OREGON WHEAT COMMISSION

Research Progress Reports
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2019-2020 Oregon Wheat Commission Progress Report

Title: Developing improved winter wheat cultivars for Oregon

Principal Investigator: Dr. Robert Zemetra – OSU Corvallis

Cooperators: Dr. Chris Mundt – OSU Corvallis – plant pathology
Dr. Andrew Ross – OSU Corvallis – cereal chemistry
Dr. Andrew Hulting – OSU Corvallis – weed science
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Dr. Christina Hagerty – OSU Pendleton – plant pathology
Dr. Larry Lutcher – OSU Morrow County – cereal extension
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Dr. Craig Morris – USDA-ARS Pullman, WA – cereal chemistry

Funding History: 2018-2019: $178,343
2019-2020: $192,800

Abstract:

The OSU Wheat Breeding and Genetics Program has four primary breeding projects with several sub-projects nestled within a primary project. The four breeding projects are based on market class; soft white winter wheat, hard white winter wheat, hard red winter wheat and winter club wheat. The hard red winter breeding project and the winter club project were started in 2013 and 2016, respectively, to address the needs of Oregon wheat producers. The goal of the breeding program is to develop new wheat cultivars with improved agronomic performance and superior end-use quality in all four winter wheat market classes.

Objective: Develop and release improved winter wheat cultivars

a. Develop new soft white, hard white, hard red winter and winter club wheat cultivars adapted to the high and low rainfall wheat growing regions of eastern and western Oregon with superior biotic and abiotic resistance/tolerance to minimize production risks and increase economic returns to growers.
b. Increase demand and marketability of PNW wheat through development of soft and hard winter wheat cultivars with superior end-use quality.
c. Identify and incorporate important genes for disease resistance, adaptation, and end-use quality using molecular marker technologies and biochemical analyses.
d. Develop herbicide resistant wheat cultivars as tools for Oregon wheat producers in the management of grassy weeds.

Procedures and Accomplishments:

The OSU breeding program utilizes classical breeding approaches with molecular breeding to develop wheat varieties in four market classes with improved disease resistance, high yield potential and superior end-use quality. The breeding program uses a system that integrates work in the laboratory, greenhouse and field to optimize productivity of the program.

Soft White Winter Wheat (SWW): The soft white winter (SWW) wheat breeding project is the primary project of the breeding program. Recent releases include Norwest Duet and Norwest Tandem that were co-developed with Limagrain Cereal Seed. Both are finding homes in growers' fields in Oregon and Washington. A new release from the breeding program is 'Nixon', a soft white winter wheat, a Tubbs x Skiles cross with the best features of both varieties. Nixon has good stripe rust resistance, strawbreaker foot rot resistance conferred by the *Pch1* gene, and good yield potential. In addition to breeding SWW varieties with broad adaptability, some regions in Oregon need specific traits included in wheat varieties. The program addresses these needs through sub-projects within a market class. These sub-projects include breeding for herbicide resistance, resistance to unique diseases, and for abiotic stress tolerance such as for drought or heat stress.

<u>Herbicide Resistant Wheat (SWW CF)</u>: To address control of grassy weeds such as downy brome (cheat grass) and jointed goatgrass the breeding program has been developing wheat cultivars resistant to the herbicide Beyond. The breeding program released 2 two-gene Clearfield SWW cultivars in 2019, 'OR2X2 CL+' and 'Appleby CL+'. The OR2X2 CL+ name comes from the fact it carries two genes for Beyond resistance and two genes (*Pch1* and *Pch2*) for strawbreaker foot rot resistance. The disease resistance package for this variety is unique among two-gene Clearfield varieties. OR2X2 CL+ has excellent stripe rust resistance as well and is targeted at the higher rainfall regions of the state where strawbreaker foot rot could be an issue. Appleby CL+ is a two-gene Clearfield variety that has an earlier flowering date and is targeted at the lower rainfall regions of the state where late season heat stress may cause reduced test weight and yield in late flowering varieties. Both varieties have been tested by the Pacific Northwest Wheat Quality Council and have been found to have acceptable to good end-use quality.

<u>Soil-Borne Wheat Mosaic Virus Resistant Wheat (SWW sbWMV)</u>: In irrigated and higher rainfall regions of the state there has been a new disease slowing expanding in acreage, sbWMV. Spread by a water mold in the soil, once the disease is in the field it can't be chemically controlled so the only control is resistant varieties. The breeding program has introgressed the resistance gene into three market classes of wheat (SWW, HWW and HRW) and currently is testing advanced lines of all three market classes for sbWMV resistance in the field.

Low Rainfall Adapted Wheat (SWW LR): A request was made in 2016 to the OSU Wheat Breeding Program by wheat growers in the low rainfall regions of Oregon to target development of varieties with traits better suited to produce in lower precipitation growing regions. These traits would include earlier flowering for drought and heat avoidance and taller varieties to allow for adequate height in years when low moisture stunts growth. The advanced line, OR2130755, is under consideration as the first release from the SWW LR sub-project. OR2130755 is a tall semi-dwarf with an early to intermediate heading date, two genes for strawbreaker foot rot resistance, good stripe rust resistance, good straw strength, and good yield potential in low to intermediate rainfall zones. OR2130755 was tested by the Pacific Northwest Wheat Quality Council and was been found to have good end-use quality, similar to slightly better than Norwest Duet.

Hard White Winter Wheat (HWW): The OSU Wheat Breeding Program has had a HWW breeding project for over twenty years. The challenge over those years has been developing varieties with the stripe rust resistance, agronomic performance and end-use quality needed for HWW. The breeding program has succeeded in combining all three traits in and has recently recommended two HWW lines for release, 'Irv' and 'Millie'. Both have good stripe rust resistance, good to excellent yield potential and good end-use quality. The program is working with Bailey Jenks, wheat outreach coordinator, to create a market for HWW in the Pacific Northwest.

Hard Red Winter Wheat (HRW): Some Oregon wheat growers have looked to diversify their wheat production by growing hard red winter wheat. One challenge for these producers, especially those trying to grow HRW under high rainfall or irrigated conditions, is finding HRW varieties with the straw strength and height that can be produced without lodging. In 2013, the wheat breeding program started a HRW project to develop varieties that work better for Oregon growers. Four HRW advanced lines are currently in statewide extension testing.

Winter Club Wheat: In 2016, the breeding program initiated a winter club wheat breeding project at the request of Oregon wheat growers who wanted a club wheat that was adapted to Oregon growing conditions. Desired traits included; earlier flowering, reduced height and awns. In addition, any club wheat developed would have to have the seed characteristics and end-use quality expected from a club wheat. Currently there is one wither club advanced line, OR5170022 in statewide extension testing and 15 advanced lines in elite testing.

Impacts:

The availability of new wheat varieties for the OSU wheat breeding program allows the Oregon wheat producers to have varieties that are better adapted to their growing conditions resulting in improved profitability.

Relation to other Research:

The wheat breeding program interacts with the cereal plant pathology projects of Dr. Chris Mundt and Dr. Christina Hagerty and assists their projects by providing germplasm and equipment when needed. The program works closely with the cereal extension projects of Dr. Ryan Graebner and Dr. Larry Lutcher by working together at field research sites and providing germplasm for field trials when needed. The breeding program also works in conjunction with Dr. Andrew Ross's cereal chemistry program providing germplasm for end-use quality testing when requested.

2019-2020 Oregon Wheat Commission Progress Report

Title: Gene Introgression and Gene Editing for Developing New and Improved Oregon State University Wheat Varieties

Principal Investigator: Dr. Robert Zemetra – OSU Corvallis

Cooperators: Dr. Kali Brandt – OSU Corvallis – molecular biotechnology
Dr. Chris Mundt – OSU Corvallis – disease screening
Dr. Andrew Ross – OSU Corvallis – end-use quality screening

Funding History: 2018-2019: $74,016
2019-2020: $107,233

Abstract:

The OSU Wheat Genetics Program was integrated into the OSU Wheat Breeding Program in 2015 due to retirement of Dr. Jeff Leonard and to better integrate gene introgression of disease resistant and end-use quality traits into advanced breeding lines and new varieties in the wheat breeding program. Bringing genes into Oregon State University (OSU) wheat germplasm for herbicide tolerance, biotic / abiotic resistance and end-use quality can be challenging depending on the source of the gene(s). The problem is that if the genes are in genetic backgrounds that are not adapted to Oregon growing environments or are in the wrong market class of wheat; there will be many undesirable genes/traits also transferred that will need to be eliminated. To speed the transfer or introgression of the desired traits/genes it is possible to use molecular markers to advance only lines carrying the desired genes and do rapid generation cycling in the greenhouse to shorten the time it takes to develop true breeding lines. The funded research is focused in three areas.

Objectives:

1) Develop winter wheat breeding lines of soft white (SWW), hard red (HRW), hard white (HWW) and club wheat carrying genes for improved disease resistance and low polyphenol oxidase (PPO) reaction.

2) Continue a two-year project to transfer of genes for CoAXium herbicide resistance into SWW, HRW, HWW and club winter wheat.

3) Initiate a two-year project to determine the feasibility of using CRISPR-Cas9 gene-editing to modify OSU wheat varieties and breeding lines for improved end-use quality.

Procedures and Accomplishments:

Gene introgression for improved disease resistance and low polyphenol oxidase (PPO) reaction**:** Crosses have been made to combine two major stripe rust resistance genes (*Yr5* and *Yr15*) into PNW adapted breeding lines in the winter greenhouse crossing program. As of April 15, 2020, the majority of the crosses to combine the two resistance genes have been made targeting 50 seeds per combination. Top and backcrossing is being done to transfer disease resistance genes for barley yellow dwarf virus and soil borne wheat mosaic virus from Midwestern germplasm. Top and backcrossing is also being done to transfer agronomic and quality traits from breeding lines from Colorado and Utah. Crossing continues to integrate a null gene for polyphenol oxidase (PPO) reaction into soft white winter and hard red winter cultivars and advanced breeding lines. Field testing of early to mid-generation hard white winter breeding lines carrying the null gene for PPO reaction has started.

<u>Introgression of CoAXium herbicide resistance into SWW, HRW, HWW and club winter wheat cultivars and breeding lines</u>**:** The CoAXium herbicide resistance introgression project is in its second year of a two-year project to rapidly transfer two herbicide resistance genes into four market classes of wheat currently being bred by the OSU wheat breeding program. Based on a graduate student's research, the breeding program is concentrating on transferring the resistance genes on the A and D genomes since the A/D combination showed the greatest level of herbicide resistance.

The HRWW introgression effort is the most advanced due to the donor lines from Colorado State University being HRWW. Four-way and three-way combinations with the A/D resistance were planted as headrows in the field at Hyslop in late fall, 2019 and backcross combinations with the A/D resistance were planted as head rows in the same field in mid-winter, 2020. All head rows emerged and were sprayed April 14, 2020 with 1.5X Agressor herbicide to screen for herbicide resistance. The 1.5X rate is based on the graduate student's research that at 1.5X rate only the plants / lines homozygous for the two resistance genes would show no or minimal injury. Later in the spring the head rows will be screened for stripe rust resistance based on natural infection.

The SWWW introgression work utilized two approaches for introgressing the resistance genes from the A and D genomes into OSU cultivars and advanced breeding lines. The first was using a spring wheat 'bridge' to more rapidly develop resistant lines with the desired disease resistance and end-use quality traits needed for PNW SWWW cultivars. An added benefit of this approach was it overcame hybrid necrosis that limited the number of SWWW breeding lines that could have the herbicide resistance genes introgressed into their genetic background by conventional breeding approaches. The second approach was to do conventional backcross breeding to transfer the resistance genes. While successful, it was limited to just two cultivars, Norwest Tandem and Nixon due to hybrid necrosis. Both approaches have been successful and head rows of SWWW carrying the A/D resistant gene combination will be planted late fall 2020 for initial field-testing.

The HWWW introgression work utilized just conventional backcross breeding to introgress the herbicide resistance genes. Work has progressed with initial field-testing of head rows targeted for the 2021/2022 growing season.

The club winter wheat introgression effort initially involved the double approach (spring wheat bridge and conventional backcrossing) like the SWWW work but the conventional backcrossing approach was dropped because all cross combinations died in the F_1 generation due to hybrid necrosis. The spring wheat bridge approach was successful and club wheat lines carrying the A/D resistance genes are being crossed back to winter club lines to convert the resistant lines back to winter habit. Planting of head rows may occur in winter 2021 if all goes well with the conversion back to winter growth habit.

Determining the feasibility of using CRISPR-Cas9 gene-editing to modify OSU wheat varieties and breeding lines for improved end-use quality**:** Research was initiated to develop a protocol for the use of gene editing to improve the end-use quality of winter wheat cultivars and advanced breeding lines in the OSU breeding program. The approach uses a technique that does not involve DNA in the modification of the wheat genes making the modified lines not transgenic in the conventional sense. Target genes include a gene to reduce pre-harvest sprouting, a gene to reduce the level of acrylamide in baked products, and a gene to reduce PPO reaction in wheat. To date we have successfully tested our target RNA sequences for the acrylamide gene and the pre-harvest sprout gene for CRISPR-Cas9 gene editing *in vitro* on wheat DNA and *in vivo* on wheat protoplasts. Work has been initiated in optimizing a pollen transformation system using electroporation to modify the targeted wheat genes in pollen as a way to introduce the modified gene in to wheat to produce wheat seeds heterozygous for the modified gene. This is the first year of a two-year gene-editing project.

Impacts:

This research will provide Oregon wheat producers with new varieties with improved disease resistance, herbicide resistance and end-use quality. The combination and transfer of major stripe rust resistance genes into Oregon wheat varieties will result in less inputs costs by reducing cost associated with stripe rust control. Reducing the PPO reaction in all classes of wheat bred by the OSU wheat breeding program could lead to an expanded market for OSU wheat in areas of the world where PPO reaction can impact the quality of their wheat products. Introgression of a new source of herbicide resistance will give Oregon wheat producers a new tool for controlling grassy weeds in their fields. The work of gene-editing, if successful, would put the OSU wheat breeding and genetics program on the cutting-edge of research for rapidly modifying traits in wheat that would benefit the OSU wheat producers and OSU wheat consumers.

Relation to Other Research:

The research complements the work done on cultivar development by moving new genes into breeding lines that are better adapted to Oregon growing conditions. This makes it possible to more rapidly breed OSU wheat varieties with improved productivity, profitability and marketability. The wheat breeding effort is funded in a separate research project funded by the Oregon Wheat Commission. The disease research portion of this research is done in coordination with Dr. Chris Mundt and the end-use quality work is done in coordination with Dr. Andrew Ross.

Progress Report for the Agricultural Research Foundation
Oregon Wheat Commission

Title:	Oregon Barley Variety Development and Deployment
Investigator(s):	Patrick Hayes. Dept. of Crop and Soil Science, Oregon State University, Corvallis, Oregon 97331
Cooperator(s):	Andrew Ross; Ryan Graebner; Caio Brunharo; Daniela Carrijo; All Dept. of Crop and Soil Science, Oregon State University

List OWC support amount for this project and for the previous two years if applicable.

This project (2020): $30,000; 2019: $30,000; 2018: $35,000

Abstract:
We proposed to develop, test, and deploy barley varieties for Oregon. The major focus of this year's project was on imazamox tolerant varieties. We transferred imazamox tolerance from the WSU variety "Survivor" and sister line 07MWA-201, to Oregon-adapted varieties, which are now being evaluated in the field. We continued development and statewide testing of malting, feed, and food varieties with an emphasis on facultative and winter growth habit malting and feed types. Per previous years, we continued with our program of strategic variety testing in representative Oregon environments. We expanded our focus on on-farm strip plots of available or near-available varieties in order to generate sufficient grain for product assessment and to generate data under grower-relevant production scales. We leveraged funding from the USDA competitive grants program to develop multi-use naked varieties.

Objective(s)

1. Accelerate the development of imazamox herbicide-tolerant varieties adapted to Oregon (Successor Project).
2. Develop, release, and demonstrate the utility of facultative and winter malting varieties adapted to Oregon and elsewhere in the USA.
3. Spring-planted spring and facultative variety development and release
4. Create and deploy naked multi-use barley germplasm.

Procedures

Objective 1

1. Crosses were made of Oregon adapted barley (DH130910 and RCSL124) and imazamox tolerant barley (Survivor and 07MWA-201) in 2018.
2. In 2019, 411 doubled haploids were produced, grown in the greenhouse, and harvested.

3. Leaf tissue was collected from all 411 lines and sent to the USDA North Central Small Grains Genotyping Lab for genotyping on the 50K Illumina Infinium iSelect SNP chip.
4. The 411 lines were planted in the greenhouse and sprayed with imazamox at the 2-leaf stage to identify lines having imazamox tolerance.
5. 171 lines were found to be tolerant to imazamox and were sent to New Zealand for seed increase over the winter.
6. In March of 2020, the 171 tolerant lines, in addition to the four parents, were planted in two field trials (Corvallis and Pendleton) for agronomic and quality trait assessments.

Objectives 2-4
The same general procedures are used to meet objectives 2, 3 and 4:

1. Crosses are made in the field or greenhouse.
2. Doubled haploids are generated in the lab, increased in the greenhouse, and advanced to field trials/seed increase.
3. Field trials are conducted in Oregon, across the USA, and throughout the world following recommended practices for each location and using standard planting, maintenance, harvest, and grain processing procedures.
4. Malting and quality analysis is accomplished in collaboration with the USDA Cereal Crops Research Unit (CCRU), at the OSU Malthouse, and/or in collaboration with industry cooperators (Great Western Malting, Rahr Malting, and the Hartwick College Center for Craft Food and Beverage).
5. Food quality analyses are conducted in collaboration with Dr. Andrew Ross, OSU.
6. Brewing trials are conducted in collaboration with industry collaborators and/or academic partners.
7. Sensory analyses are conducted with academic or industry cooperators.
8. Data are analyzed using standard statistical methods.
9. Project profiles, bulletins, and data are posted at barleyworld.org.
10. Papers and book chapters are published in peer-reviewed outlets.
11. Financial support is obtained from the Oregon State University College of Agricultural Sciences, grants from growers, industry, and federal agencies, and specific cooperative agreements with the USDA Agricultural Research Service (ARS).
    a. The winter/facultative 2-row malting breeding and testing program is supported by the American Malting Barley Association (AMBA), Brewers Association, Great Western Malting, and the Oregon Wheat Commission.
    b. The spring 2-row program is supported by the Brewers Association and the Oregon Wheat Commission.
    c. The naked barley program is supported by the USDA-NIFA-Organic Agriculture Research and Extension Initiative (OREI) competitive grants program and the Oregon Wheat Commission.

Report of Accomplishments:

Objective 1 – Successor project

- In a period of two years, crosses were made, doubled haploid lines were developed and genotyped, and tolerant lines were identified and are now being assessed for agronomic and quality traits in field trials.

Objective 2 – Facultative and winter malting barley

Research Trials

- Breeding program trials were planted in the fall of 2018 and 2019. 2018 plantings were harvested in 2019. Harvest of trials planted in 2019 is planned to begin July 1, 2020. For trial lists and locations please see https://barleyworld.org/breeding-genetics/variety-development-and-oregon-brand
- The "Romp of Otters" (doubled haploids derived from crosses with Maris Otter, an iconic British winter variety with notable flavor) were malted in the Custom Laboratory Products (CLP) small-scale malting unit and increased for mini-malting, brewing, and sensory analysis (2019 crop). Larger-scale malting in the mini-malter is completed; brewing in collaboration with Deschutes Brewery is scheduled.

Pre-commercial trials/American Malting Barley Association Pilot Scale trials

  - Pilot Program status is summarized in Table 1.
  - Seed increase and assessment blocks of current and prospective submissions were planted in fall 2018 and 2019 in OR and ID.
    - These included DH130910 and DH140963.

Variety release:

- Lightning (tested as DH130910) is proposed for release in spring, 2020.
  - This selection has excellent disease resistance and agronomic features and it passed its first year of AMBA Pilot testing.
  - There is ongoing Foundation Seed Production in cooperation with Washington State Crop Improvement (WSCIA), Idaho Crop Improvement Association and the New York Seed Improvement Project (2020 crop).
  - The variety is proposed for release under non-exclusive license with no PVP.

Objective 3 – Spring barley

Research trials

- Oregon Promise
  - This Flavor Project progressed to selection of the top three doubled haploids out of 200.
  - Using Oregon-grown grain, selections were malted at OSU and brewed by Deschutes Brewing. Copeland was used as the check. The resulting beers were used for sensory analysis at six breweries and by trained and consumer panels at OSU. The same beers underwent metabolomics analysis at Colorado State University.

- The beer made from one of the selections – DH120285 – was rated highest by the consumer panel and unique aroma compounds were identified per metabolomics studies.
- The selection will be proposed for release in 2020 as Oregon Promise.
- The variety is proposed for release under non-exclusive license with no PVP.

Objective 4 – Multi-use naked barley

Research trials

- The project involves five states (OR, WA, MN, WI, and NY). At cooperating locations, there were fall-planted and spring-planted regional yield trials, ~ 1 acre seed increases, and assessment of a diversity panel designed for a genome wide association study (GWAS). All experiments were grown on certified organic land. Details on the project are available at http://barleyworld.org/orei-project.
  - In Oregon, the research trials were planted at the Lewis Brown Farm (near Corvallis, OR) and on-farm trials were grown at the Simmons Farm (near Salem, OR, the Olsen Farm (near Adair Village, OR), and the Blanchard Farm (near Grants Pass, OR).

Variety maintenance and release:

- Buck, a naked 6-row winter OSU public variety, is in Foundation seed increase with WSCIA (2020 harvest).
- 10.1492, a naked 6-row winter is in seed increase with WSCIA (2020 planting).

Impacts:

Realization of the four objectives is intended to meet the Land Grant University missions of (1) stimulating economic development, (2) contributing to the fundamental body of knowledge, and (3) enhancing education opportunities. Per economic opportunity, the goal is to have varieties available when Oregon growers want/need them. The imazamox-tolerance project is intended to allow growers to resume using barley in their rotations in cases where there are herbicide residues. The focus on facultative growth habit is intended to provide a tool for meeting the challenges of climate change. The focus on flavor is intended to provide an additional value-added dimension to malting barley production. The multi-use naked barley project is intended to lay the groundwork for providing multiple markets for the same variety and to assist in meeting human health challenges and provide organic growers with varieties that will do well in their production systems. Fundamental contributions to the body of knowledge are generated during the course of our breeding efforts, and via special research projects (summarized in the "Relation to Other Research" section). These contributions are documented in our publication record, available at http://barleyworld.org/news-and-publications. We use barley in formal and informal educational activities. These include partnering with schools to use barley to increase awareness of agriculture, science, and nutrition (http://barleyworld.org/orei-project). We provide the Oregon Wolfe Barley population as an international resource for genetics research and teaching (http://barleyworld.org/owb). Informally, we engage in numerous outreach activities featuring barley foods and beverages – examples being the Variety Showcase (https://www.culinarybreedingnetwork.com/events/) and the Cascadia Grains Conference (https://cascadiagrains.com/).

Other Research:

In addition to the four objectives outlined in the preceding section, we have "upstream" research on the genetics of resistance to abiotic and biotic stresses, and the genetic basis of barley contributions to beer flavor. These areas of endeavor are documented at www.barleyworld.org

- Low temperature tolerance
- Resistance to stripe rust
- Resistance to UG-99 (TTKSK) stem rust
- Development of germplasm resistant to Fusarium Head Blight
- Barley flavor

Table 1. Descriptors and status of OSU germplasm in the AMBA Pilot Program.

Selection	Pedigree	Growth Habit	EPH	AMBA Status	Regional Trial Submissions
DH120304	Maris Otter/Full Pint	Winter	Producer	Eligible for Plant Scale Testing	WMBT 2017-18, 2018-19
DH130910	TC6W265/29494_2991	Facultative	Producer	Pilot Submission 2019 Crop (Second Year)	WMBT 2016-17, 2017-18, 2018-19, 2019-20
DH140088	Violetta/Charles//Full Pint	Facultative	Non-Producer	Pilot Submission 2019 Crop (Second Year)	WMBT 2017-18, 2018-19, 2019-20
DH140963	04_028_36/Archer	Winter	-	Pilot Submission 2019 Crop (First Year)	WBGN 2017-18; WMBT 2018-19, 2019-20
DH141132	Violetta/Archer	Winter	-	Pilot Submission 2019 Crop (First Year)	WBGN 2018-19; WMBT 2019-20
DH141222	10.1044/Violetta	Winter	-	Potential Pilot Submission 2020 Crop	-
DH141225	10.1044/04_028_36	Winter	-	Potential Pilot Submission 2020 Crop	-

Title: Wheat and Spring Barley Variety Testing for Oregon (Final Report)

Investigator(s): Ryan Graebner, Columbia Basin Agricultural Research Center

Cooperator(s): Robert Zemetra, Crop and Soil Science Department, OSU, Corvallis

Andrew Ross, Crop and Soil Science Department, OSU, Corvallis

Chris Mundt, Botany and Plant Pathology Department, OSU, Corvallis

Funding History: 2016 – 2017 - $92,100
2017 – 2018 - $155,000
2018 - 2019 $152,205

Abstract:

The Oregon statewide variety testing program provides growers with performance information on commonly grown and newly released wheat and spring barley varieties from the public and private breeding programs. Wheat varieties are split into five categories (Oregon Soft Winter Elite Yield Trial or OWEYT; Hard Winter Elite Yield Trial or HWEYT; Clearfield Winter Elite Yield trial or CWEYT; Oregon Soft Spring Elite Yield Trial or OSSYT; and Oregon Hard Spring Elite Yield Trials or OHSYT) for evaluation. Spring barley varieties are evaluated in the Oregon Spring Barley Variety Trial (OSBVT). In the 2018-19 season, the variety testing program 20 winter wheat, 7 spring wheat, and 6 spring barley locations throughout Oregon, eastern Washington, and northern California. The northern California trials are done in collaboration with the California extension program. The eastern Washington trials are done in collaboration with the Washington State University variety trial program and Northwest Grain Growers. Trial locations are chosen to capture a range of environmental conditions and/or cropping systems (such as no-till) in the wheat production areas of Oregon. Trial results are reported through email alerts, web publications, grower meeting, crop tours, and field days.

Objective(s):

Evaluate the performance of commonly grown varieties, new varieties, variety blends, and variety candidates from the regions wheat and spring barley breeding programs in the major wheat and spring barley-producing areas of Oregon. Provide growers with up-to-date information on variety performance, adaptation, and disease resistance.

Procedures:

Commonly grown varieties, new varieties, and variety candidates from the PNW wheat breeding programs are being evaluated in the OSU statewide variety trials. Wheat varieties are split into categories based on wheat class and winter/spring type for evaluation. Soft white winter wheat varieties and lines are being evaluated at 20 locations throughout Oregon, eastern Washington, and northern California in the Oregon Winter Elite Yield Trials (OWEYT). Hard winter wheat varieties and lines are evaluated at 15 locations throughout Oregon and eastern Washington in the Hard Winter Elite Yield Trials (HWEYT). Spring wheat varieties and variety candidates are split into soft and hard classes and evaluated at seven locations throughout Oregon and northern California in the Oregon Soft Spring Elite Yield Trials (OSSYT) and the Oregon Hard Spring Elite Yield Trials (OHSYT). There are 55 entries in the OWEYT, 25 entries in the HWEYT, 17 entries in the OSSYT, 30 entries in the OHSYT, and 15 entries in the Oregon Spring Barley Variety Trial (OSBVT). All trials have four replications. Trial locations are listed in Table 1. The OSU statewide variety trials are co-located with several OSU wheat breeding trials, OSU cereal extension agronomic trials, and Chris Mundt's disease screening nurseries to best utilize our personnel, equipment, and monetary resources to achieve the goals of each program.

Table 1. Proposed variety trial locations and trials.

Location	Trials
Condon	OWEYT, HWEYT
Dayton, WA (collaborative)	OWEYT, HWEYT
Dufur (not in original proposal)	OWEYT, HWEYT
Eureka, WA (collaborative)	OWEYT, HWEYT
Hermiston	OWEYT, HWEYT
Klamath Falls	OWEYT, OSSYT, OHSYT, OSBVT
La Grande	OWEYT, HWEYT
Lexington	OWEYT, HWEYT
Madras	OWEYT, OSSYT, OHSYT
Moro- CBARC	OWEYT, HWEYT
Moro-Kaseberg	OWEYT, HWEYT
Morrow County, Echo	OSSYT, OHSYT, OSBVT
North Willamette Valley	OWEYT
Northern California 1 (Tulelake)	OWEYT, OSSYT, OHSYT
Northern California 2 (Montague)	OWEYT
Ontario (not in original proposal)	OWEYT, HWEYT
Pendleton-CBARC	OSSYT, OHSYT, OSBVT, OWEYT, HWEYT
Pomeroy, WA	OWEYT, HWEYT
South Sherman County (New)	OWEYT, HWEYT, OSSYT, OHSYT, OSBVT
South Willamette Valley (Hyslop)	OWEYT, HWEYT, OSSYT, OHSYT, OSBVT
Walla Walla, WA (collaborative)	OWEYT, HWEYT

Report of Accomplishments:

In summer 2019, research trials for the 2018-2019 grant period were harvested, grain was analyzed, and reports were generated to describe the performance of varieties in each variety testing locations. In total, 49 reports detailing performance of varieties in a variety class for a specific location were released, along with six reports containing regional averages, and three reports containing disease data. Nine reports were not released, due to weed pressure, planting errors, and management issues. In addition to providing additional data for established cereal varieties, this work has helped to give attention to several promising new varieties, including Appleby CL+, Stingray CL+, and LCS Shine. Wheat samples from trials funded by the 2018-2019 grant period were sent to the Western Wheat Quality Lab and the OSU wheat breeding program to determine the end-use quality of the grain.

Impacts:

Because cereal varieties are typically entered into these trials before they are released, we are often able to accumulate 1-3 years of data detailing their agronomic performance before they are available to growers. Because top varieties often differ in yield by 10%, a conservative estimate of the value of these trials for determining the best varieties is a 1% increase in Oregon wheat production (approximately $3 million in 2018). Similarly, disease data from these trials allows growers to select varieties that are resistant to major diseases, which protects yield in the case of major epidemics, and reduces the number of fungicide applications needed for a successful crop. By working with the Western Wheat Quality Lab to determine the end-use quality of wheat varieties, we are able to ensure the continued high quality of wheat grown in Oregon and Washington, protecting overseas markets and improving the quality of products for consumers. Finally, these trials provide both a strong incentive for cereal breeders to produce the best possible varieties for Oregon, and a venue to test which of their experimental lines has the greatest potential in the state.

Relation to Other Research:

This project complements current research efforts and be conducted through collaboration with the OSU Wheat Breeding Program, the OSU Wheat Quality Improvement Program, Chris Mundt's plant pathology program, the Western Wheat Quality Laboratory, the WSU variety testing program, Oregon's agricultural experiment stations, and local extension faculty.

Title: Wheat and Spring Barley Variety Testing for Oregon (Progress Report)

Investigator(s): Ryan Graebner, Columbia Basin Agricultural Research Center

Cooperator(s): Robert Zemetra, Crop and Soil Science Department, OSU, Corvallis

Andrew Ross, Crop and Soil Science Department, OSU, Corvallis

Chris Mundt, Botany and Plant Pathology Department, OSU, Corvallis

Funding History: 2017 - 2018 - $155,000
2018 - 2019 - $152,205
2019 – 2020 - $144,100

Abstract:

The Oregon statewide variety testing program provides growers with performance information on commonly grown and newly released wheat and barley varieties from the public and private breeding programs. Wheat varieties are split into four categories for evaluation (Oregon Soft Winter Elite Yield Trial or OWEYT; Hard Winter Elite Yield Trial or HWEYT; Oregon Soft Spring Elite Yield Trial or OSSYT; and Oregon Hard Spring Elite Yield Trials or OHSYT). Barley varieties are evaluated in the Oregon Spring Barley Variety Trial (OSBVT) and the Oregon Winter Barley Variety Trial (OWBVT). In 2019-20, the variety testing program is proposing 18 winter wheat, 7 spring wheat, 3 winter barley, and 6 spring barley locations throughout Oregon, eastern Washington, and northern California. The Klamath Falls and Tulelake trials are conducted in collaboration with the Klamath Basin Research and Extension Center (KBREC) and the Intermountain Research and Extension Center (IREC), while the Walla Walla and Eureka trials are conducted in collaboration with the Washington State University variety testing program and Northwest Grain Growers. Trial locations are chosen in an attempt to provide relevant variety performance data for all major Oregon wheat and barley growing regions. Trial results are reported through email alerts, web publications, grower meeting, crop tours, and field days.

Objective(s):

Evaluate the performance of commonly grown varieties, new varieties, variety blends, and variety candidates from the regions wheat and spring barley breeding programs in the major wheat and spring barley-producing areas of Oregon. Provide growers with up-to-date information on variety performance, adaptation, and disease resistance.

Procedures:

Commonly grown varieties, new varieties, and variety candidates from the PNW wheat breeding programs are being evaluated in the OSU statewide variety trials. Wheat varieties are split into categories based on wheat class and winter/spring type for evaluation. Soft white winter wheat varieties and lines are being evaluated at 18 locations throughout Oregon, eastern Washington, and northern California in the Oregon Winter Elite Yield Trials (OWEYT). Hard winter wheat varieties and lines are evaluated at 14 locations throughout Oregon and eastern

Washington in the Hard Winter Elite Yield Trials (HWEYT).Winter barleys are grown in three locations in Oregon and Northern California in the Oregon Winter Barley Variety Trial (OWBVT). Spring wheat varieties and variety candidates are split into soft and hard classes and evaluated at six locations throughout Oregon and northern California in the Oregon Soft Spring Elite Yield Trials (OSSYT) and the Oregon Hard Spring Elite Yield Trials (OHSYT). Spring barleys are evaluated in five locations in Oregon and Northern California in the Oregon Spring Barley Variety Trial (OSBVT). There are 55 entries in the OWEYT, 30 entries in the HWEYT, 18 entries in the OSSYT, 30 entries in the OHSYT, and 15 entries in the Oregon Spring Barley Variety Trial (OSBVT). All trials have four replications. Trial locations are listed in Table 1. The OSU statewide variety trials are co-located with several OSU wheat breeding trials, OSU cereal extension agronomic trials, and Chris Mundt's disease screening nurseries to best utilize our personnel, equipment, and monetary resources to achieve the goals of each program.

Table 1. Variety trial locations and trials.

Location	Trials
Condon	OWEYT, HWEYT
Dufur	OWEYT
Eureka, WA (collaborative)	OWEYT, HWEYT, CWEYT
Hermiston	OWEYT, HWEYT
Kent	OWEYT, HWEYT, OSSYT, OHSYT, OSBVT
Klamath Falls	OWEYT, OWBVT, OSSYT, OHSYT, OSBVT
La Grande	OWEYT, HWEYT
Lexington	OWEYT, HWEYT
Madras	OWEYT, OSSYT, OHSYT
Moro- CBARC	OWEYT, HWEYT
Moro- Kaseberg	OWEYT, HWEYT
Ione	OSSYT, OHSYT, OSBVT
North Willamette Valley	OWEYT
Ontario	OWEYT, HWEYT
Pendleton-CBARC	OSSYT, OHSYT, OSBVT, OWEYT, HWEYT, OWBVT
Pomeroy, WA	OWEYT, HWEYT
South Willamette Valley	OWEYT
Tulelake	OWEYT, OSSYT, OHSYT, OSBCT
Walla Walla, WA (collaborative)	OWEYT, HWEYT, CWEYT

Report of Accomplishments:

Work from the 2018-2019 grant period is ongoing, and results will not be available until after the plots are harvested in July and August of 2019. For the 2018-2019 season, the HWEYT trial was dropped in Kent and Dufur due to field space constraints, the HWEYT and Protected OWEYT were dropped from South Willamette Valley due to logistical constraints associated with transporting the grain back, and the OSSYT, OSHYT, and OSBVT were dropped from the North Willamette Valley due to COVID-19 travel restrictions. However, the remainder of the trials appear to be growing well, so we expect to have an excellent set of results this year. This work will be followed by future variety trials for the foreseeable future, to ensure that wheat and barley growers in Oregon always have a resource to understand the potential of new cereal varieties in Oregon.

Impacts:

Because cereal varieties are typically entered into these trials before they are released, we are often able to accumulate 1-3 years of data detailing their agronomic performance before they are available to growers. Because top varieties often differ in yield by 10%, a conservative estimate of the value of these trials for determining the best varieties is a 1% increase in Oregon wheat production (approximately $3 million in 2018). Similarly, disease data from these trials allows growers to select varieties that are resistant to major diseases, which protects yield in the case of major epidemics, and reduces the number of fungicide applications needed for a successful crop. By working with the Western Wheat Quality Lab to determine the end-use quality of wheat varieties, we are able to ensure the continued high quality of wheat grown in Oregon and Washington, protecting overseas markets and improving the quality of products for consumers. Finally, these trials provide both a strong incentive for cereal breeders to produce the best possible varieties for Oregon, and a venue to test which of their experimental lines has the greatest potential in the state.

Relation to Other Research:

This project will complement current research efforts and be conducted through collaboration with the OSU Wheat Breeding Program, the OSU Wheat Quality Improvement Program, Chris Mundt's plant pathology program, the Western Wheat Quality Laboratory, the WSU variety testing program, Oregon's agricultural experiment stations, and local extension faculty. Due to COVID-19 travel restrictions, we have played an increased role in managing plots from the OSU Wheat Breeding Program.

Progress Report for the Agricultural Research Foundation
Oregon Wheat Commission 2019-20

TITLE: Oregon State University Cereal Quality Laboratory

PRINCIPAL INVESTIGATORS:
Dr. Andrew S. Ross, **Dr. Teepakorn Kongraksawech:** Crop & Soil Science, Oregon State University (OSU)

COOPERATORS:
Dr. Robert Zemetra, **Dr. Patrick M. Hayes, Dr. Ryan Graebner, Susan Trittinger,** Crop & Soil Science Department, OSU; **Dr. Craig F. Morris, Dr. Alecia Kiszonas, Douglas A. Engle** USDA Western Wheat Quality Laboratory, Pullman WA.

FUNDING HISTORY:

2017-18	$65,000
2018-19	$65,000
2019-20	$65,000
Request 2020-21	**$65,000**

ABSTRACT:
The OSU cereal quality laboratory provides benefit to Oregon grain growers by applying due diligence to the quality of cereal varieties bred at OSU. In 2019-20, quality selections and other support for the wheat breeding program were the primary focus. Testing was focused on early generation screening for kernel hardness, milling performance, dough strength potential, and polyphenol oxidase, applied as appropriate to the relevant wheat classes and breeding nurseries. We continued to apply our faster milling protocol, validated during 2018-19, to screen for soft wheat quality at early generations. We have also implemented, in cooperation with Dr. Zemetra, micro-SDS testing for early generation testing for dough strength potential in the hard wheat nurseries and conduced 500 of those tests in CY 2019. The quality lab has continued to support the variety development work of PhD graduate Susi Trittinger in her transition to post-doc researcher in Dr. Zemetra's group. Her work on mapping genes for pentosan (fiber) composition in soft wheats required over 1400 pentosan analyses to be run through the quality lab in CY 2019. Work of the quality lab has supported the potential release of soft white winter variety candidate OR2130755, targeted for use in low to intermediate rainfall regions in Oregon. End use-quality is good to acceptable, falling between Nixon and Norwest Duet. OR2150755 was submitted to the Pacific Northwest Quality Council for end-use quality evaluation and was found to have similar quality to Norwest Duet indicating it would get a 'Desirable' rating for end-use quality in the preferred variety lists.

PROCEDURES: See Appendix 1

ACCOMPLISHMENTS LISTED BY OBJECTIVE IN ORIGINAL PROPOSALS

Objective 1: *Provide and interpret wheat quality data for the wheat breeding, cereal extension, genetics, and quality programs*. **Outcome:** *Delivered actionable quality data to breeder that resulted in the selection of high-quality lines*.

The quality lab ran approximately 14,000 analyses in CY 2019 which encompasses both the 18-19 and 19-20 funding cycles. Of this total around 10,000 analyses were in the direct service of the wheat breeding program (Table 1). Data is immediately (on a daily basis in the summer) transferred to the wheat breeder for selection purposes.

Work of the quality lab has supported the potential release of soft white winter variety candidate OR2130755, targeted for use in low to intermediate rainfall regions in Oregon. End use-quality is good to acceptable, falling between Nixon and Norwest Duet. OR2150755 was submitted to the Pacific Northwest Quality Council for end-use quality evaluation and was found to have similar quality to Norwest Duet indicating it would get a 'Desirable' rating for end-use quality in the preferred variety lists

Table 1: Numbers of key quality testis for the wheat breeding program in calendar year 2019

Test	Total
Single Kernel Hardness Testing	6400
Micro-milling	660
Micro-SDS	500
Flour NIR	720
Solvent retention capacities	782
Polyphenol oxidase	1100
Arabinoxylans	1440
Falling Number	200

Objective 2: *Maintain appropriate communication with PNW-based and national research partners and the Oregon wheat industry through appropriate travel to scientific, laboratory, and grower meetings, and technical workshops*. **Outcome:** *Maintenance of our network of cereal scientists and technologists that enables us to influence the community in relation to critical issues (e.g. Falling Number, Preferred Variety Lists)*.

In the period covered by this progress report the PIs have travelled to two PNW Wheat Quality Council (WQC) meetings where we presented information on "Falling Number: The Test, Alternatives, Frames of Reference, and Inertia" and led the 1st Falling Number Special Session. The PIs also collaborated with Kali Brandt and Bob Zemetra of OSU, Steve Delwiche (USDA

ARS Beltsville MD), and Camille Steber (USDA ARS Pullman WA) to anchor the 2nd Falling Number workshop with the presentation "LMA vs PHS: Towards field applicable and definitive analytical reference methods".

PNW WQC meetings also allow us to meet face-to-face with WWQL personnel to ratify an have input into the inclusion of new wheat varieties in the quality-based Preferred Variety Lists for the PNW.

PI Ross travelled to the one Cereals and Grains Association Annual meeting in the timeframe. At that meeting the PI was active in the Technical Committees appropriate to OWC funded activities: Soft Wheat Methods, Asian Products, and Oats and Barley.

Objective: *Ancillary and Exploratory projects.* **Outcome***: Assist in progress towards completion of special projects by OSU cereal researchers.*

The quality lab continued to support the work with training, supervision, and data monitoring for the projects to introduce additional strength into our hard wheat germplasm through introgression of a gene ($Bx7^{oe}$), and to map genes for arabinoxylan (fiber/pentosan) composition in the Xerpha x Bobtail mapping population. The latter has required over 1400 pentosan analyses to be run through the quality lab in 2019 alone. The pentosans are critical in determining important processing constraints in, for example, cookie and cracker manufacturing. The work is as yet incomplete, and impacts are not available at this time. Dr. Kongraksawech and Susi test baked over 100 additional doughs to make the final assessment of the efficacy of the $Bx7^{oe}$ gene in improving baking performance.

Dr. Kongraksawech also assisted in an OSU dairy group project, in collaboration with High Desert Milk in Burley, ID. The project was focused on butter performance in croissants and other laminated pastries. For Dr. Kongraksawech's efforts the Cereal Quality Lab was able to get a new dough sheeter funded 50% by the dairy group and to trial and validate our skills in producing laminated pastries. As these are a key soft-wheat product we aim to leverage the new equipment and skills to add a new perspective on soft wheat quality once we can return to the labs.

Publications

-Ross, A.S., 2019. A Shifting Climate for Grains and Flour. Cereal Foods World. 64 (4): https://doi.org/10.1094/CFW-64-5-0050

Reports

-Ross A.S. 2019. Selecting for Quality 2019: What's going on under the hood? Oregon Wheat. October 2019: 27 (5): 16-17.
-Ross A.S. 2018. Selecting for Quality 2018: Falling Number revisited, 30 years on. Oregon Wheat. October 2018: 26 (4): 13-14.

Presentations

-Ross A.S., Brandt K., Kongraksawech T., Zemetra R., Delwiche S., Steber C. 2020. LMA vs PHS: Towards field applicable and definitive analytical reference methods. Forget the symptoms, treat the cause. Cereals and Grains Association Pacific Northwest Section and Pacific Northwest Wheat Quality Council Meeting, Spokane WA, January 2020. Invited
-Ross A.S. Falling Number and SRC demonstrations. Hyslop Farm Field Day. June 2019.
-Ross A.S., 2019. Food Barley: health & wellness and product samples. Lewis Brown Farm Field Day. June 2019. Invited
-Ross A.S. Falling Number: The Test, Alternatives, Frames of Reference, and Inertia. Cereals and Grains Association Pacific Northwest Section and Pacific Northwest Wheat Quality Council Meeting, Portland, OR, January 2019. INVITED
-Ross A.S. The scope and development of enzyme applications in baked goods and other cereal based foods. Cereals and Grains '18. October 2018, London, UK. INVITED.
-Ross A.S. The scope and development of enzyme applications in baked goods and other cereal based foods. Cereals and Grains '18. October 2018, London, UK. INVITED.

Posters
-Daisy Chen, Kellen Ka'imipono Takeharu Kunitomo, Andrew Ross Teepakorn Kongraksawech. Shelf-life of Whole-wheat Bread: Effects of sourdough and sweeteners. OSU Summer Undergrad Research Symposium, Corvallis OR, September 2019.-Trittinger Susanne, Andrew S. Ross, Teepakorn Kongraksawech, and Robert S. Zemetra. 2018. Functional impacts of introgression of $Bx7^{oe}$ glutenins into hard wheat germplasm. 13th International Gluten Workshop, Mexico City, Mexico, March 2018.
-Angel Hammon, Teepakorn Kongraksawech, Douglas Engle, Andrew Ross. Whole-wheat for everyone: predicting the quality of whole-wheat cookies. STEM Leadership Symposium, OSU, Corvallis OR, January 2018.

RELATION TO OTHER RESEARCH
OSU cereal quality research is conducted in collaboration with OSU faculty in Crops, Soils, Extension, and Plant Pathology throughout the state. This project is designed to fully integrate, support, and complement OWC-funded research of Bob Zemetra, Patrick Hayes, Ryan Graebner, Craig Morris, and others. Other collaborations include germplasm development, and genetics research throughout the tri-state region and the U.S., including projects with cereal researchers at the University of Idaho, USDA-ARS, and WSU. These efforts, including projects funded from other sources (USDA NIFA, commercial contracts) that are targeted at improving outcomes for Oregon grain farmers by strengthening the market competitiveness of the SW, HRW, and HWW classes, and seeking avenues to reduce risk or improve crop value for farmers.

APPENDIX 1: Procedures

Objective 1: ***Providing data for breeding programs***. We test selected breeding nurseries chosen by the breeders. In general, locations must meet No 2 or better grade specification for test-weight and have appropriate grain protein content. A strong focus is quality screening of early-generation lines and, as requested by the breeders, other nurseries from the current season (e.g. lines harvested in summer 2019 will be selected or rejected for quality prior to planting in fall 2019).

Objective 2: ***Improving analytical methods***. Samples grown by the breeding and or extension programs are used as raw materials for method development. This maximizes value by leveraging the routine data generated for the breeding program.

Objective 3: ***Maintain appropriate communication with PNW-based and national research partners.*** Procedures here are to take leaderships roles in the scientific societies and the cereals communities that impinge on our research, outreach, and educational roles. This involves travel to off-campus locations, and deliberate action to ensure our visibility and credibility within these societies and communities.

Objective 4: ***Ancillary and Exploratory projects.*** As required we conduct research in collaboration with other OSU researchers or with external researchers to achieve goals to further the quality of Oregon-grown cereal crops, improve our analytical effectiveness, or improve understanding of the fundamental science in service of the prior two practical goals.

METHODS:

We apply Approved Methods of AACC-International (now the Cereals and Grains Association), established and validated methods from the scientific literature, or in-house procedures, for quality screening of grain, flour, doughs, batters, and end-products and for research ends. Testing encompasses kernel texture, grain and flour protein and moisture contents, grain enzyme activities, milling performance, flour absorption properties, gluten composition and fine chemistry, dough mixing, strength and extensibility properties, starch and flour paste viscosities, falling number, oxidative gelation, batter viscosities, beta-glucan and arabinoxylan analyses, and end-product manufacture and assessment. It is also vital to adapt quality-testing methods to match the contemporary food formulations and manufacturing processes in which wheat is used.

Progress Report for the Agricultural Research Foundation
Oregon Wheat Commission

Title:	**Preliminary screening of Oregon cereal germplasm for acrylamide forming potential**
Investigator(s):	**Andrew Ross, Patrick Reardon, Teepakorn Kongraksawech.** Oregon State University, Corvallis, OR.
Cooperator(s):	**Robert Zemetra, Patrick Hayes, Ryan Graebner**.
Funding History:	There is no funding history for this project. **2019-20 $25,000 (This proposal)**

Abstract: Acrylamide is a compound that is arguably harmful at the levels found in some foods cooked at high-temperature. Accordingly, soft white wheat buyers are concerned about acrylamide formation during baking of products like cookies and crackers. There is no mandated minimum level of acrylamide in foods. However, the FDA recommends the use of cereal raw materials with low levels of free asparagine to minimize acrylamide accumulation. The FDA outlined crop management practices that reduce free asparagine in cereals (adequate soil sulfur without excessive nitrogen) but also recommend using wheat varieties that are intrinsically lower in free asparagine. The primary purpose of this study is to establish a preliminary database of the levels of free asparagine in Oregon grown cereal varieties across multiple environments. We proposed to quantitatively screen elite cereal genotypes (genetic component of the experimental design) for the presence of free asparagine using magnetic resonance spectroscopy (NMR) techniques. We are ready to test best-practices for extraction of free asparagine from wheat flour matrices. Because routine lab work is shut down as a result of OSU directives related to COVID-19, we are delayed in achieving the outcomes of the study. During winter 2020 we were in the process of training the student worker and reselecting samples. The latter was to address both the original objective, and to leverage NMR's ability to quantify all soluble compounds (metabolites) in the kernel to address issues related to late-maturity amylase (LMA) and preharvest sprout (PHS). This can be achieved via simple reanalysis of the collected spectra [at no extra cost to OWC]. Collaborations with WSU on rapid FN testing and distinguishing LMA from (PHS) have suggested that screening of all extracted compounds may identify compounds that can be used as targets for rapid testing (e.g. antibody-based tests) to differentiate LMA from PHS. When this work can recommence is unknown but we hope for late summer into the Fall of 2020.

Objectives:

1. **Quantitatively screen** elite cereal germplasm and candidate parents for the presence of the acrylamide precursor, free asparagine, using the most applicable method, Nuclear Magnetic Resonance Spectroscopy (NMR).

2. **Make a preliminary identification of genotypes lower in asparagine concentration** across multiple locations and two harvest years to account for Genetic X Environment interactions.

Achievements:

There are no outcomes to report as a result of the university's directive to halt all research activities except those that are deemed critical e.g. growing plants and managing animals. The acrylamide lab work was scheduled for the late winter through spring and into early summer of 2020. This timing represents a natural lull in the demands on the lab and personnel as a result of the seasonal decrease in the amount of work needed to service to the breeding program during the spring. This period has always been our opportunity to focus on other research. We are primed to recommence this project once we are able to access our laboratories on a consistent basis and can identify a new student worker to run the extractions. With respect to the funding, the $25,000 granted by OWC will remain in the ARF account until such times as we recommence when it will be moved to the operating account.

The experiment was originally planned across 4 locations within the state of Oregon that encompassed dryland (high and low rainfall) and irrigated management, 15 key genotypes (10 wheat and 5 barley) across 2 harvest years (total of 120 samples). We originally reserved 80 samples for method optimization with the OSU NMR Facility and comparison with earlier extraction procedures for method validation. We were in the process of retooling the experimental design to incorporate samples grown in the PNW that were LMA-affected versus LMA-free and that were PHS-affected versus PHS-free when we were shut down.

The reimagined experimental design retains the basic structure of the original: 4 diverse locations, 2 years, and key genotypes. To this we plan to add around 30 samples to be shared by Camille Steber and Stephen Delwiche (USDA Pullman WA and Beltsville MD respectively) that are LMA affected/free pairs. We also have in hand sprouted and sound pairs of 5 key soft white lines grown in two years that can fit both the acrylamide and the extended aims with respect to LMA and PHS. The PHS affected/free and the LMA affected/free sample pairs can perform double duty on acrylamide and LMA/PHS. The PHS affected/free sample pairs also have the potential to provide a preliminary insight about the impact of PHS on free asparagine levels.

The reason we can extend the aims without additional effort is because the collected spectra quantify *all* of the soluble metabolites in each sample. Accordingly, once they are collected, we can use the spectra to mine for other metabolites or groups of metabolites that may distinguish LMA and PHS from the same spectra that we use to quantify the free asparagine. Subsequently, if specific metabolites are identified, we would work with Dr. Amber Hauvermale at WSU to see if the identified metabolites could be suitable targets for rapid (e.g. antibody) testing to differentiate LMA and PHS.

Metabolite extractions will be conducted in the cereal labs and spectra collected on the 800 MHz Bruker NMR spectrometer located in the OSU NMR Facility. Dr. Reardon will manage NMR spectra processing and computer analysis.

Publications, reports, presentations:

There are none to report at this juncture.

Relation to Other Research: This work supports projects investigating the impact on cereal quality of changes to agronomic practices, soil fertility, and the enterprise of improving quality through genetics. Accordingly, this work is a part of assessing cereal quality more generally and thus fits into the mandate of the cereal quality lab. It is also intrinsically related to the work of the wheat and barley breeding programs researching in how genetics affect cereal quality, and agronomy programs researching in how environment also affects cereal quality.

2020 Progress Report for the Agricultural Research Foundation
Oregon Wheat Commission

TITLE: Screening for Resistance to Major Wheat Diseases in Oregon
INVESTIGATOR: Chris Mundt, Botany and Plant Pathology, Oregon State University (OSU), Corvallis
COOPERATORS: Bob Zemetra, Crop and Soil Science, OSU, Corvallis – wheat breeding
Ryan Graebner, CBARC Pendleton – extension cereals
Christina Hagerty, CBARC Pendleton – plant pathology

FUNDING HISTORY: $47,000 for 2017-18; $52,330 for 2018-19; $54,844 2019-2020

ABSTRACT: A combination of locations, production practices, and inoculation techniques will be used to provide high levels of disease pressure in trials of stripe rust, Cephalosporium stripe, Fusarium crown rot, strawbreaker foot rot, and Septoria tritici blotch. Inoculated trials for sharp eyespot will be conducted for a subset of nurseries, and barley yellow dwarf data will be taken in any nurseries where it occurs naturally. Resistance levels of entries in statewide yield trials will be determined to evaluate potential new varietal releases and to allow growers to make the best varietal decisions when new varieties are first available to them. Resistance levels of entries in elite and advanced yield trials from the OSU Wheat Breeding Program will be used to determine which lines to advance in the program towards potential release. We will continue evaluating data from mapping populations to evaluate the genetics of inheritance and identify genetic markers that can be used to screen for resistance to disease more efficiently in a breeding program. The studies described above are crucial to continued progress in the OSU Wheat Breeding Program, increased profitability for Oregon wheat growers, and ability to adopt conservation tillage practices.

OBJECTIVES: 1) Evaluate elite and advanced wheat lines and mapping populations for resistance to stripe rust, Septoria tritici blotch, Cephalosporium stripe, Fusarium crown rot, strawbreaker foot rot, sharp eyespot, and barley yellow dwarf virus. 2) Determine genetics and identify molecular markers associated with disease resistance.

PROCEDURES:
Lines to be Evaluated - The following nurseries from the OSU Wheat Breeding and Cereals Extension programs are being evaluated:

SWELT+: soft white winter elite entries from the OSU Wheat Breeding Program, including Clearfield and CoAXium lines
SWADV 1: advanced soft white winter lines from OSU
SWADV 2: advanced soft white winter lines from OSU
HRADV: hard red advanced lines from OSU
HWADV: hard white advanced lines from OSU
OSU Club: elite and advanced lines from the OSU club wheat breeding project
OWEYT: OSU Extension soft white winter statewide variety trial, Clearfield and non-Clearfield
HWEYT: OSU Extension hard wheat winter statewide variety trial, red and white

Elite nurseries from the OSU Wheat Breeding Program will contain the most promising lines nearing consideration for release. Evaluating the advanced nurseries will aid the OSU Wheat Breeding Program in making decisions as to which lines to advance towards evaluation in the elite trials. The statewide winter wheat yield trials run by the OSU Cereals Extension Program incorporates soft white winter wheat and red winter varieties that are currently grown in Oregon, recently released winter wheat varieties, and elite lines most likely to be released from university and private breeding companies in the PNW within the next few years. These trials will provide a direct comparison of established varieties so as to evaluate potential new releases and to allow growers to make the best varietal decisions when new varieties are first available.

Data will also be collected from earlier generation nurseries of the OSU Wheat Breeding Program when severe natural infection occurs, especially for stripe rust. Data may also be collected from earlier generation OSU nurseries as well as from any of the above nurseries when severe natural infection occurs. In addition we would continue to test lines for Cephalosporium stripe resistance for both the USDA-ARS/WSU Wheat Breeding Program (63 lines) and Limagrain (68 lines) at CBARC, Pendleton.

A Madsen x Foote population consisting of 217 recombinant inbred lines are being studied to evaluate genetics of durable stripe rust resistance in Madsen and to evaluate and combine genes for quantitative resistance to Septoria from Madsen and Foote. Markers for this population will be developed via a genotyping-by-sequencing effort, which should provide more precise markers than were available in the past. The Einstein x Tubbs population also has been genotyped by sequencing to develop improved markers, as we have found this population to be a particularly rich source of disease resistance. This population is currently being evaluated for resistance to sharp eyespot of wheat at two locations.

Field trials completed to test PNW-adapted wheat varieties for ability to suppress build-up of the take-all pathogen, based on promising research that has recently been reported from England. These trials included six wheat varieties that have shown the highest yield performance under high rainfall and irrigated conditions, as well as Stephens as a historical check.

Establishment and measurement of diseases. Early seeding dates were utilized to encourage Cephalosporium stripe, strawbreaker foot rot, Fusarium crown rot, and barley yellow dwarf virus (BYDV). Plots were artificially inoculated for Cephalosporium stripe, Fusarium crown rot, and strawbreaker foot rot. Naturally occurring inoculum was used for stripe rust, Septoria, and BYDV. Specific fungicides and combinations of fungicides were used to help isolate effects of Cephalosporium stripe, Fusarium crown rot, Septoria, and BYDV. Percentage of whiteheads is used to measure Cephalosporium stripe and Fusraium crown rot. Percent lodging is generally used to quantify strawbreaker foot rot. Percent leaf area covered by lesions is used for stripe rust and Septoria, and percent of infected leaves is used to quantify BYDV. A root rot rating and whitehead percentages are used for take-all.

We were unable to obtain significant stripe rust data for the last two years because of low rust pressure, yet stripe rust remains the disease of most concern to Oregon wheat growers and epidemics are likely to return. We thus began a new system for stripe rust testing at the Botany Farm in Corvallis during the 2019-20 season. Plots to test for strawbreaker foot rot resistance are planted in mid-September at this farm and always contain at least a small amount of stripe rust because of the very early seeding date and high rainfall of the Willamette Valley. We planted stripe rust test plots on the same farm with a standard planting date (mid-October) and surrounded them with spreader rows of the highly susceptible variety 'Foote'. Spores from the earlier planted strawbreaker plots are expected to disperse to our stripe rust testing plots, multiply rapidly on 'Foote', and then spread into our test plots, providing high rust levels even if no significant stripe occurs at any of our other test sites.

REPORT OF ACCOMPLISHMENTS:

Accomplishments in 2020: All plots planted by the Cereal Pathology Program for the 2018-19 season have been well established, for a total of 8,634 plots (Table 1), and all artificial inoculations have been accomplished. Our new system for stripe rust screening appears to be successful thus far, as substantial rust was developing by mid-April.

Accomplishments in 2019. We obtained data from a total of 8,052 plots (Tables 2 and 3). Few data were obtained from plots planted by the Wheat Breeding and Extension programs this year, mostly due to lack of sufficient natural infection, particularly that of stripe rust.

Examples of more specific results include conformation that combining resistance genes *Pch1* and *Pch2* for strawbreaker resistance provides a very high level of resistance to this disease. Importantly, a set of several two-gene Clearfield lines with an ORCF-102 background carry these two genes, and show exceptional resistance to strawbreaker foot rot, and are also resistant to stripe rust. This resulted in the new release of OR 2×2 CL+. Data that were collected also contributed to release of the varieties Norwest Tandem and Norwest Duet. We have identified varieties with moderate resistance to both Cephalosporium stripe and Fusarium crown rot, including in Norwest Duet. We confirmed that the variety Bobtail can be used to reduce the severity of the take all disease, and growers are already using this practice.

The Foote x Madsen population corroborated previous data from the Einstein x Tubbs population that the stripe rust resistance gene *Yr17* can provide durable resistance to stripe rust when combined with other resistance genes. We have also conducted data analyses of several mapping populations, suggesting that there are genetic markers associated with resistance to multiple wheat diseases.

We have begun compiling summaries of resistance rankings of wheat varieties to different diseases that will be available online. This was completed for eyespot (strawbreaker foot rot) in 2019 and we hope to do the same for stripe rust and Cephalosporium stripe soon. These summaries will be updated annually.

IMPACTS:

Varietal resistance is the most effective and economical method to reduce losses caused by the many diseases that impact wheat productivity in Oregon. In addition, resistant wheat varieties are required to adopt conservation practices that reduce soil erosion, as these practices often increase the severity of wheat diseases. The Statewide trials will help to provide a direct comparison of disease resistance in established varieties so as to evaluate potential new releases and to allow growers to make the best varietal decisions when new varieties are first available. Elite nurseries aid the breeding program in identifying lines for potential release. Evaluating the advanced nurseries aids the OSU Wheat Breeding Program in making decisions as to which lines to advance towards evaluation in the elite trials, while data collected from preliminary yield trials helps to eliminate susceptible material earlier in the breeding process. Molecular mapping data will be used for marker discovery with several diseases.

Though many diseases impact wheat production in Oregon, we have focused on several of particular importance. Stripe rust is currently the most important wheat disease because of favorable climatic conditions, fast rates of spread, and new pathogen races with increased aggressiveness and overwintering ability. Though controlled effectively for decades by high temperature adult plant resistance, the new races are able to establish very effectively in the seedling stage. Increased levels of resistance to Cephalosporium stripe and Fusarium crown rot are required to reduce chronic losses being experienced by growers in eastern Oregon. Septoria tritici blotch is the most important disease of wheat in the Willamette Valley when rust is absent. This highly variable pathogen is constantly adapting to resistance in commercial varieties, and we have shown that the pathogen is developing resistance to commonly used fungicides. Approximately 2 million acres of wheat in the PNW would require fungicide application annually to control strawbreaker foot rot in absence of genetic resistance. In the past, PNW breeders relied almost entirely on a single source of resistance to strawbreaker foot rot. This single gene does not provide sufficient resistance in highly conducive environments, and new sources of resistance are required to protect against potential adaptation of the pathogen to this resistance. Disease resistance is often quantitative in nature, i.e., there are multiple genes involved and levels of resistance can vary continuously from very high to very low. Quantitative resistance usually is very stable over time. To effectively breed for such resistance, however, requires diligent efforts to obtain accurate and repeatable disease ratings in the field. Mapping of molecular markers associated with resistance to disease can increase both the speed and accuracy of selection, but field ratings still are required both for initial discovery of appropriate markers and to confirm resistance levels before new lines are released as varieties. Take-all has long been a problem for wheat-on-wheat crop sequences, and only very recently have potential genetic solutions become available. Recent outbreaks of barley yellow dwarf virus and sharp eyespot suggest that these two diseases require attention.

RELATION TO OTHER RESEARCH: The proposed trials are crucial to the overall OSU wheat breeding efforts and molecular marker discovery funded by the OWC, the Oregon Agricultural Experiment Station, and wheat royalty dollars. The work also complements basic research studies of epidemiology and pathogen population genetics in the OSU Cereal Pathology Program funded through USDA-NIFA, the OSDU Agricultural Experiment Station, the OSU Agricultural Research Foundation.

Table 1. Numbers of plots planted by the Cereal Pathology Program in 2019 for evaluation of disease levels in 2020.

Nursery	Entries	Reps	Ceph. stripe	Fusarium crown rot	Straw-breaker	Septoria	Stripe rust	Sharp eyespot	Total
Statewide Yield Trials - Soft	60	4	240	240	240	240	240	160	1360
Statewide Yield Trial - Hard	30	4	120	120	120	120	120		600
Soft White Elite+	60	4	240	240	240	240	240	160	1360
Hard White Advanced	30	4	120	120	120	120	120		600
Hard Red Advanced	30	4	120	120	120	120	120		600
Soft White Advanced 1	40	3	120	120	120	120	120		600
Soft White Advanced 2	30	3	90	90	90	90	90		450
OSU Club	30	4	120	120	120	120	120		600
Foote x Madsen Population	225	4					900		900
Einstein x Tubbs Population	280	4						1120	1120
WSU/ARS	60	4	240						240
Limagrain	68	3	204						204
Total			1614	1170	1170	1170	2070	1440	8,634

Table 2. Numbers of plots planted by the Cereal Pathology Program and evaluated for disease levels in 2019.

Nursery	Entries	Reps	Ceph stripe	Fusarium Crown rot	Straw-breaker	Septoria	BYDV	Take-all	Total
Statewide Yield Trials - Soft	40	4	160	160	160	160	160		800
Statewide Yield Trial - Hard	30	4	120	120	120	120	120		600
Soft White Elite	40	4	160	160	160	160	160		800
Clearfield Elite	40	4	160	160	160	160	160		800
OSU Club	13	4	52	52	52	52	52		260
Soft White Advanced 1	40	3	120	120	120	120	120		600
Soft White Advanced 2	40	3	120	120	120	120	120		600
Soft White Advanced 3	30	3	90	90	90		90		360
Hard White Advanced	40	3	120	120	120	120	120		600
Hard Red Advanced	40	3	120	120	120	120	120		600
Foote x Madsen Population	225	4				900			900
Limagrain	66	3	198						198
WSU/ARS	63	4	252						252
Wheat Take-All	14	4						56	
Barley	15	4					60		60
Subtotal 2019 Pathology									7486

Table 3. Numbers of plots planted by the Wheat Breeding Program and evaluated for disease levels in 2019.

Nursery	Entries	Reps	Septoria	Stripe rust	Total
Statewide Yield Trials - Soft	40	3	120	120	240
Grand Total 2019					7726

2020 Progress Report for the Agricultural Research Foundation
Oregon Wheat Commission

TITLE: Screening for Resistance to Major Wheat Diseases in Early Generation Material from Private Breeding Programs

INVESTIGATOR: Chris Mundt, Botany and Plant Pathology, Oregon State University (OSU), Corvallis

COOPERATORS: Christina Hagerty, CBARC Pendleton – plant pathology
Ryan Graebner, CBARC Pendleton – extension cereals

FUNDING HISTORY: $21,680 for 2018-19.

ABSTRACT: A combination of locations, production practices, and inoculation techniques were used to test promising wheat lines from private companies against high levels of disease pressure in trials of stripe rust, Cephalosporium stripe, Fusarium crown rot, strawbreaker foot rot, and Septoria tritici blotch. The resulting data will increase the probability of attaining higher resistance levels in lines that are ultimately released to growers. Though all major wheat breeding companies in the PNW were contacted, we initially received only a request for testing of 20 lines from Syngenta/Agripro, which were evaluated along with three checks (Stephens, Bobtail, and Madsen) in randomized complete block design trials with four replications per entry. Remaining funds are being used to evaluate additional lines for Agripro in 2019-20 and 2020-21, and also to evaluate 300 lines from Limagrain for resistance to Fusarium crown rot in 2019-2020 for the purpose of molecular marker discovery.

OBJECTIVES: Evaluate early generation breeding material from private breeding programs for resistance to stripe rust, Septoria tritici blotch, Cephalosporium stripe, Fusarium crown rot, and strawbreaker foot rot.

PROCEDURES:

Lines evaluated. Though all major wheat breeding companies in the PNW were contacted, we initially received only a request for testing of 20 lines from Syngenta/Agripro, which were evaluated along with three checks (Stephens, Bobtail, and Madsen) in randomized complete block design trials with four replications per entry. Agripro submitted 40 lines for evaluation against the same five diseases in 2019-20. At the end of the 2019-20 season, there will be sufficient funds available from the 2018-19 grant to evaluate 40 Agripro lines in 2020-2021. Limagrain expressed a strong interest in development of molecular markers for resistance to major wheat diseases, with a particular interest in Fusarium crown rot. To address this interest, we planted 300 Limagrain lines × 4 reps at the Sherman Station in Fall 2019 and inoculated them with six strains of *Fusarium*.

Establishment and measurement of diseases. A decision was made to establish plots for stripe rust rather than barley yellow dwarf virus mentioned in the original proposal, as stripe rust is likely to be of more interest to companies and growers. To do so, a new procedure was established whereby plots were planted nearby our early-sown strawbreaker plots, and surrounded by spreader rows of the highly susceptible variety ‘Foote’. Stripe rust usually becomes established in these early-seeded plots, which can then move to the Foote spreader rows.

Early seeding dates were utilized to encourage Cephalosporium stripe, strawbreaker foot rot, and Fusarium crown rot. Plots were artificially inoculated for Cephalosporium stripe, Fusarium crown rot, and strawbreaker foot rot. Naturally occurring inoculum was used for stripe rust and Septoria. Specific fungicides and combinations of fungicides were used to help isolate effects of Cephalosporium stripe, Fusarium crown rot, and Septoria. Percentage of whiteheads were used to measure Cephalosporium stripe and Fusarium crown rot. Percent lodging was used to quantify strawbreaker foot rot. Percent leaf area covered by lesions was used for stripe rust and Septoria.

REPORT OF ACCOMPLISHMENTS: Excellent plant stands and disease levels were attained for all trials in 2018-19 and there appear to be substantial differences among entries. Our new procedure to establish current races of stripe rust was successful and provided high rust pressure. The only difficulty experienced was that a rare flooding of the Willamette River in spring 2019 resulted in death of a significant number of plots in the strawbreaker foot rot trial.

We tested 20 Syngenta Agripro lines for resistance to five diseases (stripe rust, Septoria, Cephalosporium stripe, Fusarium crown rot, and strawbreaker foot rot) in 2018-19. These results were highly useful in establishing differences in disease response among their advanced lines, which should aid Agripro in releasing varieties with improved resistance. Agripro submitted 40 lines for evaluation against five diseases in 2019-20, and these plots have been successfully established and inoculated. At the end of the 2019-20 season, there will be sufficient funds available from the 2018-19 grant to evaluate 40 Agripro lines in 2020-2021. Westbred initially expressed considerable interest in having material screened, but have not yet provided entries. Limagrain indicated that they were instead interested in having my program evaluate a large number of lines for development of molecular markers for resistance to Fusarium crown rot. To address this interest, we planted 300 Limagrain lines × 4 reps at the Sherman Station in Fall 2019 and inoculated them with six strains of *Fusarium*. Disease levels will be measured this spring. Limagrain will use these disease data, combined with the extensive set of genomic data they currently possess on the wheat lines, to conduct a genome-wide association study (GWAS). Identity of the publically available genetic markers that are most closely associated with quantitative trait loci for Fusarium crown rot resistance will be shared with the Oregon State University Wheat Breeding Program.

IMPACTS:

Diseases are a highly important factor impacting wheat productivity, production costs (through fungicide application), and ability to adopt soil conservation practices. Varietal resistance is by far the most effective, economical, and environmentally sound method to reduce losses caused by the many diseases that impact wheat productivity in Oregon. The proposed work will enhance the ability of private breeding companies to produce varieties with increased levels of disease resistance, and would allow growers to evaluate resistance levels of new varieties at the time of initial release. The GWAS study should enhance the ability of both Limagrain and OSU to increase levels of resistance to Fusarium crown rot, which is an important disease across a wide swath of the PNW. Increased levels of disease resistance will result in increased profitability for Oregon wheat growers, and ability to more effectively adopt conservation tillage practices.

RELATION TO OTHER RESEARCH: The proposed work will complement trials being conducted for the OSU Wheat Breeding Program and funded by the OWC, the Oregon Agricultural Experiment Station, and wheat royalty dollars.

Progress Report for the Agricultural Research Foundation and
The Oregon Wheat Commission

Title: Oregon Wheat Statewide Weed Management Research and Extension – 2019-2020

Investigators: **Andrew G. Hulting**, Extension Weed Management Specialist, Corvallis
Caio Brunharo, Weed Research Project Leader, Corvallis
Judit Barroso, Assistant Professor Weed Science, Pendleton

Cooperators: OSU Extension Faculty, statewide including: Brian Tuck, Wasco and Hood River Counties, Jordan Maley, Gilliam County, Darrin Walenta, Union County and Nicole Anderson, North Willamette Valley, and others
Statewide agribusinesses including: Pratum Coop, Marion Ag Service, McGregor Co., Nutrien Ag, Valley Agronomics, Wilbur Ellis Co. and others

Funding History:		
	Statewide 2017-2018 Allocation:	$56,900
	Statewide 2018-2019 Allocation:	$52,900
	Statewide 2019-2020 Allocation:	$55,600

Abstract: We are conducting a coordinated program to test herbicides for use in wheat across statewide environments thereby facilitating a more rapid registration and statewide labeling for all Oregon wheat production systems. Because of the extreme diversity between eastern and western Oregon wheat cropping environments and spectrum of weed species across the region, it is necessary to test new compounds in both regions before a complete data package can be submitted to EPA for statewide product registration. All of the major herbicide manufacturing companies collaborate with the investigators listed on this proposal and rely on their data to successfully obtain new herbicide registrations for Oregon wheat. In addition, we are conducting more in-depth studies to determine best methods for management of problem weed species and biotypes in wheat including rattail fescue and multiple resistant Italian ryegrass. New information derived from statewide weed research will be disseminated to Oregon wheat growers and consultants using an array of Extension programming methods.

Objectives

1) Coordinated statewide evaluation of new wheat herbicide products and combinations for weed control under statewide Oregon conditions.
2) Evaluate herbicide combinations and cultural weed management strategies to manage downy brome, rattail fescue and multiple herbicide resistant Italian ryegrass populations.
3) Extend research results to wheat growers and crop management consultants and provide weed management related educational programming to wheat growers throughout Oregon

Procedures and Report of Accomplishments:
Studies are being conducted using standard field research techniques, typically at OSU research stations or in commercial wheat fields. Herbicides are applied with small plot or tractor mounted

plot sprayers. Crop injury and weed control are evaluated visually. Yield parameters will be determined with use of small plot harvesting and seed cleaning equipment.

1) Field experiments were set up to evaluate the efficacy and crop safety of pinoxaden, fenoxaprop, pyroxsulam, florasulam, pyrasulfotole, halauxifen, clopyralid, fluroxypyr, and pyroxasulfone, as well as combinations among these compounds. We have been working with the wheat group to test advanced OSU lines (1086, 118H, and 0755) for crop safety of commonly used herbicides, as pyroxasulfone, diuron, flufenacet, metribuzin, fenoxaprop, pinoxaden, fenoxaprop, chlorsulfuron, metsulfuron, pyroxsulam, sulfosulfuron, florasulam, MCPA, carfentrazone, flucarbazone, halauxifen, and pyroxasulfutole. We also initiated studies to assess weed control and crop safety of tiafenacil and tolpyralate, both of which are not currently registered in wheat, but we believe have potential for registration in the near future. We have proposed in FY2020-2021 to study these two herbicides in more detail in future growing seasons.

2) We have screened several Italian ryegrass populations for herbicide resistance. Our preliminary results indicate that several populations have evolved resistance to quizalofop-P-ethyl, surviving up to eight time the recommended rate. We have brought this to the attention of the Commission, and would like to pursue a project in FY2020-2021 to map resistance to this herbicide in the state. We have also initiated efforts among the PI's to expand this screenings and include populations of downy brome to group 2 herbicides.

3) Until April, statewide Extension activities have included delivery of research results at traditional grower meetings, field day presentations and plot demonstrations of current research activities outlined in Objectives 1 and 2 with collaboration from OSU county Extension faculty. Due to COVID-19, we are changing our extension activities to virtual meetings and the information is being delivered through our websites (http://cropandsoil.oregonstate.edu/weeds/, http://oregonstate.edu/weeds/), zoom meetings, phone and emails. Updates and changes in herbicide labeling in wheat, to growers and crop consultants are published in the mentioned websites in addition to the online version of the PNW Weed Management Handbook (free access).

Relation to other research

As stated above, we collaborate with other research groups in the state. For example, we are involved in the herbicide screening of new wheat varieties from the OSU wheat breeding program. We are also collaborating with the barley breeding program to develop an imazamox-tolerant variety. Finally, we work closely with the chemical companies to facilitate herbicide registration in wheat in the state.

Impacts

Most of the experiments from 2019-2020 are still ongoing, and yield will be assessed at the end of the season. Greenhouse studies indicate that quizalofop-resistant Italian ryegrass populations are found in the Willamette Valley, and future studies will indicate where adoption CoAXium Wheat is feasible.

Final Project Report

Project Title: Russian thistle Management in Wheat Cropping Systems.

Investigator: Judit Barroso, Weed Scientist, OSU-CBARC.

Funding History: 2016-2017: $31,110
2017-2018: $30,321
2018-2019: $35,206

Abstract:
Growers in the low-rainfall region of northeastern Oregon, where wheat-summer fallow is the predominant cropping system, rely on repeated applications of non-selective herbicides, predominately glyphosate, to control Russian thistle. With the recent glyphosate resistance reported in some Russian thistle populations in the region, farmers see Russian thistle as an imminent threat to the sustainability of their cropping systems.

The goal of this project is to improve Russian thistle management in wheat cropping systems by:
1) Optimizing the herbicide application time,
2) Learning how to increase herbicide efficacy with the use of adjuvants, and
3) Diversifying control strategies with the help of residual herbicides and cultural management.

Our anticipated results are to gain a better understanding of:
1) Herbicide efficacy regarding Russian thistle growth stage and environmental conditions,
2) The value of adding adjuvants to herbicide applications at different treatment times, and
3) Some tools to develop a more integrated Russian thistle management and prevent the development of more resistance cases in this species.

Objectives:
1) Effect of Russian thistle growth stage on post-emergence herbicide efficacy.
2) Evaluation of different adjuvants to improve Russian thistle chemical control.
3) Russian thistle management with residual herbicides.
4) Effect of crop density, crop species, and inter-row space on Russian thistle germination, development, and seed production.

Procedures (by objective):
1) Effect of Russian thistle growth stage on post-emergence herbicide efficacy. Spraying weeds when they are most susceptible to herbicides is important to optimize money invested in weed control. I established a greenhouse study, complemented with a field study, to investigate the growth stage when this species is most susceptible to herbicides. The herbicides evaluated were Huskie® (bromoxynil + pyrasulfotole) at 15 oz/A and 2,4-D amine at 1.5 pt/A. The greenhouse experiment had five pots per treatment and one Russian thistle plant per pot. Treatments were applied every week, starting when Russian thistle plants were between 2 and 4 leaves, until plants flowered. Herbicide treatments were applied using a compressed air, greenhouse cabinet sprayer with a single 8002E nozzle delivering 15 gal/A. Evaluations were conducted three weeks after treatments (WAT) by counting and taking the fresh weight of the surviving plants with respect to the control. The field experiment will be a complete randomized block design with four repetitions. All plots were sprayed with the same herbicide and rate but at

different dates or Russian thistle growth stages. Data were analyzed with non-linear regression and analysis of variance.

2) Evaluation of different adjuvants to improve Russian thistle chemical control. Adjuvants are added to the spray tank to improve herbicidal activity or application characteristics. However, adjuvant effect could be more critical at certain environmental conditions or weed size. We established four trials, two in Pendleton and two in Moro, to evaluate several post-emergence herbicides with different adjuvant options (Table 1 and 2) to control Russian thistle in fallow and post-harvest. The trials in fallow were a complete randomized block design with four repetitions and a plot size of 10 ft by 30 ft. The trials in spring wheat were a split-plot randomized complete block design with four repetitions, where the main plot (10 ft x 40 ft) was the chemical treatment and the sub-plot (10 ft x 20 ft) was the cutting height (low or high). Russian thistle seeds were sprinkled in the experiment area in April to secure a uniform infestation. The trials in fallow were treated in May when Russian thistle plants were less than 8 inches tall and the trials post-harvest were treated between two and four weeks after harvest. Treatments were conducted with a CO_2-powered backpack sprayer delivering 15 gal/A. Visual weed control assessments were performed 3, 6, and 9 WAT to evaluate herbicide and adjuvant efficacy. Data were analyzed with analysis of variance.

3) Russian thistle management with residual herbicides. From an herbicide resistant strategy point of view, it is necessary to provide growers with as many tools as possible to control this problematic weed. We established two trials in fallow, one in Pendleton and one in Moro, to evaluate three different application times (fall, winter, and a split application) of sulfentrazone + carfentrazone, flumioxacin + pyroxasulfone, and metribuzin for Russian thistle control (Table 3 and 4). The trials were a complete randomized block design with four repetitions. The plot size was 10 ft by 30 ft. Russian thistle seeds were sprinkled in the experiment area to secure a uniform infestation. Treatments were conducted with a CO_2-powered backpack sprayer delivering 15 gal/A. Visual weed control assessments were performed in May, June, July, August, and September to evaluate herbicide efficacy. Data were analyzed with analysis of variance.

4) Effect of crop density, crop species, and inter-row space on Russian thistle germination, development, and seed production. Crop competition is key to prevent Russian thistle establishment and the need for subsequent control. We established two field experiments, one in Pendleton and one in Moro to evaluate the effect of two seeding rates, two crop row spacings, and two crop species (spring wheat and barley) on Russian thistle suppression. The experimental design was a split-plot randomized complete block with four repetitions, where the main plot (10 ft x 120 ft) was the inter-row spacing and the sub-plots (10 ft x 30 ft) were the four combinations of crop species and density (var.1 x den.1, var.1 x den.2, var.2 x den.1, and var.2 x den.2). Russian thistle seeds were sprinkled in the experiment area before crop seeding to secure a uniform infestation. In spring, Russian thistle germination and development were evaluated by throwing a sampling frame (0.5 m x 0.5 m) five times randomly in each sub-plot, counting Russian thistle plants, and estimating percentage or Russian thistle cover inside each frame. The same sampling was repeated before harvest. Seed production (number of seed per plant) was evaluated from five random plants per sub-plot. Data were analyzed with analysis of variance.

Report of Accomplishments (by objective):

Objective 1: Unfortunately, the discontinuous Russian thistle germination in the field invalidated the results from the field trial. In the greenhouse experiment, we observed that Huskie controlled Russian thistle better than 2,4-D (Figure 1), Huskie control was 99% on average during the first 4 weeks, while 2,4-D control was 87% on average during that time. Russian thistle growth stage impacted 2,4-D herbicide more than Huskie herbicide, the average Russian thistle control with 2,4-D for the weeks 5, 6, and 7 was 41% against 88% with Huskie. 2,4-D also lost efficacy one week earlier than Huskie with maturing Russian thistles. In addition, the variation in Russian thistle control with 2,4-D increased much more than with Huskie (see standard deviation of the mean in Figure 1). Note: Russian thistle growth is probably faster in the greenhouse than in the field due to more optimum temperatures. A field study would be recommended to support and advance the observed results in the greenhouse.

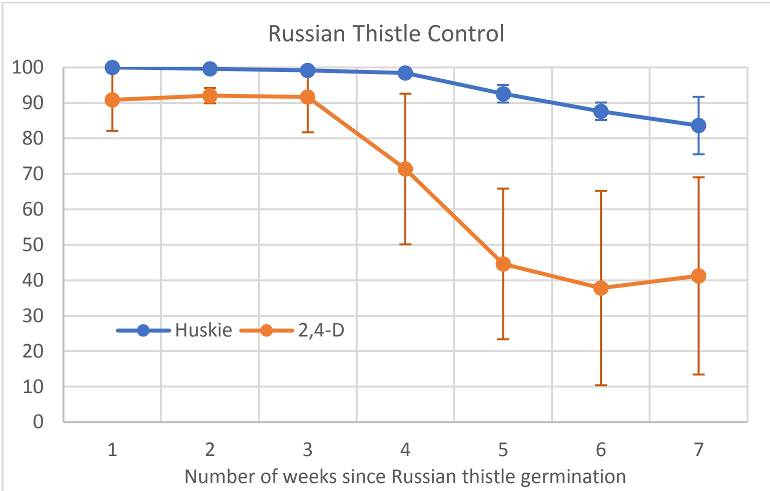

Figure 1: Russian thistle control in percentage with Huskie and 2,4-D herbicides according to different plant growth stages. Week 1= 2.8 leaves, week 2 = 5.6 leaves, week 3= 15.4 leaves, week 4 = 2.2 shoots, weeks 5 = 5.8 shoots, weeks 6 and 7 = 5.8 shoots (starting to flower). Points in the lines indicate mean control values and the vertical lines coming out of the means indicate the standard deviation that informs of the variance in the data.

Objective 2:
Trial in Pendleton in fallow: All Deadbolt treatments, along with Sharpen + Strikelock and Sharpen + Fire-zone showed the best Russian thistle control (90-100%) throughout the evaluation period (Table 1). Sharpen alone showed the poorest control of sprayed treatments throughout the evaluation period (2-16%). GlyStar Original showed the least effective control throughout the evaluation period, ranging from 39-80% on the final evaluation. The addition of the adjuvants to Sharpen greatly improved its performance, with Hel-Fire being the least effective (45% for final evaluation). Deadbolt did not show any significant difference with the addition of the three adjuvants, ranging from 90-95% on the final evaluation. GlyStar Original was most helped with the addition of Hel-Fire (80% control), followed by Fire-zone (62%) and Strikelock (48%).

Table 1. Weed Control (%) of Russian thistle for the treatments applied in fallow in Pendleton.

Treatments	Rate	% Weed Control 21 DAT* 6/8/2018	% Weed Control 40 DAT 6/27/2018	% Weed Control 56 DAT 7/13/2018
1. Untreated	-	0d	0e	0d
2. Sharpen	2 fl oz/A	16c	10d	2d
3. Sharpen + Strikelock	2 fl oz/A + 0.5% v/v	100a	96a	93a
4. Sharpen + Fire-Zone	2 fl oz/A + 1.0% v/v	100a	97a	91a
5. Sharpen + Hel-Fire	2 fl oz/A + 0.75% v/v	91b	86bc	45c
6. Deadbolt	32 fl oz/A	100a	96a	91a
7. Deadbolt + Strikelock	32 fl oz/A + 0.5 % v/v	100a	96a	94a
8. Deadbolt + Fire-Zone	32 fl oz/A + 1.0 % v/v	100a	96a	95a
9. Deadbolt + Hel-Fire	32 fl oz/A + 0.75 % v/v	100a	97a	90a
10. GlyStar Original	32 fl oz/A	91b	80c	39c
11. GlyStar Original + Strikelock	32 fl oz/A + 0.5 % v/v	89b	85bc	48c
12. GlyStar Original + Fire-Zone	32 fl oz/A + 1.0 % v/v	90b	88ab	62bc
13. GlyStar Original + Hel-Fire	32 fl oz/A + 0.75 % v/v	91b	90ab	80ab

*DAT= Days after treatment.

Trial in Moro in fallow: All Deadbolt treatments and GlyStar Original + Hel-Fire were significantly different in the control of Russian thistle on the final evaluation date (97-99%) compared to the other treatments (Table 2). The least control was observed with Sharpen alone (3%), Sharpen + Hel-Fire (11%), GlyStar Original alone (8%) and GlyStar Original + Strikelock (11%). The addition of the adjuvants to Sharpen showed mixed results, with each adjuvant being significantly different from the others. Sharpen + Fire-Zone showed the highest control (73%), followed by Strikelock (45%) and Hel-Fire (11%). The addition of the adjuvants to Deadbolt did not significantly change the control of Russian thistle (98-99% for the final evaluation). GlyStar Original also showed significant differences among the three adjuvants, with Hel-Fire showing the most control (97%), followed by Fire-Zone (79%) and Strikelock (11%) on the final evaluation.

Table 2. Weed control (%) of Russian thistle for the treatments applied in fallow in Moro.

Treatments	Rate	% Weed Control 22 DAT* 6/13/2018	% Weed Control 37 DAT 6/28/2018	% Weed Control 64 DAT 7/25/2018
1. Untreated Check	-	0d	0g	0e
2. Sharpen	2 fl oz/A	11c	4f	3d
3. Sharpen + Strikelock	2 fl oz/A + 0.5% v/v	85a	76c	45c
4. Sharpen + Fire-Zone	2 fl oz/A + 1.0% v/v	90a	88b	73b
5. Sharpen + Hel-Fire	2 fl oz/A + 0.75% v/v	48b	18e	11d
6. Deadbolt	32 fl oz/A	100a	98a	97a
7. Deadbolt + Strikelock	32 fl oz/A + 0.5% v/v	100a	100a	99a

8. Deadbolt + Fire-Zone	32 fl oz/A + 1.0% v/v	100a	99a	98a
9. Deadbolt + Hel-Fire	32 fl oz/A + 0.75% v/v	100a	100a	98a
10. Glystar Original	32 fl oz/A	56b	37d	8d
11. Glystar Original + Strikelock	32 fl oz/A + 0.5% v/v	54b	21e	11d
12. Glystar Original + Fire-Zone	32 fl oz/A + 1.0% v/v	84a	90b	79b
13. Glystar Original + Hel-Fire	32 fl oz/A + 0.75% v/v	97a	99a	97a

*DAT= Days after treatment.

Trial in Pendleton post-harvest: The wheat crop was harvested on July 31, 2018. The first 20 ft of each plot was cut at a low stubble height of 5.25 in, while the remaining 20 ft of each plot was cut at a higher stubble height of 18 in. Russian thistle was 5.5-24 in tall at the time of application. Control of Russian thistle improved for most treatments in the low stubble height area and for all treatments in the high stubble height area over the evaluation period. The low stubble height had more consistent numbers between evaluations, while the high stubble height showed more variation. Sharpen and Deadbolt, with any of the three adjuvants, had the best control for both stubble heights at 34 DAT (89-96%). GlyStar Original alone and GlyStar Original + Strikelock had the lowest control (9-18%). Overall, GlyStar Original, with any of the adjuvants, had the lowest control (9-50%) (Table 3).

Table 3. Weed control (%) of Russian thistle on first and last evaluation date for the different treatments applied post-harvest of spring wheat in Pendleton in 2018.

Treatments	**Rate**	**% Weed Control 8 DAT* Low 8/22/2018**	**% Weed Control 34 DAT Low 9/17/2018**	**% Weed Control 8 DAT High 8/22/2018**	**% Weed Control 34 DAT High 9/17/2018**
1. Untreated	-	0d	0c	0c	0d
2. Sharpen	2 fl oz/A	6c	5c	2c	13cd
3. Sharpen + Strikelock	2 fl oz/A + 0.5% v/v	88b	93a	36b	89a
4. Sharpen + Fire-zone	2 fl oz/A + 1.0% v/v	90ab	89a	47b	89a
5. Sharpen + Hel-Fire	2 fl oz/A + 0.75% v/v	94a	90a	49b	90a
7. Deadbolt + Strikelock	32 fl oz/A + 0.5 % v/v	95a	97a	86a	95a
8. Deadbolt + Fire-zone	32 fl oz/A + 1.0 % v/v	95a	99a	86a	96a
9. Deadbolt + Hel-Fire	32 fl oz/A + 0.75 % v/v	95a	99a	88a	96a
10. Glystar Original	32 fl oz/A	0d	18c	2c	14cd
11. Glystar Original + Strikelock	32 fl oz/A + 0.5 % v/v	2cd	9c	2c	16cd
12. Glystar Original + Fire-zone	32 fl oz/A + 1.0 % v/v	2cd	49b	2c	50b
13. Glystar Original + Hel-Fire	32 fl oz/A + 0.75 % v/v	1d	23c	2c	23c

*DAT= Days after treatment.

Trial in Moro post-harvest: This trial was sprayed at the same time as the one conducted in fallow by mistake, consequently killing the crop with the glyphosate treatment. Therefore, evaluations were conducted only in treatments with Sharpen and Deadbolt (1 to 9).
Deadbolt treatments, with and without adjuvants, and Sharpen + Fire-Zone had the best Russian thistle control throughout the evaluation period (94-100%). Sharpen alone and Sharpen + Hel-

Fire had the least control of all sprayed treatments over the evaluation period (3-26%) (Table 4). The effect of an adjuvant to increase the Deadbolt efficacy is doubtful based on our results. However, Sharpen really needs an MSO adjuvant to exert control.

Table 4. Weed control (%) of Russian thistle for the treatments in spring wheat in Moro in 2018.

Treatments	**Rate**	**% Weed Control 22 DAT* 6/13/2018**	**% Weed Control 37 DAT 6/28/2018**	**% Weed Control 64 DAT 7/25/2018**
1. Untreated Check	-	0f	0e	0c
2. Sharpen	2 fl oz/A	10e	19d	3c
3. Sharpen + Strikelock	2 fl oz/A + 0.5% v/v	88b	87ab	65b
4. Sharpen + Fire-Zone	2 fl oz/A + 1.0% v/v	99a	97a	94a
5. Sharpen + Hel-Fire	2 fl oz/A + 0.75% v/v	23d	26d	12c
6. Deadbolt	32 fl oz/A	100a	96a	97a
7. Deadbolt + Strikelock	32 fl oz/A + 0.5% v/v	100a	100a	100a
8. Deadbolt + Fire-Zone	32 fl oz/A + 1.0% v/v	100a	99a	99a
9. Deadbolt + Hel-Fire	32 fl oz/A + 0.75% v/v	99a	97a	98a

*DAT= Days after treatment.

Objective 3: In both trials, late fall treatments were applied on November 16, 2017 and late winter treatments, including the treated check, were applied on March 12, 2018.

Trial in Pendleton: This site received 0.5 in of precipitation within the first five days after both late fall and late winter treatments were applied. The trial was sprayed after the first and third evaluation using 48 fl oz/A of GlyStar Plus on 5/21/18 and on 7/16/18.

The best Russian thistle control was obtained with Spartan Charge applied in late winter (99%). However, that control was not significantly different from the split applications of Spartan Charge, Fierce, or Metribuzin 75, the applications of Fierce and Metribuzin 75 in later winter, or the Fierce application in late fall which values ranged from 83% to 98%. The Russian thistle control with Spartan Charge and Metribuzin 75 applied in late fall was not significantly different from the untreated check (Table 5). Dr. Lutcher in Morrow County has found that a late fall application of Spartan Charge can provide similar Russian thistle control than a late winter application. However, we could not confirm those results under 2018 conditions in Umatilla County.

Trial in Moro: Russian thistle infestation in the trial at Moro was very low and data for Russian thistle control was not trustable. However, the heavy and uniform downy brome (*Bromus tectorum*) infestation in the trial area allowed us to evaluate the treatments for this weed. Spartan Charge did not control downy brome because that herbicide does not have grass activity. Fierce did control downy brome when it was already germinated as it happened with the late winter application (2% of control), however, it exerted an 88% of downy brome control with the late fall application. The downy brome control with metribuzin was close to 95% for the three treatments (late fall, late winter, and the split application).

Table 5. Russian thistle (RT) plants per plot and RT control (%) for the treatments in Pendleton and downy brome (DB) cover (%) and RT control (%) for the treatments in Moro.

Treatments	**Rate**	**RT Plants/plot Pendleton**	**RT Control (%) Pendleton**	**DB cover (%) Moro**	**DB Control (%) Moro**
1. Untreated check	-	480ab	0ab	100a	0a
2. Treated Check **(as needed)** - Glyphosate + Actamaster	32 fl oz/A + 17 lb ai/100 gal	593a	0a	18b	82b
3. Spartan Charge **(Late Fall)**	8 fl oz/A	225bc	53bc	98a	2a
4. Spartan Charge **(Late Winter)**	8 fl oz/A	3c	99c	99a	1a
5. Spartan Charge **(Late Fall)** + Spartan Charge **(Late Winter)**	4 fl oz/A + 4 fl oz/A	10c	98c	100a	0a
6. Fierce **(Late Fall)**	4.5 oz/A	47c	90c	12bc	88bc
7. Fierce **(Late Winter)**	4.5 oz/A	16c	97c	98a	2a
8. Fierce **(Late Fall)** + Fierce **(Late Winter)**	2.25 oz/A + 2.25 oz/A	7c	98c	20b	80b
9. Metribuzin 75 **(Late Fall)**	10.5 oz/A	469ab	2ab	6c	94c
10. Metribuzin 75 **(Late Winter)**	10.5 oz/A	15c	97c	5c	95c
11. Metribuzin 75 **(Late Fall)** + Metribuzin **(Late Winter)**	5.25 oz/A + 5.25 oz/A	83c	83c	5c	95c

Objective 4:
Russian thistle density was significant with the site and the crop. Germinations were higher in Pendleton (5.5 plants m^{-2}) than in Moro (2 plants m^{-2}) and higher in spring wheat (SW) (4.2 plants m^{-2}) than in spring barley (SB) (3.4 plants m^{-2}). In Moro, these spring crops did not suppress Russian thistle during the growing season, but they did it in Pendleton. In Pendleton, during the growing season, Russian thistle was reduced 65% in SB and 36% in SW. Row spacing impacted Russian thistle germination as well as its mortality during the growing season. At harvest, Russian thistle density was 1 and 2.3 plant/m^2 for narrow and wide inter-row space in SB and 2.9 and 4.3 plant/m^2 in SW respectively. These results indicate that SB is more competitive than SW to suppress Russian thistle, although, level of crop competitiveness depended on field site.

Yield for SB and SW was 4 and 3.7 times higher in Pendleton (84 and 59 bu/ac) than in Moro (21 and 16 bu/ac). In Moro, inter-row space and crop density did not clearly affected yield. In Pendleton, high crop density increased crop yield significantly for SW (p-value <0.05) and marginally significantly (p-value <0.1) for SB. The Russian thistle infestation in the trial was not dense enough to cause significant yield losses (Pearson correlation coefficient was not significant).

Russian thistle seed production after harvest was not clearly impacted by crop, row spacing or density. However, Russian thistle in Pendleton produced significantly higher number of seeds (1054 seeds/plant) than in Moro (516 seeds/plant).

a)  b) 

Image 1. View of spring wheat plots in Pendleton a) with wide row spacing (14 in) and b) with narrow row spacing (7 in).

<u>Impacts</u>:

It is necessary to collect one more year of data to confirm some of these preliminary results, but so far, our findings are indicating that:

- The use of best herbicide + adjuvant combination is herbicide-adjuvant specific. For the three herbicides we studied to control Russian thistle, Sharpen (saflufenacil) needs an MSO adjuvant, Deadbolt (bromoxynil +2,4-D) does not seem to gain much with the addition of an adjuvant, and glyphosate really seems to improve its activity with the adjuvant Hel-Fire.
- Residual herbicides look very promising to control Russian thistle in fallow and help delay the development of glyphosate-resistant populations in more Russian thistle populations. In general, the late winter applications seem to control Russian thistle better than the late fall applications. Split applications (fall and winter) could be a good option as well.
- Spring barley showed clearly higher Russian thistle suppression than spring wheat.
- Inter-row spacing seems to be more important than crop density to suppress Russian thistle for the two studied crops. Seven inches of inter-row space prevented Russian thistle germinations in both sites compared to 14 in of inter-row space.

<u>Relation to other research</u>:

This proposal is the base of the project titled "Weed Management in North-Central and Northeastern Oregon" recently funded by OWC for the fiscal year 2019/2020. Objectives 2, 3, and 4 are being repeated and more robust finding will be provided in the progress and final report of the new project. In addition, the results from this project supported the application of a USDA-NIFA grant ($225,000) to leverage the research on Russian thistle management and the OWC funds that was funded in September 2019.

Progress Project Report

PROJECT TITLE: Weed Management in North-Central and Northeastern Oregon.

INVESTIGATOR: Judit Barroso, Weed Scientist, OSU-CBARC.

FUNDING HISTORY:

	2017-2018:	$30,321
	2018-2019:	$35,206
	2019-2020:	$35,000

ABSTRACT:

Growers in the semi-arid region of north-central and northeastern Oregon, where wheat-fallow is the predominant cropping system, rely on repeated applications of non-selective herbicides in fallow, predominately glyphosate, to control Russian thistle. With the recent glyphosate resistance reported in some Russian thistle populations in the region (Barroso et al. 2018), farmers see in Russian thistle an imminent threat to the sustainability of their cropping systems.

In addition to the Russian thistle threat, wheat growers of this region need to control several winter annual grasses, such as, downy brome, cereal rye, rattail fescue, jointed goatgrass, and/or Italian ryegrass, to prevent yield losses. Due to the limited herbicide options, growers depend heavily on the acetolactate synthase (ALS) inhibitors (group II herbicides) to control those weeds and concerns about cases of resistance to those products have recently risen.

The main goals of this project are to improve Russian thistle management in wheat cropping systems by optimizing herbicide application time, by learning how to increase herbicide efficacy with the use of adjuvants, and by diversifying control strategies with the help of residual herbicides and cultural management. Another goal of the project is to evaluate the existence of resistance to group II herbicides in grassy weeds. If the resistance is confirmed, then determine the magnitude of the problem.

Anticipated results from this project will:

a) Help growers to optimize herbicide applications and consequently, maximize investment in Russian thistle control,
b) Provide growers with different alternatives to control Russian thistle helping them to develop herbicide resistance strategies and prevent them from having resistance problems,
c) Help to reduce herbicide pressure, and therefore, the probability of developing resistant Russian thistle,
d) Help growers to learn about their potential resistance problems in grassy weeds and the need for more integrated weed management in their productions.

OBJECTIVE(S):

1) <u>Improve Russian thistle management in wheat cropping systems</u>
   - 1.1- Evaluation of different adjuvants to improve post-emergence Russian thistle chemical control.
   - 1.2- Russian thistle management with residual herbicides.
   - 1.3- Cultural Russian thistle control: Effect of crop type, crop density, and row spacing on Russian thistle germination, mortality, seed production, and crop yield.
2) <u>Evaluation of occurrence of resistance to several herbicides in important grassy weeds such as downy brome, cereal rye, jointed goatgrass, rattail fescue, and/or Italian ryegrass</u>

PROCEDURES:

1) Improve Russian thistle management in wheat cropping systems

1.1-Evaluation of different adjuvants to improve post-emergence Russian thistle chemical control. Adjuvants are added to the spray tank to improve herbicidal activity or application characteristics. However, the cost of these products is significant and its need may vary depending on the herbicide used, environmental conditions and/or weed size. Four trials, two in Pendleton and two in Moro, were established to evaluate several post-emergence herbicides with different adjuvant options (Tables 1, 2, 3, and 4) to control Russian thistle in fallow and post-harvest. The trials in fallow were a complete randomized block design with four repetitions and a plot size of 10 ft by 30 ft. Russian thistle seeds were sprinkled in the experiment area right before seeding to secure a uniform infestation. The trials post-harvest were a split-plot complete randomized block design with four repetitions, where the main plot (10 ft x 40 ft) was the chemical treatment and the sub-plot (10 ft x 20 ft) was the application time (in the first 48 hours after harvest and in two weeks after harvest). Treatments were conducted with a CO_2-powered backpack sprayer delivering 15 gal/A. Visual weed control assessments were performed 3, 6, and 9 WAT to evaluate herbicide and adjuvant efficacy.

1.2-Russian thistle management with residual herbicides. From an herbicide resistant strategy point of view, it is necessary to provide growers with as many tools as possible to control this problematic weed. Two trials in fallow, one in Pendleton and one in Moro, were established to evaluate three different application times (fall, winter, and a split application) of sulfentrazone+carfentrazone, flumioxacin+pyroxasulfone, and metribuzin for Russian thistle control (Tables 5 and 6). The trials were a randomized complete block design with four repetitions. The plot size was 10 ft by 30 ft. Russian thistle seeds were sprinkled in the experiment area to secure a uniform infestation. Treatments were conducted with a CO_2-powered backpack sprayer delivering 15 gal/A. Visual weed control assessments were performed in March, April, May, and June to evaluate herbicide efficacy.

1.3-Effect of crop density, crop species, and row spacing on Russian thistle germination, development, and seed production. Crop competition is key to prevent Russian thistle establishment and the need for subsequent control. We established two field experiments, one in Pendleton and one in Moro to evaluate the effect of two seeding rates, two crop row spacings, and two crop species (spring wheat and spring barley) on Russian thistle control. The experimental design was a split-plot randomized complete block with four repetitions, where the main plot (5 ft x 120 ft) was the inter-row spacing, and the sub-plots (5 ft x 30 ft) were the four combinations of crop species and density (B x den.1, B x den.2, SW x den.1, and SW x den.2). Half of the sub-plots (sub-sub-plot) were sprinkled with Russian thistle before crop seeding to secure a uniform infestation and the other half (5 ft x 15 ft) were left Russian thistle-free. In spring and summer, Russian thistle germination and development was evaluated by throwing a sampling frame (0.5 m x 0.5 m) five times randomly in each sub-sub-plot, counting Russian thistle plants, and estimating percentage or Russian thistle cover inside each frame. Seed production was evaluated from five random plants per sub-sub-plot after harvest.

2) Evaluation of occurrence of resistance to several herbicides in important grassy weeds such as downy brome (*Bromus tectorum*), cereal rye (*Secale cereale*), jointed goatgrass (*Aegilops cylindrica*), rattail fescue (*Vulpia myuros*), and/or Italian ryegrass (*Lolium perenne* spp.

multiflorum). The study of herbicide resistance is being conducted in the greenhouse with dose-response curves. Several grassy weed populations have been collected from growers' fields experiencing control problems. The populations are being tested for the herbicide/s that growers claim to have problems with and for some others that are supposed to control them as well; that way, we will be able to confirm the existence of a resistance problem and potentially provide growers with other chemical options that could help them. Results are being communicated to growers as soon as they are available.

REPORT OF ACCOMPLISHMENTS (BY OBJECTIVE):

Objective 1.1:

Trial in Pendleton in fallow: Treatments were sprayed June 5, 2019. The conditions on June 5 were: air temperature of 72.9 F, relative humidity of 30% and wind from the E at 2.9 mph. Russian thistle was at the 6 leaf to 8 shoot stage and 2-4 inches tall. All treatments showed good control at the 3 weeks after treatment (WAT) evaluation, ranging from 90-100%. However, Russian thistle plants recovered at different levels depending on the treatment. By the 9 WAT evaluation, Sharpen + 2,4-D + Exuro, Sharpen + Exuro, GlyStar Plus + Hel-Fire, and Sharpen + Fire-Zone showed the best control among sprayed treatments, ranging from 89-100%. GlyStar Plus and Sharpen + 2,4-D, both without any adjuvant, had the least control at 58% and 48%, respectively (Table 1). Sharpen, as it was observed in 2018, required of an MSO adjuvant to exert control, adding 2,4-D controlled completely Russian thistle when an MSO adjuvant was added to the tank as well. Glyphosate control was improved with adjuvants. Hel-Fire was the adjuvant in combination with GlyStar Plus that provided the best Russian thistle control (92%).

Table 1. Weed Control (%) of Russian thistle for the treatments at CBARC, Pendleton, OR.

Treatments	**Rate**	**% Weed Control 3 WAT 6/28/2019**	**% Weed Control 6 WAT 7/19/2019**	**% Weed Control 9 WAT 8/6/2019**
1. Untreated	-	0d	0c	0c
2. Sharpen + Fire-Zone + Soln 32	2 fl oz/A + 1% v/v + 2.5% v/v	100a	92a	89a
3. Sharpen + Exuro + Soln 32	2 fl oz/A + 2 pt/A + 2.5% v/v	100a	95a	98a
4. Sharpen + 2,4-D + Soln 32	2 fl oz/A + 16 fl oz/A + 2.5% v/v	94bc	49b	58b
5. Sharpen + 2,4-D + Exuro + Soln32	2 fl oz/A + 16 fl oz/A + 2 pt/A + 2.5% v/v	100a	99a	100a
6. Glystar Plus + AMS	32 fl oz/A + 17 lb/100 gal	90c	57ab	48b
7. Glystar Plus + In-Place + AMS	32 fl oz/A + 17 lb/100 gal + 8 fl oz/A	92c	75ab	75ab
8. Glystar Plus + AccuDrop + AMS	32 fl oz/A + 17 lb/100 gal + 3 fl oz/A	96ab	78ab	75ab
9. Glystar Plus + Hel-Fire + AMS	32 fl oz/A + 17 lb/100 gal + 4 pt/100 gal	98a	88a	92a

Trial in Moro in fallow: Treatments were sprayed on June 10, 2019. On June 10, conditions were as follows: air temperature of 58.7 F, relative humidity of 50% and wind from the S at 1.0 mph. Russian thistle was at the 1-12 shoot stage and 2.5-13 inches tall. Treatments in Moro showed much more variation than those in Pendleton probably due to the higher variability in the Russian thistle plants. At 3 WAT, control ranged from 52-100%. As it was observed in

Pendleton, plants recovered at different levels depending on the treatment. By the 9 WAT evaluation, Sharpen + 2,4-D + Exuro showed the best control (95%) as it happened in Pendleton. This was followed by Sharpen + Exuro (89%) and GlyStar Plus + Hel-Fire (89%). In Moro, the use of In-Place and Accudrop adjuvants with GlyStar Plus did not improve the effect of the herbicide contrarily to observations in Pendleton. Sharpen + 2,4-D without adjuvant had the least control at 1% followed by GlyStar Plus with In-Place or Accudrop where both adjuvants reduced the herbicide effect (Table 2).

Table 2. Weed Control (%) of Russian thistle for the different treatments at CBARC, Moro, OR.

Treatments	**Rate**	**% Weed Control 3 WAT 6/25/2019**	**% Weed Control 6 WAT 7/24/2019**	**% Weed Control 9 WAT 8/5/2019**
1. Untreated	-	0d	0e	0d
2. Sharpen + Fire-zone + Soln 32	2 fl oz/A + 1% v/v + 2.5% v/v	100a	87ab	78b
3. Sharpen + Exuro + Soln 32	2 fl oz/A + 2 pt/A + 2.5% v/v	100a	95a	89ab
4. Sharpen + 2,4-D + Soln 32	2 fl oz/A + 16 fl oz/A + 2.5% v/v	52c	29d	1d
5. Sharpen + 2,4-D + Exuro + Soln 32	2 fl oz/A + 16 fl oz/A + 2 pt/A + 2.5% v/v	100a	98a	95a
6. Glystar Plus + AMS	32 fl oz/A + 17 lb/100 gal	83b	88ab	70b
7. Glystar Plus + AMS + In-Place	32 fl oz/A + 17 lb/100 gal + 8 fl oz/A	60c	78bc	34c
8. Glystar Plus + AMS + AccuDrop	32 fl oz/A + 17 lb/100 gal + 3 fl oz/A	56c	75c	21c
9. Glystar Plus + AMS + Hel-Fire	32 fl oz/A + 17 lb/100 ga + 4 pt/100 gal	99a	96a	89ab

Trial in Pendleton post-harvest: When plots were sprayed 2 days after harvest (DAH), most treatments performed more poorly than when treated 2 weeks after harvest (WAH) (Table 3). This may be due to the plants having extra time to regrow after harvest, therefore having more surface area to be treated and/or growing more actively. GlyStar Plus treatments and Huskie treatment were the less affected by the spray time. All four GlyStar Plus treatments, as well as the Huskie treatment, showed Russian thistle control of 94-100% on the final evaluation date. The remaining treatments, including all Sharpen treatments, Deadbolt, Brox-M, and Starane NXT, showed varying degrees of significant difference ranging from 53-100% on the final evaluation date. Brox-M showed the lowest Russian thistle control (53%) among sprayed treatments. All Sharpen treatments, Deadbolt and Starane NXT treatments showed similar control to GlyStar Plus and Huskie treatments when they were sprayed 2WAH. There was not significant difference among the adjuvants applied with GlyStar Plus (glyphosate) or Sharpen (saflufenacil).

Trial in Moro post-harvest: Similarly to the results in Pendleton, all treatments improved their Russian thistle control when they were sprayed 2WAH compared to 2DAH (Table 4). GlyStar Plus and Sharpen treatments were the least affected by the spray time with percentage of control between 93 and 100 on the final evaluation. The remaining treatments, including all Sharpen treatments, Deadbolt, Brox-M, and Starane NXT, showed varying degrees of significant difference ranging from 51-100% on the final evaluation date. Brox-M showed the lowest Russian thistle control (51%) among sprayed treatments. Sharpen + adjuvants treatments and the

Deadbolt treatment had similar percentages of control than Huskie and GlyStar Plus when they were sprayed 2WAH. Sharpen showed the need for an MSO adjvant, the control with Sharpen + MSO was always higher that with the tank mix Sharpen + 2,4-D as it can be observed in the Pendleton trial as well. There was not significant difference among the adjuvants applied with GlyStar Plus or Sharpen.

Table 3. Weed control (%) of Russian thistle for the different treatments at 2 DAH and 2 WAH at CBARC, Pendleton, OR in 2019.

Treatments	Rate	% Weed Control 3 WAT - 2 DAH 9/11/2019	% Weed Control 3 WAT – 2 WAH 9/23/2019	% Weed Control 6 WAT - 2 DAH 10/4/2019	% Weed Control 6 WAT – 2 WAH 10/17/2019
1. Untreated	-	0e	0d	0h	0c
2. Sharpen + Fire-Zone + Soln 32	2 fl oz/A + 1% v/v + 2.5% v/v	80ab	96a	72ef	99a
3. Sharpen + Exuro + Soln 32	2 fl oz/A + 2 pt/A + 2.5% v/v	81ab	95a	79de	99a
4. Sharpen + 2,4-D + Soln 32	2 fl oz/A + 16 fl oz/A + 2.5% v/v	72abc	90a	63fg	98a
5. Sharpen + 2,4-D + Exuro + Soln 32	2 fl oz/A + 16 fl oz/A + 2 pt/A + 2.5% v/v	93a	98a	89bcd	100a
6. Huskie + Soln 32 + R-11	15 fl oz/A + 2 qt/A + 2 qt/100 gal	75ab	91a	94abc	100a
7. Deadbolt	16 fl oz/A	65bc	78b	85cd	97a
8. Brox-M	16 fl oz/A	31d	70c	53g	89b
9. Starane NXT	16 fl oz/A	51c	82b	72ef	98a
10. Glystar Plus + AMS	32 fl oz/A + 17 lb/100 gal	88ab	95a	95ab	99a
11. Glystar Plus + AMS + In-Place	32 fl oz/A + 17 lb/100 gal + 8 fl oz/A	92ab	93a	99a	98a
12. Glystar Plus + AMS + AccuDrop	32 fl oz/A + 17 lb/100 gal + 3 fl oz/A	94a	95a	99a	100a
13. Glystar Plus + AMS + Hel-Fire	32 fl oz/A + 17 lb/100 gal + 4 pt/100 gal	97a	98a	99a	100a

Table 4. Weed control (%) of Russian thistle for the different treatments at 2 DAH and 2 WAH at CBARC, Moro, OR in 2019.

Treatments	Rate	% Weed Control 3 WAT - 2 DAH 9/19/2019	% Weed Control 3 WAT - 2 WAH 9/19/2019	% Weed Control 6 WAT - 2 DAH 10/2/2019	% Weed Control 6 WAT – 2 WAH 10/16/2019
1. Untreated	-	0d	0d	0e	0c
2. Sharpen + Fire-zone + Soln32	2 fl oz/A + 1% v/v + 2.5% v/v	77ab	93a	83abc	98a
3. Sharpen + Exuro + Soln32	2 fl oz/A + 2 pint/A + 2.5% v/v	86ab	96a	85abc	100a
4. Sharpen + 2,4-D + Soln32	2 fl oz/A + 16 fl oz/A + 2.5% v/v	71b	78ab	74c	86b
5. Sharpen + 2,4-D + Exuro + Soln32	2 fl oz/A + 16 fl oz/A + 2 pint/A + 2.5% v/v	94a	97a	96ab	100a

6. Huskie + Soln 32 + R-11	15 fl oz/A + 2 qt/A + 2 qt/100 gal	86ab	88a	93ab	100a
7. Deadbolt	16 fl oz/A	85ab	83a	79bc	90ab
8. Brox-M	16 fl oz/A	44c	59c	51d	87b
9. Starane NXT	16 fl oz/A	71b	58c	82abc	87b
10. Glystar Plus + AMS	32 fl oz/A + 17 lb/100 gal	92ab	75abc	98ab	100a
11. Glystar Plus + AMS + In-Place	32 fl oz/A + 17 lb/100 gal + 8 fl oz/A	95a	79ab	96ab	99a
12. Glystar Plus + AMS + AccuDrop	32 fl oz/A + 17 lb/100 gal + 3 fl oz/A	91ab	63bc	98ab	100a
13. Glystar Plus + AMS + Hel-Fire	32 fl oz/A + 17 lb/100 gal + 4 pt/100 gal	95a	94a	99a	100a

Objective 1.2: The late fall treatments were applied on mid-late November 2018 in Pendleton and Moro. The late winter treatments, including the treated check, were applied on March 16, 2019. Both trials were sprayed after the first evaluation was done using 48 fl oz/A of GlyStar Plus on 5/28/19.

Trial in Pendleton: Russian thistle plants m^{-2} were not significant with the treatments due to the high variability in the replications observed this year. However, we found less Russian thistles in the late winter and split applications compared to the spring applications (Table 5). Studying the treatment effect on two other problematic weeds, we observed that Fierce and Metribuzin 75 at all applications reduced prickly lettuce (*Lactuca serriola*) compared to the untreated checks. Tumble mustard (*Sisymbrium altissimum*) was significantly reduced with all treatments compared with the untreated plots. However, the control seemed better with Fierce or Metribuzin 75.

Table 5. Russian thistle (RT), tumble mustard (TM), and prickly lettuce (PL) density for the different treatments in Pendleton 2019.

Treatments	Rate	RT plants m^{-2} 5/15/2019	RT Total 25 m^{-2}	PL Plants m^{-2} 5/15/2019	TM plants m^{-2} 5/15/2019
1. Untreated check	-	0.4a	16.3a	27.3a	9.2a
2. Treated Check **(as needed)** - Glyphosate + Actamaster	32 fl oz/A + 17 lb ai/100 gal	0.7a	28.3a	13.1ab	1.2b
3. Spartan Charge **(Late Fall)**	8 fl oz/A	0.2a	8.3a	24.5a	2.6b
4. Spartan Charge **(Late Winter)**	8 fl oz/A	0a	0.3a	19ab	1.9b
5. Spartan Charge **(Late Fall)** + Spartan Charge **(Late Winter)**	4 fl oz/A + 4 fl oz/A	0a	0a	22.1a	2.2b
6. Fierce **(Late Fall)**	4.5 oz/A	0.3a	9a	1.9b	0b
7. Fierce **(Late Winter)**	4.5 oz/A	0a	0a	0.5b	0.1b
8. Fierce **(Late Fall)** + Fierce **(Late Winter)**	2.25 oz/A + 2.25 oz/A	0a	0.5a	0.1b	0b
9. Metribuzin 75 **(Late Fall)**	10.5 oz/A	1.8a	48.8a	11.6b	0.1b
10. Metribuzin 75 **(Late Winter)**	10.5 oz/A	0a	0.3a	0b	0b
11. Metribuzin 75 **(Late Fall)** + Metribuzin **(Late Winter)**	5.25 oz/A + 5.25 oz/A	0.2a	6a	0b	0b

Trial in Moro: The low Russian thistle density in this trial made the results on its control not very reliable. In addition, as it happened in Pendleton, the high variability observed in the data prevented detection of significant differences between the treatments and the untreated plots. However, a natural and pretty uniform infestation of prickly lettuce and tumble mustard allowed us to evaluate the treatments for these important species. The herbicide effect on prickly lettuce control was not significant but no prickly lettuce plants germinated with Fierce herbicide. The herbicide effect on tumble mustard was significant for Fierce and Metribuzin 75. No tumble mustard plants were observed with Fierce at all application times. Spartan Charge did not reduce the tumble mustard infestation significantly.

Table 6. Russian thistle (RT), tumble mustard (TM), and prickly lettuce (PL) density for the different treatments in Moro 2019.

Treatments	Rate	RT Plants m^{-2} 5/16/2019	RT Total $25m^{-2}$	PL Plants m^{-2} 5/16/2019	TM plants m^{-2} 5/16/2019
1. Untreated check	-	0.6ab	15.3ab	0.8a	2.8ab
2. Treated Check **(as needed)** - Glyphosate + Actamaster	32 fl oz/A + 17 lb ai/100 gal	1a	25.3a	0.8a	0.7bc
3. Spartan Charge **(Late Fall)**	8 fl oz/A	0b	0b	0.7a	3a
4. Spartan Charge **(Late Winter)**	8 fl oz/A	0.2ab	5ab	0.3a	0.6bc
5. Spartan Charge **(Late Fall)** + Spartan Charge **(Late Winter)**	4 fl oz/A + 4 fl oz/A	0b	0b	0.1a	0.7bc
6. Fierce **(Late Fall)**	4.5 oz/A	0.1b	2.5b	0a	0c
7. Fierce **(Late Winter)**	4.5 oz/A	0b	0b	0a	0c
8. Fierce **(Late Fall)** + Fierce **(Late Winter)**	2.25 oz/A + 2.25 oz/A	0.1b	2.5b	0a	0c
9. Metribuzin 75 **(Late Fall)**	10.5 oz/A	0.2ab	5ab	0.3a	0.1c
10. Metribuzin 75 **(Late Winter)**	10.5 oz/A	0b	0b	0.1a	0c
11. Metribuzin 75 **(Late Fall)** + Metribuzin **(Late Winter)**	5.25 oz/A + 5.25 oz/A	0.1b	2.5b	0.3a	0.2c

Objective 1.3: In 2019, Russian thistle infestation was significantly different with the site. In Pendleton, Russian thistle density pre-harvest (0.78 plants m^{-2}) was twice higher than in Moro (0.4 plant m^{-2}). Differences in Russian thistle densities between spring wheat (SW) and spring barley (SB) were not detected this year. Both crops at both sites suppressed Russian thistle, but this year (compared to 2018 observations) the suppression efect was higher in Moro (29% on average) than in Pendleton (20% on average). In Moro, where the crop was more competitive this year, Russian thistle germination and mortality was impacted by row spacing. Russian thistle germination was twice higher in the wide inter-row space than in the narrow inter-row space and almost double at the end of the growing season. In Pendleton, the narrow inter-row spacing produced less Russian thistle than the wide inter-row space, however, we think that this result could be as a consequence of a common lambsquarter (*Amaranthus albus*) problem that occurred in the experiment. When the lambsquarter infestation was detected, it was controlled in the plots by hand weeding, but it interacted with the crops and Russian thistle germination for several weeks. It could have happened that the high lambsquarter pressure germinated less in the narrow inter-row space and, when it was time for the Russian thistle to germinate, it found less competition in the narrow inter-row spacing than in the wide inter-row spacing. Crop density did not have an effect on Russian thistle germination or suppression in line with 2018 observations.

Crop yield was significantly affected by site and crop. Moro had higher yields than Pendleton with SB yielding higher than SW, 73 and 52 bu/ac on average in Moro, and 49 and 35 bu/ac in Pendleton, respectively. The higher yields in Moro could be explained by the fact that the trial's field was in fallow the previous year, while the trial's field followed winter wheat in Pendleton. In Pendleton, high SB density increased yield significantly but that effect was not observed for the SW. In Moro, the wide inter-row space increased yield compared with the narrow inter-row space. Russian thistle density did not impact yield due to the very low Russian thistle density in both locations and crops.

This year, Russian thistle seeds per plant were affected by the site and the crop. Plants in Moro had higher amount of seeds (1279 seeds/plant) than in Pendleton (374 seeds/plant) and in SW (1144 seeds/plant) than in SB (509 seeds/plant). Consequently, the highest amount of seeds were found in Moro after SW (1883 seeds/plant) and the lowest in Pendleton after SB (343 seeds/plant). Row spacing and/or crop density did not affect Russian thistle seed production as it was observed in 2018.

Objective 2: The first set of experiments has been conducted and the second set of greenhouse experiments are being conducted. More populations are expected to be collected this summer. Results on this objective will be provided in the final report.

From the first set of experiments, we observed that resistance to group 2 herbicides in downy brome seems to be very common in northeastern Oregon. We also found Italian ryegrass and cereal rye resistant to Beyond (imazamox). Jointed goatgrass will be tested against Beyond this summer.

IMPACTS:

- The use of best herbicide + adjuvant combination is herbicide-adjuvant specific. Saflufenacil with an MSO adjuvant and bromoxynil products have shown to be good alternatives to control Russian thistle in fallow or post-harvest. Glyphosate effect is improved with the adjuvant Hel-Fire.
- Spartan Charge (sulfentrazone + carfentrazone), Fierce (flumioxazin + pyroxasulfone) and metribuzin are good options to control Russian thistle in fallow. Best results are obtained when the residual herbicides are applied in late winter or in split applications (late fall + late winter).
- Metribuzin and Fierce can be used to control downy brome, tumble mustard and prickly lettuce as well. However, to control downy brome with Fierce, a late fall application is needed.
- A good crop is necessary to suppress Russian thistle germination and reduce its density during the growing season. Spring barley has shown to be more competitive than spring wheat to suppress Russian thistle.
- Benefits of different crop inter-row spacing or crop density are not clear to suppress Russian thistle during the growing season or to affect its seed production after harvest.

RELATION TO OTHER RESEARCH:

The objective 1 of this proposal is the second year of the project titled "Russian thistle Management in Wheat Cropping Systems" funded by OWC for the fiscal year 2018/2019. In addition, the research of this project is related and complement the research of a NIFA project recently funded to improve Russian thistle control.

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To: Oregon Wheat Commission
RE: 2018-2019 Funding Report
Notes: Please keep reports as brief as possible and focused on applicable results.

Affordable Management for Soilborne Wheat Mosaic Virus

"Wheat soil-borne mosaic: yield loss and distribution in the US Pacific Northwest" was accepted for publication in plant disease.

Abstract with results: Soil-borne wheat mosaic virus (SBWMV), the causal agent of Wheat soil-borne mosaic (WSBM) was discovered for the first time in the dryland wheat production zone of the US Pacific Northwest (PNW) in 2008. Current WSBM distribution in the Walla Walla Valley that spans the Oregon/Washington border was documented during 2017 and 2018. Yield loss estimates of rainfed winter wheat were also determined for this growing region. WSBM is more widely distributed in the Walla Walla Valley than was previously estimated. Significant reductions of grain yield (40%), biomass (37%), and heads per area (34%) were documented in association with SBWMV infection in commercial winter wheat fields each year. Test weight was reduced by 2.3% (P=0.08). No significant difference in the number of spikelets per head was observed in association with WSBM. This work is part of an ongoing effort to provide management solutions to WSBM.

Assessment of soil acidity on soil-borne pathogens, weed spectrum, herbicide activity, yield and crop quality on dryland wheat production

Preliminary results associated with WGC/OWC soil acidity plots in Pendleton (OR), Moro (OR), Clark Farm (WA), and the Palouse Conservation Field Station (PCFS, WA)

- At all four locations, the lime application in fall 2016 created a pH gradient at the soil surface (0-3in). The gradient at Pendleton (pH 4.87 – 5.93) may be most compelling.
- At all four locations, the lime application in 2016 has yet to impact soil pH below 3in.
- At all four locations, there was no yield response to the lime application in harvest 2019. However, we expect to observe a yield response in time, as the lime treatment moves down further into the soil profile.

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Affordable Management for Soilborne Wheat Mosaic Virus

Soilborne wheat mosaic virus symptoms were excellent in our nursery this year, but symptoms are already starting to fade away. SBWMV has not been a huge issue in the region this year, and plant clinic samples with SBWMV seem to be down. I think it is a combination of resistant varieties and blends are getting planted in fields with known SBWMV issues, and that most farmers/consultants are familiar enough with SBWMV symptoms now. All programs breeding for the PNW have a source of resistance that they are working with. We are also approaching our second year if seeing nitrogen top dress may prevent yield loss.

Assessment of soil acidity on soil-borne pathogens, weed spectrum, herbicide activity, yield and crop quality on dryland wheat production

We have leveraged OWC and WGC funds to complete microbiome work on the pH plots. We are preparing a manuscript titled, “Impacts of lime application on soil bacterial microbiome in dryland wheat soil in the Pacific Northwest” – which will be submitted to Applied Soil Ecology

We will complete disease notes and harvest the plots to complete three years of data on this trial in Summer 2020.

This OWC soil acidity study has gained NRCS attention, and this work will be continued in an NRCS funded trial in collaboration with Dr. Amber Moore.

Progress (Final) Report for the Agricultural Research Foundation
Oregon Wheat Commission
April 2020

TITLE: Effects of Sulfentrazone Application on Russian Thistle Control in Fallow

INVESTIGATOR: Larry Lutcher (Columbia Plateau Region; Oregon State University—Morrow County Office); larry.lutcher@oregonstate.edu; 541-676-9642 and 541-571-4454

COOPERATORS: Wheat Producers (Bill Jepsen, Brent Martin, Eric Orem, Chris Rauch, John Rietmann, Corey Miller, Mark Miller).

FUNDING HISTORY: $12,950; Effects of Sulfentrazone / Russian Thistle Control; 2017
$10,730; Effects of Sulfentrazone / Russian Thistle Control; 2018

ABSTRACT: Russian thistle (*Salsola tragus* L.) is one of the most troublesome weed species in fields of no-till fallow in Oregon. Control of Russian thistle has traditionally been accomplished with three-to-four applications of glyphosate. This approach appears to be less effective than it once was. Reduced control may be the result of a developing herbicide resistance problem in biotypes exposed to long-term selection pressure i.e., repeated applications of glyphosate. Research evaluated the potential for a weed control program that relied on applications of glyphosate AND sulfentrazone. Russian thistle control in experimental fields of fallow, treated with either a fall or spring treatment, was good-to-excellent. Residual levels of sulfentrazone in soil treated with either a fall or spring application of Spartan® Charge were statistically similar. There was no observable carryover effect on subsequently planted winter wheat.

OBJECTIVES: The primary goal of this research was to evaluate the efficacy of a fall sulfentrazone (Spartan® Charge) application in fields of no-till fallow. This project was also an attempt to introduce a more diversified approach to killing thistle plants—an option that may be used, along with other methods, to delay or postpone an evolving glyphosate resistance problem in weed species of Oregon.

PROCEDURES:

Location and Duration of Field Research/Treatments

Eight field experiments were conducted in farmers' fields in Morrow County, Oregon. Sulfentrazone was applied at a relatively high rate (8 oz Spartan® Charge/acre) at four sites in the fall of 2016 and spring of 2017. The same treatment was applied to four other sites in the fall of 2017 and the spring of 2018.

REPORT OF ACCOMPLISHMENTS: There were multiple flushes of thistle plants in control plots (plots treated with glyphosate only). Sulfentrazone treatments killed thistle plants as they were emerging. Fall and spring treatments were equally effective.

Sulfentrazone levels in soil were measured in mid-October of the crop year. These measurements, made eight months after the spring treatment and 12 months after the fall treatment, support weed control data. Seventy-five percent of the sulfentrazone in soil was concentrated in the top four inches of the profile. The remaining 25% was measured in the 4-to-8 inch layer. There was no evidence of leaching below this depth.

Sampling Depth (inches)	**Average Residual Concentration of Sulfentrazone in Soil**† (ppm)		
	Control	**Fall Treatment**	**Spring Treatment**
0-4	0.000	0.063	0.064
4-8	0.000	0.020	0.022
8-12	0.000	0.000	0.000
Total	0.000	0.083	0.086

† *Sulfentrazone concentrations in soil are mean values from composited samples collected within the boundaries of eight field trials in Morrow County, Oregon.*

The potential for crop injury was initially evaluated using a simple visual assessment of wheat growing in plots treated with sulfentrazone during the previous year. Plants looked healthy, and there was no observable difference in plant growth for either one of the sulfentrazone treatments. Data from a yield component analysis are consistent with visual observations. Yield component analysis evaluated the number of heads growing in a designated area (HPU), thousand kernel weight (TKW) of grain, and the number of kernels per spike (KPS). Yield components (and plant height measurements), determined just before harvest, are listed in the table below.

Treatment	Yield Component and Plant Height Data			
	HPU	TKW	KPH	Plant Height (inches)
No Sulfentrazone (Control)	30	36	44	32
Fall Sulfentrazone Application	34	36	44	32
Spring Sulfentrazone Application	33	37	44	32

† *HPU (number of heads per unit area); TKW (thousand kernel weight); KPS (number of kernels per head).*

Soil pH and soil organic matter have a significant effect on the persistence (*and effectiveness*) of sulfentrazone in soil. Average soil pH and organic matter data, collected from the eight sites used in this experiment, can be found in the table below. The use of sulfentrazone or sulfentrazone-containing products may vary in fields when these soil properties fall outside the range of values encountered during this project. **Always read and follow label directions.**

Sampling Depth (inches)	-----------Soil pH†-----------		Soil Organic Matter† (%)	
	Mean†	Range	Mean†	Range
0-4	6.2	5.1 – 7.2	1.8	1.2 – 2.3
4-8	6.7	5.6 – 7.8	1.2	0.9 – 1.7
8-12	7.4	6.7 – 8.3	1.0	0.9 – 1.4

† *Soil pH and organic matter data are averages from samples collected at eight trials in Morrow County, Oregon.*

IMPACTS: Knowledge generated from this research is useful because it documents the effectiveness of a fall (*never used before*) application for sulfentrazone. Fall treatments are an option that can be used to reduce spring work load. Increased awareness of the effects of sulfentrazone application are an outcome of field demonstrations during local and regional crop tours. On-farm use of sulfentrazone, which is increasing, should postpone an evolving glyphosate resistance problem in weed species of Oregon.

RELATION TO OTHER RESEARCH: Proposed research is a unique, stand-alone project. The overall goal of this research is the same as that for other field experiments being conducted by the investigator—to increase profit associated with dryland wheat production.

Progress Report for the Agricultural Research Foundation
Oregon Wheat Commission
April 2020

TITLE: **Product Evaluation for Wheat Producers**

INVESTIGATOR: Larry Lutcher (Columbia Plateau Region; Oregon State University—Morrow County Office); larry.lutcher@oregonstate.edu; 541-676-9642 and 541-571-4454

COOPERATORS: Wheat Producers (Brent Martin, Eric Orem, Corey Miller, Mark Miller)

FUNDING HISTORY: $12,950; Effects of Sulfentrazone / Russian Thistle Control; 2017
$10,730; Effects of Sulfentrazone / Russian Thistle Control; 2018
$13,248; Product Evaluation for Wheat Producers; 2019

ABSTRACT: Profit margins for dryland wheat production are shrinking at an alarming rate. Increased revenue may (or may not) be achieved from the use of two relatively new products. The first product is a zinc seed treatment called TMC Seed Start. The second product is the active ingredient (pyroxasulfone) found in different formulations (Zidua® or Zidua® SC) of a group 15 herbicide.

OBJECTIVES: The primary goal of proposed research is to evaluate the efficacy and cost associated with use of a zinc seed treatment and a new group 15 herbicide.

PROCEDURES: Field work is on-going. Methodology is as described in the approved proposal.

REPORT OF ACCOMPLISHMENTS: Zinc Seed Treatment Research. Planting occurred in September of 2019. Topsoil moisture was adequate at the experimental site, and plants emerged quickly. The stand looks good at the present time, but soil moisture is depleted and rain is not in the forecast. Yields (and the potential for a response to the zinc seed treatment) will be reduced unless it rains soon. Necessary plant sampling has been completed. Plant samples will be tested for zinc concentration and dry matter weights will be used to calculate uptake.

Pyroxasulfone Evaluation of Cheatgrass Control. Fall treatments were applied in November of 2019. Spring treatments went on during the first week of April (2020).

IMPACTS: N/A

RELATION TO OTHER RESEARCH: Proposed research is a unique, stand-alone project. The overall goal of this research is the same as that for other field experiments being conducted by the investigator—to increase profit associated with dryland wheat production.