeding rates on average crop establishment was 43% on average for all treatments. Yields increased as seeding rates increased. Yield for the seeding rate of 79 seeds m$^{-1}$ (12 lb A$^{-1}$) was significantly higher than the lowest seeding rate of 26 seeds m$^{-1}$ (4 lb A$^{-1}$), with 1362 lb A$^{-1}$ compared to 824 lb A$^{-1}$. No reduction in yield was observed as seeding rate increased. Previous studies have found both increases and decreases in yield as seeding rates increased (Hanson et al. 20. Crop establishment and drill type should be taken into consideration when choosing a seeding rate to utilize maximum yield and economic returns. Fertilizer requirements, cultivar type and seed cost should also be taken into consideration when choosing seeding rate.

**Table 1. Stand counts and yield for spring canola seeding rates (Hyclass 930). Pullman, WA, 2016. Means followed by the same letter are not statistically significantly different ($\alpha$=0.05).**

| | | | | *June 21, 2016* | *August 18, 2016* |
|---|---|---|---|---|---|
| **Treatment #** | **Seeding Rate** | | | **Stand Counts** | **Yield** |
| | **seed/m** | **seed/ft** | **lb/A** | **plants/meter** | **lb/A** |
| 1 | 26 | 8 | 4 | 10 a | 824 a |
| 2 | 32 | 10 | 5 | 15 ab | 985 ab |
| 3 | 39 | 12 | 6 | 16 ab | 1012 ab |
| 4 | 46 | 14 | 7 | 18 abc | 970 ab |
| 5 | 52 | 16 | 8 | 23 bc | 1006 ab |
| 6 | 66 | 20 | 10 | 25 cd | 1222 ab |
| 7 | 79 | 24 | 12 | 31 d | 1362 b |
| Hill drop | 20 | 6 | 3 | 12 a | 1139 ab |

## Soil Microbial Communities of the Lind Camelina Cropping Systems Experiment

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Acreage of *Brassica* crops in the Inland Pacific Northwest have expanded in recent years with the increased demand for oilseed products. Canola has seen the largest surge in production, but other oilseed crops such as camelina are also of interest. Oil quality, tolerance to heat and drought stress, and low input costs have accelerated the interest in camelina. Crop rotations that include *Brassicas* have been reported to increase yields and reduce fungal pathogens in subsequent crops. *Brassica* crops, including camelina, contain glucosinolates (GSLs) which hydrolyze to produce isothiocyanates (ITCs). The production of ITCs is the mechanism responsible for the "biofumigation" effect. The biofumigation effect is generally considered positive; however, the non-selectivity of ITCs has potential to impact beneficial soil organisms. The GSL profiles of canola and distribution in the plant have been extensively studied while little is known about those of camelina. We assessed the soil microbial communities of camelina (C) produced in a 3-year winter wheat (WW)-C-summer fallow (SF) rotation compared to the 2-year WW-SF rotation. Five years of data collected from a 9-year experiment at the Lind Dryland Research Station are presented. Soil microbial community composition was determined using phospholipid fatty acid (PLFA) analysis. PLFA's extracted from soil are divided into biomarker groups representing fungi, mycorrhizae, gram negative, and gram positive bacteria. Data show biomarkers amounts decreasing with

WW > C > SF in the 3-year rotation. Fungi were significantly greater in WW compared to C, and all groups significantly greater in WW compared to SF (Fig. 1). While the biomarkers for the 2-year rotation exhibited the same pattern of WW > SF in all groups except for gram + bacteria, the differences were not significant (Fig. 1). Data suggest that a 3-year cropping sequence of WW-C-SF may have effects on soil microbial communities above that associated with the decline between WW to C, and WW to TSF.

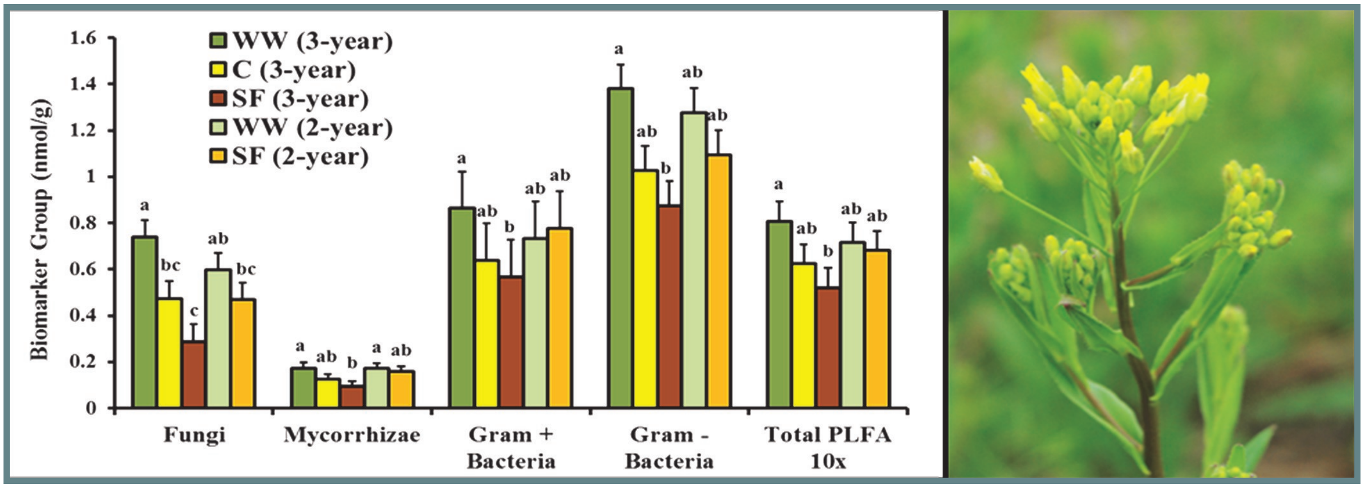

**Figure 1. Differences in microbial community groups of the WW-C-SF (3-year) and WW-SF (2-year) rotations as determined by PLFA biomarkers. Photo shows camelina at early flowering.**

# Establishing Safe Rates for Banding Urea Fertilizer Below Canola at Planting

WOCS
WASHINGTON OILSEED CROPPING SYSTEMS
*Part of the Washington State Biofuels Initiative*

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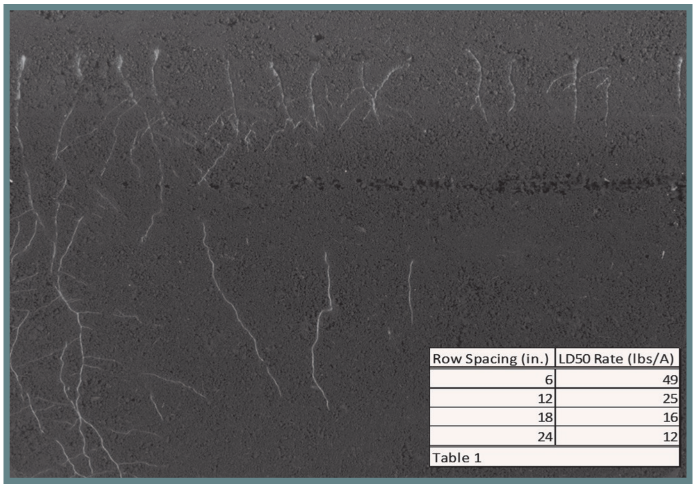
When planning fertilizer application the rate, timing, source, and placement of the fertilizer should be considered in order to optimize nutrient availability as well as avoid damage to the root system. In order to avoid damaging the root system it is advisable to consider offsetting the placement of the fertilizer, changing the timing, or selecting a less toxic nutrient source. However, there will still be cases in which the placement, source, and timing cannot be changed. In such a case a safe rate should be established. The goal of this research was to establish a “safe” rate for banding dry urea fertilizer below canola seedlings at planting. A series of images was collected in which canola roots were grown into a urea fertilizer band at increasing rates (Fig. 1). Symptoms of stunted tap root growth, necrosis, premature lateral branching, and shallow lateral branching were observed to increase with increasing rates of urea. The data from four replicates of the experiment was used to calculate a LD50 of 0.009 oz N ft$^{-1}$. The LD50 must be calculated in terms of mg N cm-1 as the toxicity is determined by the actual concentration which the individual canola root grows into. To convert this concentration to a field application rate the row spacing of the drill must be considered. As row spacing increases the concentration which an individual canola root system



| Row Spacing (in.) | LD50 Rate (lbs/A) |
|---|---|
| 6 | 49 |
| 12 | 25 |
| 18 | 16 |
| 24 | 12 |

Table 1

**Figure 1.**

faces increases given the same application rate in terms of lbs/A. The LD 50 for different row spacing can be seen in Table 1. It is also important to note that field conditions such as the moisture of the field can impact the movement of free ammonia through the soil and that drier soils will be more vulnerable to toxicity.

**Take away points:** All rates of urea do some damage to canola seedling roots. However, at rates lower canola roots may survive with some damage. The LD50 changes depending on the row spacing.

## WSU Oilseed Extension and Outreach: Full Speed Ahead!

KAREN SOWERS[1], DENNIS ROE[1], AARON ESSER[2], BILL PAN[1], RACHEL BOMBERGER[3], DALE WHALEY[2], BILL SCHILLINGER[1], AND FRANK YOUNG[4]
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It's hard to believe the WSU-based Washington Oilseed Cropping Systems (WOCS) project is reaching the 10-year milestone this summer, and there's no sign of slowing down from the dedicated team of research and Extension faculty, graduate students, and technicians. This will be a year of transition as Bill Pan, who has led the WOCS project since it began in 2007, hands over the WOCS reins to Scot Hulbert, with Karen Sowers co-coordinating the Extension side. Many thanks to Bill for his tireless, patient, and knowledgeable leadership! We are also grateful for the extensive amount of research and outreach Frank Young achieved before his retirement in December 2016, particularly in Douglas and Garfield counties.

The WOCS Oilseed Series of fact sheets continues to expand with four added during the past year, three currently in the editing process, and several others in preparation. Other outreach includes:

- the WOCS website (www.css.wsu.edu/oilseeds) and new Facebook page
- email updates and notifications
- on-farm canola variety trials (see abstract on page 49)
- presentations at university and industry events
- winter breakfast meetings in Colfax
- radio and newspaper interviews
- participation on the WSU Extension Dryland Cropping Systems team
- representation at WA Oilseed Commission and U.S. Canola Association meetings
- field tours from spring through fall that featured infrared drone technology, blackleg management, oilseed and cover crops, updates from the Plant Pest Diagnostic Clinic, and marketing updates.

Following the success of returning to smaller, local oilseed workshops last year, we chose three new locations for 2017 – Hartline, Ritzville and Clarkston. Our goals were to 1) have producers comprise 50% of attendees, 2) reach out to and connect new and experienced oilseed producers, and 3) engage in a more interactive format. Planning committees were comprised of producers, industry, and PNW university faculty. New to the workshops were 1) hands-on sessions featuring live canola and camelina plants exhibiting nutrient deficiencies and herbicide injury, and 2) attendees rotating through all of the breakout sessions. Attendance was at an all-time high (275), including a record 180 first-time attendees. More than half of attendees were producers. Surveys from the workshops indicated positive feedback to the locations, format, and hands-on sessions.

Finally, two major goals new for 2017-18 are the formation of a PNW Canola Grower Association, and completion of a PNW Canola Production Handbook, both of which are timely given the most recent Prospective Plantings report

(USDA-NASS, Mar. 31, 2017). The report shows increased canola acreage in all PNW states with Washington at 50,000 acres (up 152%), OR at 10,000 acres (up 250%), ID at 34,000 acres (up 162%), and MT at 110,000 acres (up 177%). With a significant number of first-time canola producers, continued education and outreach with relevant information is critical. The success of both goals will require widespread collaboration between the WOCS team, producers, industry, agency, and university personnel in all four states. Since collaboration has been a foundation of the WOCS project since 2007, we are confident that by this time next year not only will those goals be achieved, but that canola and other oilseed acreage will again experience record gains in Washington and the PNW.

## Fall Grazing on Winter Canola

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Dual-purpose canola can be a viable strategy for an integrated crop-livestock farming system. Fall grazing on winter canola can provide additional income to farmers. Studies in Australia have shown that grazing winter canola can be feasible in areas with greater than 18 inches of rainfall. And, if grazing is managed appropriately, yield penalties associated with grazing can be minimized or avoided. Appropriate grazing management includes practices such as an earlier planting date, strict grazing start and termination times, and proper grazing density. Our preliminary data on fall grazing of early-planted (June 28, 2016) winter canola near Ritzville, WA, indicated that livestock grazed approximately 1 ton dry matter/acre. Furthermore, we found that the canola had high moisture content (Fig. 1) and high nutritional value (Table 1). Compared with corn silage, canola has higher protein, lower neutral digestible fiber (NDF), and lower acid digestible fiber (ADF). When grazing canola, managing nitrogen (N) and sulfur (S) fertilization is important so that nitrate ($NO_3^-$) and S concentrations in the canola remain at safe levels for feed. Research has shown that safe concentration levels for $NO_3^-$ and S are 1,012 ppm and 0.4%, respectively. Providing other feed sources to livestock when grazing canola, such as wheat straw, can reduce the risk of $NO_3^-$ toxicity while supplying high-energy feed to enhance weight gain.

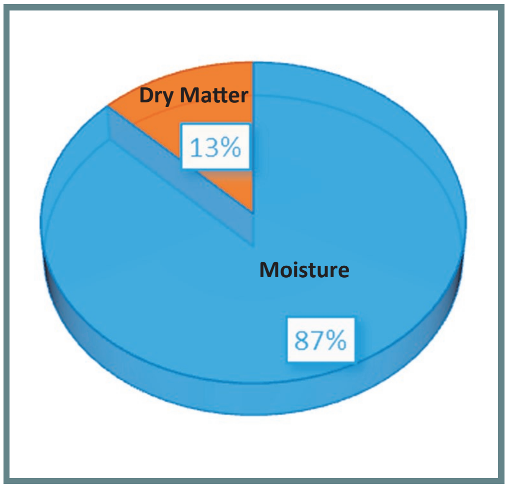

**Figure 1. Moisture and above-ground, dry matter biomass in winter canola, sampled on the grazing start date.**

**Table 1. Comparison of nutrient content between winter canola grown near Ritzville, WA, and corn silage grown near Wapato, WA, in Fall 2016.**

| | Crude protein | NDF | ADF | Crude Fat | Ash | RFV | $NO_3$-N | S |
|---|---|---|---|---|---|---|---|---|
| | ------------------------- | | % | ------------------------- | | | - ppm - | - % - |
| Corn silage 1 Sampled in 09/2016 | 6.3 | 50.3 | 33.5 | 2.3 | 6.6 | 116 | <70 | 0.07 |
| Corn silage 2 Sampled in 09/2016 | 4.9 | 68.8 | 45.2 | 1.3 | 9.88 | 73 | <70 | 0.07 |
| Canola 1 sampled on 09/14/2016 | 31.9 | 22.9 | 15.4 | 3.6 | 20.3 | 313 | 9856 | 0.88 |
| Canola 2 sampled on 09/20/2016 | 27.5 | 23.8 | 18.6 | 3.0 | 21.5 | 291 | 3779 | 0.96 |

Note: NDF: neutral detergent fiber; ADF: acid detergent fiber; RFV: relative feed value; $NO_3^-$-N-nitrate-nitrogen; S-sulfur.

# Economics – Can Oilseeds Improve the Bottom Line in a Cereal Rotation?

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Farmers and economists have historically conducted single crop net return comparisons of substituting alternative crops for traditional crops. Rotational enterprise budgeting tools have been constructed to help farmers understand a more complete economic impact of alternative crops in the context of the whole rotation. Benefits accrue in crops following canola, impacting total farm returns through increased yields, and net farm returns via input costs. There are immediate economic impacts in the year canola is grown and in years later in a rotation. Not accounted for by these budgets are the impacts that incorporating canola has on soil health and quality, rotational weed control, and the environment.

Enterprise budgets have been developed for the Low and Intermediate Rainfall areas, and are in the development phase for the High Rainfall Zones, which include expanded features that allow for canola's rotational impacts. These interactive computer tools are available on-line and can be used to assess the on-farm economics of growing canola. Due to the dramatic changes in crop prices and input prices, all prices in the budgets posted on the WSU Oilseeds site (http://css.wsu.edu/oilseeds/) are being updated.

Each enterprise budget file includes separate tabs for summary, crop calendars, crop budget sheets (differentiated by rotation), and machinery complements and costs. The summary tab presented below (based on 2017 crop prices) provides detailed, interactive summary economic information useful in comparing alternative crops and rotations with and without canola.

**Table 1. Summary of Average Annual Returns by Crop ($/acre)**

| By Crop: | Unit | Yield per acre | Price per unit | Revenue per acre ($/acre) | Variable Costs (VC) ($/acre) | Fixed Costs (FC) ($/acre) | Total Cost (TC) of Operation ($/acre) | Returns over VC ($/acre) | Returns over TC ($/acre) |
|---|---|---|---|---|---|---|---|---|---|
| **Oilseed Rotation:** Fallow--Winter Wheat--Spring Canola | | | | | | | | | |
| Soft White Winter Wheat (SWWW) | bu | 78 | $4.68 | $365 | $161 | $259 | $421 | **$204** | **-$56** |
| *Preceding fallow year costs** | | | | *$0* | *$109* | *$27* | *$136* | *-$109* | *-$136* |
| Hard Red Winter Wheat (HRWW) | bu | 73 | $4.81 | $351 | $159 | $260 | $419 | **$192** | **-$68** |
| *Preceding fallow year costs** | | | | *$0* | *$116* | *$27* | *$143* | *-$116* | *-$143* |
| Spring Canola (SC) | lb | 1500 | $0.15 | $225 | $198 | $81 | $279 | **$27** | **-$54** |
| **Cereal Rotation:** Fallow--Winter Wheat--Spring Barley/Spring Wheat | | | | | | | | | |
| Soft White Winter Wheat (SWWW) | bu | 78 | $4.68 | $365 | $161 | $259 | $421 | **$204** | **-$56** |
| *Preceding fallow year costs** | | | | *$0* | *$109* | *$27* | *$136* | *-$109* | *-$136* |
| Hard Red Winter Wheat (HRWW) | bu | 73 | $4.81 | $351 | $164 | $260 | $424 | **$187** | **-$73** |
| *Preceding fallow year costs** | | | | *$0* | *$116* | *$27* | *$143* | *-$116* | *-$143* |
| Soft White Spring Wheat (SWSW) | bu | 50 | $4.83 | $242 | $177 | $96 | $273 | **$64** | **-$32** |
| Dark Northern Spring Wheat (DNS) | bu | 45 | $6.63 | $298 | $186 | $116 | $301 | **$113** | **-$3** |
| Spring Barley (SB) | ton | 1.50 | $120 | $180 | $164 | $76 | $239 | **$16** | **-$59** |

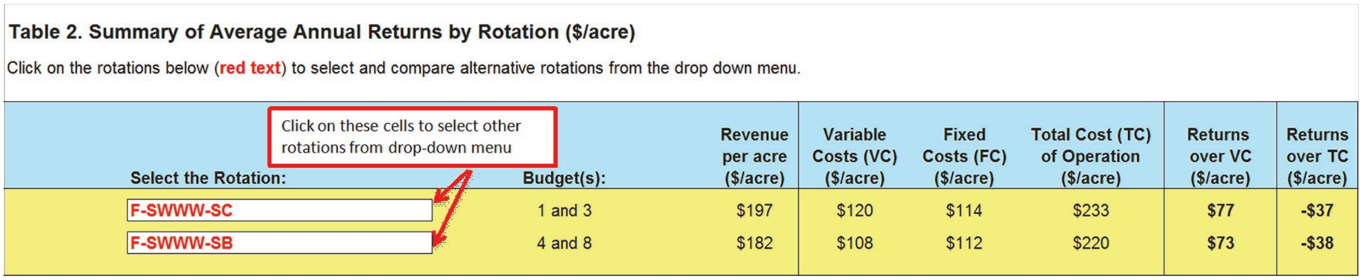

**Table 2. Summary of Average Annual Returns by Rotation ($/acre)**

Click on the rotations below (red text) to select and compare alternative rotations from the drop down menu.

Click on these cells to select other rotations from drop-down menu

| Select the Rotation: | Budget(s): | Revenue per acre ($/acre) | Variable Costs (VC) ($/acre) | Fixed Costs (FC) ($/acre) | Total Cost (TC) of Operation ($/acre) | Returns over VC ($/acre) | Returns over TC ($/acre) |
|---|---|---|---|---|---|---|---|
| F-SWWW-SC | 1 and 3 | $197 | $120 | $114 | $233 | **$77** | **-$37** |
| F-SWWW-SB | 4 and 8 | $182 | $108 | $112 | $220 | **$73** | **-$38** |

# Eight Years of Camelina Cropping Systems Research at Lind

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There has been strong interest in camelina in the US and around the world during the past ten years due to the unique fatty acid composition of the seed oil for human consumption and the meal for animal consumption. More importantly, the seed oil is valued to produce a low-carbon-emitting fuel for commercial and military aircraft. Camelina is mostly grown as a spring-planted crop with 85 to 100 days from emergence to maturity. Pod shatter is only a minor problem. Camelina seeds are very small; only about 30% the weight of a canola seed.

We initiated a long-term cropping systems experiment at Lind in 2009 to compare a 3-year rotation of winter wheat (WW)-camelina (C)-summer fallow (SF) versus the standard 2-year WW-SF rotation. All phases of both rotations are present each year (total 20 plots in 4 replicates) and individual plot size is 30 x 250 ft.

Camelina is a hardy plant, but is susceptible to frost during the first several days after emergence (cotyledon stage). We had complete loss of camelina stands in 2013 and 2015 due to hard frosts a few days after emergence. Our camelina seed yields have ranged from 300 to 1050 lbs/acre and have averaged 550 lbs/acre (Fig. 1 and Fig. 2). Average winter wheat yields in the 3-year WW-C-SF and 2-year WW-SF rotations are the same (Fig. 1). We have intensively measured soil water dynamics in this experiment and report these findings separately on page 67 of this publication. Several camelina publications from field research conducted in the Inland Pacific Northwest are available on the Washington Oilseeds Cropping Systems (WOCS) website http://css.wsu.edu/oilseeds/publications.

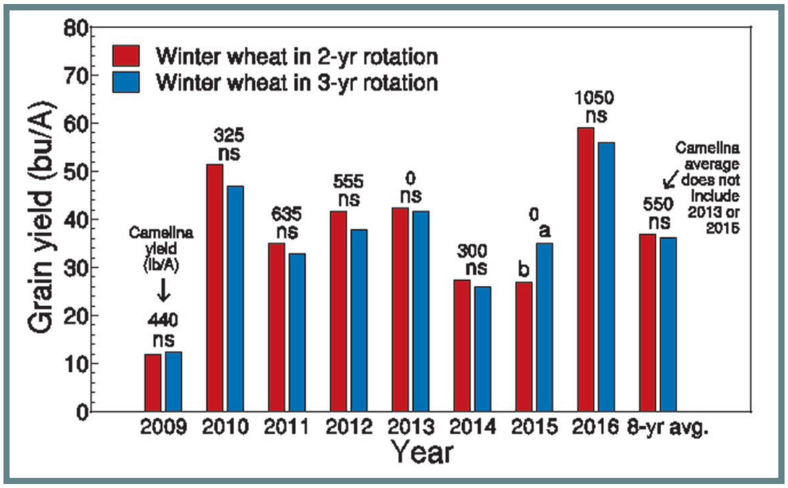

**Figure 1. Winter wheat grain yields in the 3-year winter wheat-camelina-summer fallow rotation compared to the 2-year winter wheat-summer fallow rotation during eight years at Lind, WA. Numerical values above the bars are camelina seed yields (lbs/acre).**

**Figure 2. Camelina in the Lind experiment on May 25, 2016. This crop produced a seed yield of 1050 lbs/acre.**

# Dual-Purpose Biennial Canola (*Brassica Napus* L.): Forage, Silage, and Grain Production in the Pacific Northwest

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**Figure 1. Loading (left) and packing (right) freshly harvested canola forage into ensiling tubes.**

Studies were conducted to investigate the production and quality of winter canola forage, silage, and grain. Winter canola was planted in mid-August of 2014 and 2015. Plots received one of eight nitrogen and sulfur fertilizer combinations with or without Agrotain®, a urease inhibitor. Plots were split in half with a dual-purpose treatment (DPWC) and a grain-only treatment (GOWC). Canola was harvested for forage approximately 60 days after sowing. Canola forage was ensiled with and without alfalfa cubes. Grain harvest took place July 7, 2015 and June 16, 2016. Forage yields averaged 2.1 Mg DM ha$^{-1}$ and forage DM was low, ranging from 90 – 130 g kg$^{-1}$ in 2014 and 150 – 210 g kg$^{-1}$ in 2015. Crude protein levels were higher in 2014 than in 2015. Ensiling canola reduced CP, but when ensiled with alfalfa cubes CP was maintained or increased. On average, the inclusion of alfalfa cubes increased NDF from fresh canola, while the NDF of canola silage without alfalfa remained about the same. Canola forage and silage was also high in ash, and highly digestible. Forage nitrate levels were low (<1.09 g NO3 kg$^{-1}$). Forage sulfur levels ranged from 3.75 – 6.24 g S kg$^{-1}$ and increased as fertilization increased. In general, ensiling reduced forage sulfur levels. Canola silage had a pH of 4.3 and a lactic acid concentration of 120 g kg$^{-1}$ DM. When canola was ensiled with alfalfa silage pH was 4.6, and lactic acid was 60 g kg$^{-1}$ DM. Large volumes of effluent were produced when canola was ensiled, but the addition of alfalfa cubes significantly reduced effluent. Cropping treatment did not influence winter survivability. Grain yields did not differ between fertilizer treatments, but GOWC grain yield was reduced in 2015 from 2014. Dual-purpose canola yielded around 300 g kg$^{-1}$ less than GOWC in 2014 but was not statistically different, in 2015 DPWC and GOWC yielded similarly. Net incomes were negative for both DPWC and GOWC in both years, however losses were larger for GOWC. Dual-purpose canola produced a high-quality forage and silage with any grain yield losses offset by the value of canola forage.

# Cabbage Seedpod Weevil Insecticide Trial in Winter Canola

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[1]WSU EXTENSION; [2]DEPT OF ENTOMOLOGY, WSU

Winter canola acreage in central and eastern Washington continues to increase as more producers learn about the rotational benefits and potential profitability of canola in predominantly cereal-based rotations. With more acres in production, insect pests common in other canola-growing regions of the US and Canada are now being observed in the Pacific Northwest (PNW). While many of the pests are not at thresholds to warrant control measures, the cabbage seedpod weevil, *Ceutorhynchus obstrictus* (Marsham), (Fig. 1) is becoming a problem in some areas of Washington state. The cabbage seedpod weevil (CSPW) is an introduced insect pest from Europe and causes damage to members of the

Brassicaceae or mustard family, including cultivated crops such as canola and brown mustard. When left unmanaged, the CSPW can cause significant damage to ripening canola seeds and impact overall yields by as much as 50% (Fig. 2). Unfortunately, we lack the fundamental knowledge on which insecticide provides the greatest control in our region in order to make sound management recommendations. The goal of this trial is to compare several known insecticides to determine which one will work the best at managing this pest for growers.

**Figure 1. Adult Cabbage Seedpod Weevil.**

The study design consist of randomized complete block with 5 replicates. Five insecticides: Bifenthrin (Tailgunner), Chlorantraniliprole (Altriset, Besiege, Voliam Express), Imidacloprid (Gaucho 600), Lambda-Cyhalothrin (Warrior II) and Zeta-cypermethrin (Mustang Max) were selected for this study. The seed treatment (Imidacloprid (Gaucho 600)) was applied in Fall 2016. The remaining 4 treatments will be applied the summer of 2017.

We will correlate CSPW densities in canola fields with yield losses and cost of insecticide treatment and communicate the results to farmers via our http://css.wsu.edu/oilseeds website, email listservs, online publications, and at workshops and field tours.

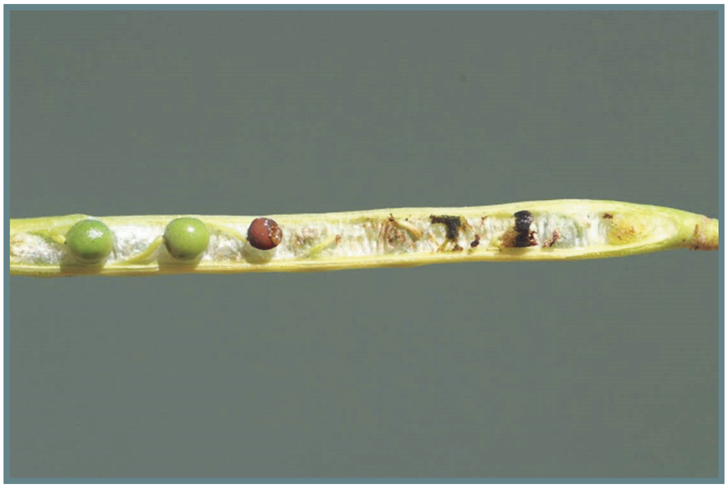

**Figure 2. Cabbage Seedpod Weevil larval feeding damage. Photo by Green Thumb Photography.**

# Soil Water Dynamics in the Long-Term Camelina Cropping Systems Experiment at Lind

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We are currently in the ninth year of a long-term cropping systems experiment to evaluate camelina (C) produced in a 3-year winter wheat(WW)-C-summer fallow (SF) rotation compared to the 2-year WW-SF rotation. Camelina is direct drilled into standing WW stubble in late February or early March. Winter wheat is planted into undercut-tillage SF in late August or early September. Soil water content to a depth of six feet is measured in all 20 plots after C and WW harvest in July and again in March, and from the eight SF plots in late August just before planting WW.

The only tillage in the experiment is during fallow and consists of one pass with an undercutter sweep + fertilizer injection in late April–early May and one rodweeding in July. These operations always take place at the same depth and same time. Every year, significantly more soil water evaporates during the summer months from SF after camelina than from SF after winter wheat. An average of 1.08 inch and 0.53 inch of soil water is lost between March and August in SF after camelina and winter wheat, respectively (Table 1). What are the reasons for this loss of an additional 0.55 inch of soil water in SF after camelina?

Since 2015, we have conducted field and laboratory tests and measurements of surface soil mulch conditions in this experiment to determine why these differences in soil water evaporative loss consistently occur. We expect the main reason may be due to surface residue cover, but it also could also be due to soil clod size distribution within the soil mulch or other factors. We plan to report the full findings in the near future.

**Table 1. Soil water content at the beginning (after harvest), early spring, and the end of fallow (just before planting of winter wheat) and associated gain or loss of water and precipitation storage efficiency (PSE) in the 6-foot soil profile in summer fallow in a 2-year winter wheat-fallow rotation versus a 3-year winter wheat-camelina-fallow rotation.**

| | Timing in fallow period | | | | | |
|---|---|---|---|---|---|---|
| Fallow treatment | Beginning (late Aug.) | Spring (mid Mar.) | Over-winter gain | End (late Aug.) | Mar. to Aug. water loss | PSE[†] (%)[††] |
| | Soil water (inches) | | | | | |
| After winter wheat | 6.28 | 9.79 | 3.51 | 9.27 | 0.53 | 29 |
| After camelina | 5.76 | 9.63 | 3.87 | 8.55 | 1.08 | 27 |
| *p-value* | 0.003 | ns | ns | < 0.001 | 0.01 | ns |

[†] Average fallow-year precip. for six fallow years (2009-2013, 2015) = 10.22".

[††] PSE (Precipitation Storage Efficiency) is % of precipitation stored in stored during fallow period.

[†††] 2013-14 and 2015-2016 fallow year not included due to a failed camelina crop in 2013 and 2015, respectively.

# Improving Nitrogen Use Efficiency for Winter Canola Using 4R Stewardship

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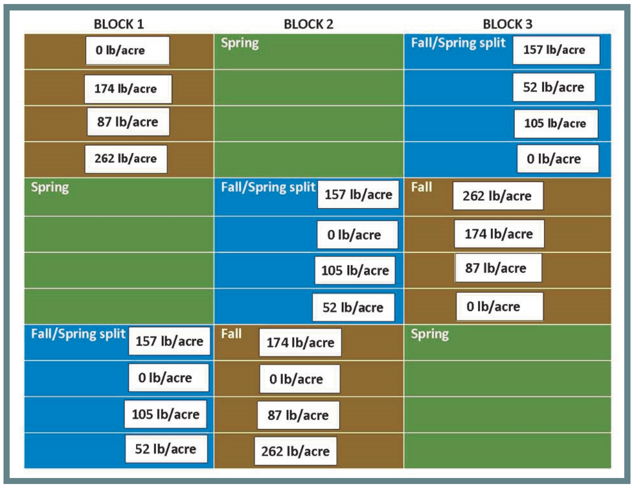
DEPT. OF CROP AND SOIL SCIENCES, WSU

Winter canola has potential as an alternative cash crop to wheat when market prices for wheat are low. Canola also has tremendous rotational benefits for soil health, weed and disease control, and the subsequent wheat crop. Careful fertility management is important to ensure maximum yield and quality; however, fertility management research specifically for winter canola production is limited. In fall 2016, we began three nitrogen (N) fertility trials to investigate the optimum rate and timing of N-fertilizer application for winter canola. Trials are established in three areas that represent different yield potentials, soil types, crop rotations, and climatic conditions. Two dryland trials are located near the towns of St. John and Hartline in Washington (WA) State and one irrigated trial is located near Odessa, WA. The primary objectives are to 1) quantify N uptake during the growing season; 2) estimate the optimum rate and timing for N fertilizer for canola grown in different environment with different yield potentials; 3) evaluate how N affects canola yield and oil content. We will also evaluate if chlorophyll meters and aerial imageries are useful tools to estimate plant N status for guiding spring N applications.



| BLOCK 1 | BLOCK 2 | BLOCK 3 |
|---|---|---|
| 0 lb/acre | Spring | Fall/Spring split 157 lb/acre |
| 174 lb/acre | | 52 lb/acre |
| 87 lb/acre | | 105 lb/acre |
| 262 lb/acre | | 0 lb/acre |
| Spring | Fall/Spring split 157 lb/acre | Fall 262 lb/acre |
| | 0 lb/acre | 174 lb/acre |
| | 105 lb/acre | 87 lb/acre |
| | 52 lb/acre | 0 lb/acre |
| Fall/Spring split 157 lb/acre | Fall 174 lb/acre | Spring |
| 0 lb/acre | 0 lb/acre | |
| 105 lb/acre | 87 lb/acre | |
| 52 lb/acre | 262 lb/acre | |

# ARS Grain Legume Genetics, Pathology, and Physiology Research Pulse Crops Breeding Programs

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REBECCA MCGEE AND GEORGE VANDEMARK
UDSA-ARS

WSU is home to the USDA-ARS Grain Legume Genetics and Physiology Research Unit. The Prospective Plantings Report of the National Agricultural Statistics Services projects that in the US in 2017 chickpeas will be planted on nearly 500,000 acres, lentils on 1million acres and peas on 1.1 million acres. The pulse crops are an important component in cereal-based cropping systems in semi-arid environments. They help break weed and pathogen cycles, add organic matter to the soil and fix atmospheric nitrogen. The pulse crops are also important in human diets because they are high in protein and fiber, low in fat and have a low glycemic index.

Chickpea production in the USA is centered in Washington, Idaho and Montana. The objectives of the chickpea breeding program are to develop new varieties that combine high yield with early maturity and desirable seed characteristics. Specific seed traits that are targets for enhancement through include increased seed size, lighter seed coat color, and improved nutritional quality. In collaboration with colleagues from Washington State University, the University of Idaho, Montana State University, North Dakota State University and local growers, the most promising chickpea breeding lines are evaluated at 10-15 locations each year. Recent releases include 'Nash', which consistently produces higher yields and larger seed than the most popular commercial variety, 'Sierra,' and 'Royal,' which produces higher yields and larger seed than Sierra in the lower rainfall areas (14-18") of eastern Washington.

Dry peas have been produced in the Palouse region of Washington and Idaho since the early 1920's and in Montana and North Dakota since the late 1980's. The objectives of the spring pea breeding program are to develop adapted varieties of green and yellow field peas with increased yield and improved levels of resistance to diseases caused by soil borne fungal pathogens, foliar fungal pathogens and viruses. We utilize Fusarium wilt race 1 and Aphanomyces root rot nurseries at the Spillman Research Farm to screen breeding lines and segregating populations for resistance to these pathogens. We screen for resistance to Pea Seed-borne Mosaic Virus, Bean Leaf Roll Virus, Pea Enation Mosaic Virus and Powdery Mildew at the Oregon State University Vegetable Research Farm in Corvallis. 'Hampton,' a recent release from the breeding program, is a high yielding spring green pea with resistance to several virus diseases as well as soil-borne and foliar fungal pathogens.

Lentils have also been produced in eastern Washington since the early 1920-1930's. The spring lentil breeding program addresses needs in each of six market classes: Turkish Red, Spanish Brown, Small Green (Eston), Medium Green (Richlea), Large Green (Laird) and Zero Tannin. The objectives of the lentil breeding programs include improving plant height and standability, yield and improved disease resistance. Lentils are also screened for resistance to Aphanomyces root rot at Spillman and for resistance to Pea Enation Mosaic and Pea Seed-borne Mosaic Viruses at the OSU Research Farm. Recent releases from the breeding program include 'Avondale', a medium green lentil with high yields and resistance to Stemphylium Blight. In 2017 the breeding line2273E will be released. This, as yet un-named, small green lentil has been extensively evaluated in WA, ID, MT and ND. It typically matures early and out-yields 'Eston' by 20%.

The lentil and pea breeding programs also have strong components investigating tolerance to drought and heat stress. We have utilized high-throughput phenotyping in controlled conditions to screen lentil germplasm for heat tolerance during flowering and are currently mapping genes associated with that tolerance.

The autumn-sown pea and lentil breeding programs have become a strong, integral part of the cool season food legume breeding program. The objectives of these two programs are to develop high value, feed and food quality pulses with very high levels of cold tolerance and disease resistance. Autumn-sown pulses will be beneficial to farmers as field work can be shifted to the autumn, planting will not be delayed by cool, wet springs and yields will exceed those of spring planted legumes. We also have an autumn-sown pea breeding program focused on developing varieties to be used as cover crops in organic and/or sustainable farming systems throughout North America. Recently released winter pea breeding lines and cultivars include PS03101269, 'Lynx' and 'Lakota'. Research, partially funded by the Amen Endowment, is currently under way to determine best planting practices with a planting date, depth and seed rate trial at the WSU Dryland Experiment Station.

## Winter Pea: Promising New Crop for Washington's Dryland Wheat-Fallow Region

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The winter wheat-summer fallow (WW-SF) rotation has been practiced by the vast majority of famers in the low-precipitation (< 12 inch annual) rainfed cropping region of east-central Washington and north-central Oregon for 140 years. Until recently, alternative crops (i.e., those other than WW) so far tested have not been as economically viable or stable as WW-SF. A 6-year field study was conducted near Ritzville, WA (11.5 inch avg. annual precipitation) to determine the yield and rotation benefits of winter pea (WP). Two 3-year rotations were evaluated: WP-spring wheat (SW)-SF versus WW-SW-SF. Winter pea yields averaged 2182 lbs/acre versus 73 bu/acre for WW. No fertilizer was applied to WP whereas 50 lbs N and 10 lbs S/acre were applied to WW. Winter pea used significantly less soil water than WW. Over the winter months, a lesser percentage of precipitation was stored in the soil following WP compared to WW because: (i) very little WP residue remained on the soil surface after harvest compared to WW, and (ii) the drier the soil, the more precipitation is stored in the soil over winter. However, soil water content in the spring was still greater following WP versus WW. Soil residual N in the spring (7 months after the harvest of WP and WW) was greater in WP plots despite not applying fertilizer to produce WP. Spring wheat grown after both WP and WW received the

**Winter pea in early May in Ritzville experiment.**

identical quantity of N, P, and S fertilizer each year. Average yield of SW was 34 and 31 bu/ha following WP and WW, respectively (P< 0.01). Adjusted gross economic returns for these two rotation systems were similar. Based partially on the results of this study, numerous farmers in the dry WW-SF region have shown keen interest in WP and acreage planted WP in east-central Washington has grown exponentially since 2013. A full article on this study will be published in the journal *Frontiers in Ecology* later this year. The article provides the first report in the literature of the potential for WP in the typical WW-SF region of the Inland Pacific Northwest.

## Soil Water Dynamics of Winter Pea versus Winter Wheat

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A 6-year field study was conducted near Ritzville, WA (11.5 inch avg. annual precipitation) to determine the yield and rotation benefits of winter pea (WP) (see related article on page 70). Averaged over the years, WP used an average of 1.2 inches less soil water than WW (P<0.001). The majority of this water savings with WP occurred at soils depths below 3.3 feet (Fig. 1) as WP does not root past this depth. These data on soil water use by WP agree closely with those reported in Montana and North Dakota. However, by late March, WP plots had only 0.5 inch more soil water than WW plots because: (i) the greater the surface residue cover, the more water will be stored in the soil (i.e., WP produces little residue compared to WW); and (ii) the drier the soil, the more overwinter precipitation will be stored in the soil.

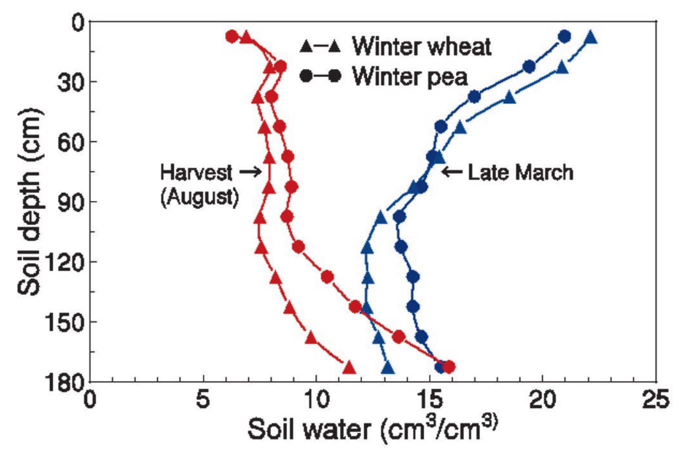

**Figure 1. Soil volumetric water content to a depth of six feet in early August after harvest of winter pea and winter wheat (red lines on left) and overwinter soil water recharge following these two crops measured in March (blue lines on right). Data are averaged over five years.**

The overwinter precipitation storage efficiency (PSE) in the soil averaged 55% and 69% following WP and WW, respectively. Similar overwinter PSE values were reported following spring lentil versus following SW in a 21-year study in Saskatchewan. This increase in overwinter PSE for WW over WP plots occurred within the first 3 feet of the soil profile whereas the relative difference in spatial water distribution at the 3-to 6-ft depths remained about the same for WP and WW plots (Fig. 1). The end result, however, was that when spring wheat was planted in late March, average overwinter soil water content was 11.4 and 10.9 inches following WP and WW, respectively. This extra soil moisture resulted in a significant yield increase in for subsequent spring wheat crop.

## Winter Triticale versus Winter Wheat: Six Years of Grain Yield Data from Ritzville

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We are conducting numerous winter triticale field experiments near Ritzville, Lind, and in the Horse Heaven Hills of Benton County. These experiments involve: (i) early versus late seeding of winter triticale and winter wheat, (ii) seeding rates for late-seeded winter triticale and winter wheat, and (iii) early versus late seeding of numerous promising winter triticale numbered lines. In this short article we will present six years of data from Ritzville.

Beginning in the fall of 2010, winter triticale was incorporated after no-till fallow in the long-term cropping systems experiment on the Ron Jirava farm near Ritzville. Our original plan was to seed winter triticale “late” in mid-October because we felt it unlikely that adequate seed-zone moisture would be present most years in no-till fallow for early seeding (first week of September). However, do to a wide assortment of weather events, we have been able to seed early into no-till fallow at Ritzville evert year for the past seven years. We, therefore, have seeded half of each triticale plot early and the other half of the plot late (mid-October). The variety used is ‘TriMark 099. These two triticale seeding dates are compared to early-seeded winter wheat (variety ‘Xerpha’ 2010-2015 and ‘Otto’ beginning in 2016), seeded into undercutter-tilled summer fallow in the first week of September. Seeding rates for early-seeded winter triticale and winter wheat is 50 pounds per acre and for late-seeded winter triticale 90 pounds per acre. Experimental design is a randomized complete block with four replications with both the crop and fallow portions of all treatments present each year. Individual plots are 30 x 500 ft.

Over the past six years, grain yield of early-seeded winter triticale averaged 5,004 lbs/ac (this would be 83 sixty-pound bushels/ac) versus 68 bushels/ac for winter wheat (Fig. 1). Yield of late-seeded winter triticale has averaged 3736 lbs/ac (62 sixty-pound bushels/ac) (Fig. 1). There were no statistically significant differences in grain yield between late-seeded winter triticale and early-seeded winter wheat in any year or averaged over the six years (Fig. 1). Average yield of early-seeded winter triticale was 22% greater than yield of early-seeded winter wheat.

April 12, 2017 grain price at Central Washington Grain Growers in Wilbur is $4.08/bushel for soft white wheat and $104/ton for triticale. Using the 6-year average grain yields from our study, early-seeded winter wheat would have a market value of $277/ac versus $260/ac for early-seeded winter triticale.

Finally, triticale has been officially approved for federal crop insurance in the Pacific Northwest beginning next year. This means that farmers will be able to obtain the same federal safety-net crop insurance that they routinely purchase for their wheat crop.

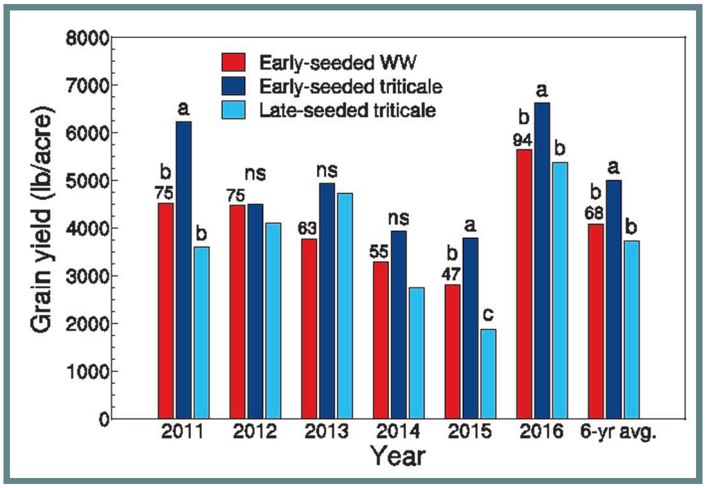

**Figure 1. Grain yield of early– and late-seeded winter triticale planted into no-till summer fallow versus early-seeded soft white winter wheat (WW) in the long-term cropping systems experiment near Ritzville, WA . Within-year and 6-year average grain yields followed by a different letter are significantly different at the 5% probability level. Numbers over the wheat yield bars indicate bushels per acre.**

Photo by OSU EESC

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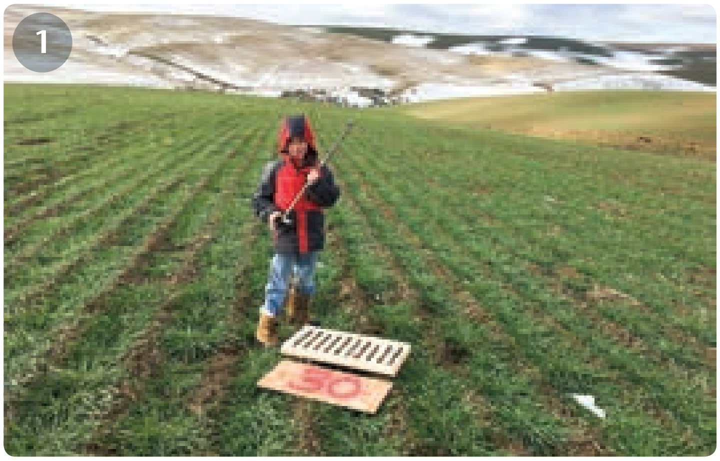

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