Montana Wheat & Barley Committee Project Reviews February 5, 2014 MSU's Thayer Conference Room (108 Plant Bioscience Building) - Bozeman	
7:55	**Opening Comments, Glenn Duff**
8:00	**Perry Miller - Grant 4W4628** (Legacy of long-term diversified cropping systems)
8:20	**Mike Giroux – Grant 4W4607** (Creation and end product quality testing with no PPO activity)
8:40	**Peggy Lamb – Grants 4W4635 - 4640** (Evaluation of materials/practices contributing to econ. crop production in MT); **- Grants 4W4617 & 4625** (soil sampling equipment & weather data collection)
9:00	**Alan Dyer – Grant 4W4614** (Pre-breeding for root health in Montana's wheat)
9:20	**Jack Martin – Grant 4W4619** (Characterization of new sources of the solid stem trait in wheat)
9:40	**Li Huang – Grant 4W4610** (Create broad-spectrum resistance to biotrophic pathogens in wheat)
10:00	**Coffee Break**
10:15	**Stephanie Ewing – Grant 4W4603,** equipment (Soil analysis: purchase of a new Lachat quickchem flow injection analysis system)
10:20	**Phil Bruckner – Grant 4W4602** (Winter wheat breeding and genetics)
10:40	**Gadi Reddy – Grant 4W4604 & 4618** (Trapping click beetles with pheromone traps – Coleoptera: Elateridae) & (truck)
11:00	**Kent McVay – Grant 4W4630** (Adding ESN to Urea as nitrogen source for irrigated spring wheat production)
11:20	**Prashant Jha via Kent McVay – Grants 4W4623 & 4W4627** (Field survey for occurrence of herbicide-resistant kochia in Northern MT) & (Light-activated sensor controlled sprayer technology)
11:35	**Ken Kephart via Kent McVay – Grant 4W4626,** equipment (Strategic investment in SARC for small grains research in S. Central MT)
11:40	**Deanna Nash – Grant 4W4613** (Improved quality of MT hard red and hard white wheats)
12:00	**Lunch Break – Kevin Brown & Dale Schuler presenting report on $500,000 grant for endowed chair in Plant Sciences**
12:40	**Bob Stougaard – Grant 4W4609** (Orange wheat blossom midge management)
1:00	**Luther Talbert – Grant 4W4601** (Spring wheat breeding and genetics)
1:20	**Mary Burrows – Grant 4W4615** (Plant disease management and education in MT)
1:40	**Jamie Sherman – Grant 4W4612** (Molecular breeding pipeline for wheat)
2:00	**Carl Yeoman – Grant 4W4611** (Potential of WSS endosymbiotic microbiata for exploitation in dev. management strategies)
2:20	**Tom Blake – Grant 4W4605** (Identifying and developing improved barley varieties for MT)
2:40	**Coffee Break**
2:55	**Tony Hartshorn – Grant 4W4606,** equipment (Soil carbon turnover: a proposal to upgrade an existing gas analyzer)
3:00	**David Weaver – Grants 4W4599, 4608 & 4616** (Expanded implementation of wheat stem sawfly IPM) ,(Integrating multiple agronomic tactics for suppression of severe WSS infestations) & (Parasitoids of the wheat stem sawfly: augmentation, impact & education)
3:20	**Kevin Wanner – Grant 4W4620** (Managing wireworm damage to wheat & barley – a growing problem in MT)
3:40	**Fabian Menalled – Grant 4W4621** (Control of glyphosate-resistant kochia in fallow w/soil active herbicides)
4:00	**Joyce Eckhoff – Grant 4W4629** (Early generation durum selection and germplasm improvement)
4:20	**Olga Walsh – Grant 4W4622** (Sensor-based nitrogen fertilization algorithm for winter wheat varieties)
4:40	**Dave Wichman – Grant 4W4634** (Post-harvest seed dormancy in barley and winter wheat cultivars)
5:00	**Paul Stoy – Grants 4W4624 & 4631** (Carbon & water exchange/purchase of infrared gas analyzer and sonic anemometer) & (Water use/carbon sequestration in MT wheat fields: towers & satellite measurements)

Note: Grant 4W4633, Continuing as an underwriter for Montana Ag Live!, report already provided by Jack Riesselman; and
Grant 4W4632, Ag Appreciation Weekend 2013, report already provided by Glenn Duff.

1. **Title**: Legacy effects of long-term diversified cropping systems (4W4628)

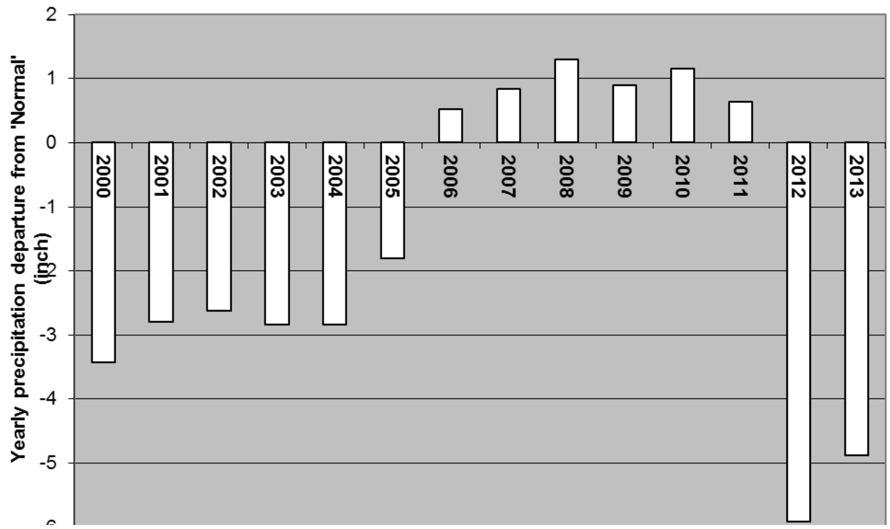
2. **Principal Investigator**: Perry Miller and Clain Jones, Dep. Land Resources & Environmental Sciences
   Project Personnel: Jeff Holmes - Field Operations; Terry Rick – Soil and Plant Analyses

3. **Objective:**
   Report long-term cropping systems legacy effects on weed communities, soil nitrogen use efficiency, and crop yield and quality.

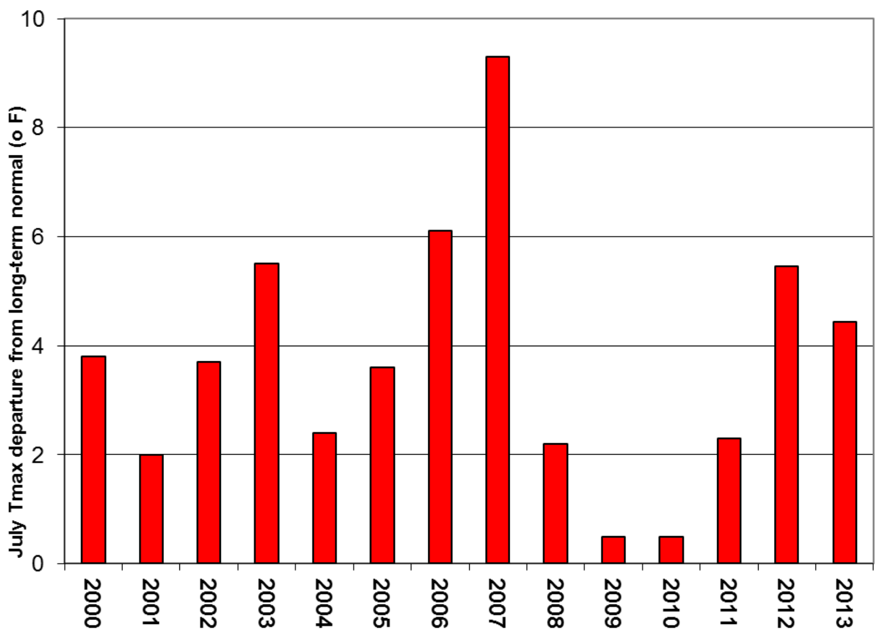
4. **Results**

2013 Weather

2012/13 was the 2nd driest crop year in the 47-yr history of weather records at the Bozeman Post research farm, following on heels of the record dry 2011/12 season (Figure 1). July continued the consistent trend of warmer than average temperatures (Figure 2).



Figures 1 (top) and 2 (bottom). Crop year (Sep - Aug) rainfall departure from LTA at the MSU A.H. Post Research Farm, Bozeman, MT. LTA = 30-yr normal from 1981-2010; 16.2 inch.



Departure from long-term mean July temperature.

2013 data that can be reported by this Jan 15 deadline is preliminary.

Table 1. Uniformly managed yellow mustard plant densities and seed yield, Bozeman, 2013.					
2012 Phase/Fert	Crop stubble	Plant stand	Seed protein	Seed yield[z]	
		per m^2	%	Mg ha^{-1}	lb ac^{-1}
Full N	NA	NA		0.89	890
Half N	NA	NA		0.89	887
	Cropping systems legacy effects				
CW	Wtr wheat	127		1.02	1020
NTD2H	Wtr wheat	155		0.78	783
NTD2L	Wtr wheat	155		0.69	692
NTD4H	O.P. corn	141		1.10	1096
NTD4L	O.P. corn	141		0.82	822
NTO2H	Spr wheat	173		1.17	1171
NTO2L	Spr wheat	173		0.73	730
NTO4H	Wtr wheat	112		0.86	860
NTO4L	Wtr wheat	112		0.75	750
NTP2H	Wtr wheat	151		1.18	1180
NTP2L	Wtr wheat	151		0.69	690
NTP4H	Spr wheat	136		1.13	1130
NTP4L	Spr wheat	136		0.91	906
Org2	Wtr wheat	130		0.59	594
Org4	Spr wheat	142		0.61	614
Nat2	Wtr wheat	136		0.79	787
Nat4	Spr wheat	171		1.10	1096
$LSD_{0.05}$		*NS*		*0.14*	*140*

[z] Mg/ha on estimated dry matter basis; lb/ac 12% moisture basis.

1) Weeds were counted May 28 – June 2, 2013, five weeks after seeding. Cotyledon-stage dicot weeds (almost entirely pennycress) were highly numerous in some plots but were ignored since they were not providing important competition. Only 2,788 weeds had reached an identifiable stage. Creeping thistle caused yield interference in several of the organic legacy plots. No post-emergent herbicide application was possible for dicot weeds.

2) Seeding date was delayed to April 24 to ensure a weed-free seedbed. Seedling densities of 150/m^2 were targeted and the average seedling density 5 weeks after planting was 144/m^2. The very dry spring caused prolonged emergence. Yellow mustard at the true leaf stage was 102/m^2 in spring wheat stubble compared with only 67/m^2 in winter wheat stubble due to heavier winter wheat residue loads that delayed emergence. Interestingly these stubbles did not differ in total final emergence. There was no effect of current, or previous, N management legacy on plant stand.

3) The target yield was 1800 lb/ac but the average trial yield was exactly half the target. The big majority of effective rainfall fell May 16 – June 25, with very little rain before, or after, that 5-wk rainy spell. Previous year crop effect showed that mustard yielded 984 lb/ac on spring wheat stubble, compared with only 868 lb/ac on winter wheat stubble ($P<0.05$) likely related to more timely emergence in spring wheat stubble. A puzzling legacy effect relates to previous N management (high vs low) where the high legacy yielded 1036 lb/ac compared with 764 lb/ac for the low legacy. Since the current year banded N applications had zero effect on seed yield this legacy effect, in a highly water-stressed year, was very unexpected and difficult to explain. Another legacy effect likely also related to soil fertility in that the 'Pulse' system yielded 975 lb/ac compared with 877 and 848 lb/ac for the 'Oilseed' and 'Diverse' systems, respectively ($P<0.05$). Note that the presence of winter and spring wheat stubbles was balanced in these legacy comparisons so these appear to be effects that are related to long-term soil properties. The organic system yielded the lowest at 604 lb/ac compared with 975 lb/ac for the 'Pulse' system (same pulse crop frequency as Organic) and 942 lb/ac for the 'Natural' system which had the same rotation as Organic, but used herbicides and fertilizer judiciously. The negative organic effects are at least partially related to yield interference by c.thistle which was observed later in the growing season.

5. Summary

Legacy effects related to soil fertility affected a uniformly managed yellow mustard crop despite zero apparent effect from current year N applications. This raises interesting questions about the potential value of long-term soil enrichment. Creeping thistle in organic systems reduced seed yields in mustard by about 35%.

6. Funding Summary

Funding from the MWBC in support of the operation of this (and one other) long-term study has been critically important in leveraging additional funding for more detailed scientific research projects. $3.5 million in independent funding has been obtained, helped directly or indirectly, by this study.

2000-present

The Montana Ag Experiment Station pays for the salary of Perry Miller and other faculty associated with these studies, and 50-75% of Jeff Holmes' salary, the research associate with primary responsibility for operating these studies.

2012-2014

A grant proposal was received from the Pacific Northwest Canola Research Program in the amount of $22,000 to study stubble microclimate effects on winter canola survival. The genesis for that proposal came directly from this study.

2012-2016
Pat Hatfield and Fabian Menalled led successful proposals to the USDA-NIFA Organic Transitions and the Organic Research and Education Initiative programs for $743,000 and $1.5 million, respectively, with the goal of reducing tillage intensity in organic cropping systems to improve soil quality. This study provided preliminary data in support of that grant, and has been helpful in refining techniques to study sheep grazing interactions with legume green manures.

2008-2011
Perry Miller and other MSU scientists received $400,000 from the USDA-NIFA NRI Managed Ecosystems Program to study energy dynamics in Montana cropping systems. The existence of these rotation studies was key to this successful grant application. Indirectly this has led to the hiring of Mac Burgess Dec 1, 2013, a new cropping systems scientist located in the Plant Sciences and Plant Pathology Dept (this USDA study provided the funding for Mac's Ph.D.)

2009-2011
Clain Jones and Perry Miller received $23,100 from the Montana Fertilizer Advisory Committee to study overwinter soil N mineralization, soil nutrient status, and nitrogen fertilizer recovery. Although this funding was not used directly to support this MWBC-sponsored study, its existence enabled a successful research application by Clain Jones.

2006-2008
Perry Miller and six other MSU scientists received $471,111 from the USDA CSREES Integrated Organic Program. Although this funding did not directly support these rotation studies, results from the organic systems were key to enabling a successful application to this grant program.

2004-2007
Rick Engel and Perry Miller received $421,084 from the USDA-CSREES NRI Air Quality Program enabled importantly by the existence of the GGRS study which was sampled intensively for two years for nitrous oxide emissions. These funds did not directly support operation of the rotation studies.

2005
Fabian Menalled and Perry Miller received $26,890 from the Montana Noxious Weed Trust fund, part of which was used to establish the residual herbicide study for the first two years.

2005
Perry Miller received $12,742 from the Organic Farming Research Foundation to investigate the role of spring vs winter pea green manures in a tilled organic system. A small portion of this funding was used to support operation of the organic system within the greenhouse gas rotation study.

2004-2005
Rick Engel and Jerry Nielsen received $78,250 to initiate baseline soil carbon sampling at the GGRS site critically important to measuring future change in soil organic carbon in response to cropping practice.

7. MWBC FY 2015 Grant Submission Plans

I plan to submit a similar request for FY 2014/15 (with Clain Jones) to continue a 2nd year of looking at legacy effects with winter wheat grown in 2014.

FY2014 Montana Wheat and Barley Compliance Midyear Report

Title: Creation and End Product Quality Testing of Wheat with No PPO Activity

Principal Investigator: Mike Giroux

Personnel: Steven Hystad, M.S. graduate student and Petrea Hofer, Research Associate

Objectives:

1. Complete segregation analysis of spring and winter wheat populations segregating for four PPO genes.
2. Determine expression levels of each PPO gene among our parental lines to determine the most important PPO genes in early generation selection.
3. Conduct field experiments and end product quality analyses of spring and winter wheat populations segregating for PPO activity.

Results:

1. Complete segregation analysis of spring and winter wheat populations segregating for three PPO genes.

Our primary focus for this funding year has been to complete PPO segregation analysis, conduct a preliminary field trial, and measure end product quality analyses of spring wheat populations segregating for four unique PPO mutations. Full end product quality analyses will require an additional funding year since we were starting with limited seed supplies and were unable to plant sufficiently large plots in 2013. We chose to focus first on completing PPO gene segregation analysis of the white spring wheat populations. Most PPO is in the outer bran layers of wheat seeds and so wheat used as whole wheat or at high flour extraction rates is most impacted by PPO variation. Commercially available low PPO white wheat lines show the greatest market potential in part due to the increasing public interest in increasing the intake of fiber through whole-grain consumption. White wheat is being used as a way of producing whole-wheat products with much of the same appearance and taste qualities that white bread and noodle consumers prefer. White wheat varieties that possess both low levels of grain PPO and favorable quality characteristics allow its utilization for whole-wheat and high-extraction flour applications in both domestic bread-baking and noodle production applications for foreign markets.

For these reasons, White Vida and White Choteau spring wheat populations, each containing roughly 250 F_3 derived lines, created by crossing either White Vida or White Choteau with nil PPO parental line 1074 (**Table 1**) were planted at the Montana State University Arthur H. Post Field Research Center near Bozeman, MT in the spring of 2013. Segregation analysis was completed on each population planted by genotyping each line for each of the three segregating PPO genes. The purpose of conducting segregation analysis is to quantify the amount that each of the three major PPO genes contributes to total PPO activity. This would then allow the identification of which PPO genes need to be selected for and the rapid development of low PPO wheat varieties.

Table 1. Spring and winter wheat populations planted in Arthur H. Post Field Research Center and Montana State University greenhouses respectively.

Female Parent Montana Wheat Variety	**Male Parent** Null Spring PPO Line	**Generation** Field 2012	Field 2013
Spring Wheat (2013 field planting in April)			
White Vida	1074	$F_{2:3}$	$F_{3:4}$
White Choteau	1074	$F_{2:3}$	$F_{3:4}$
Winter Wheat (2013 planting in October)			
Decade (Hard, Red)	1074	$F_{2:3}$	$F_{3:4}$
Judee (MTS0713) (Solid-stem, Hard, Red)	1074	$F_{2:3}$	$F_{3:4}$
Yellowstone (Lr41, Cmc4, Low PPO)	1074	$F_{2:3}$	$F_{3:4}$

This would enable us to make recommendations as to which PPO gene is most important to focus on in terms of varietal development. The results of the segregation analysis (**Table 2**) show a large reduction in total PPO activity among the offspring possessing mutant PPO genes at all three loci (PPO average 0.081 Absorbance) compared to the Choteau (0.301) and Vida (0.296) parents. Furthermore, the results seem to indicate that the PPO-A1 locus seems the greatest contributor to total PPO activity but it should be noted, that the greatest reduction in overall PPO activity is to incorporate mutant PPO allele's at all three loci. In conclusion our crosses with the white seeded versions of Vida and Choteau result in very low PPO forms to serve as an added incentive for the adoption of white wheat grown in the state of Montana.

Table 2. Segregation analysis for the 1074/White Choteau and 1074/White Vida spring wheat populations.

Genotype **PPO-A1**	**PPO-A2**	**PPO-D1**	PPO activity (mean ± SD) Population 1 #07OR1074 / White Choteau	Population 2 #07OR1074 / White Vida
Wt	Wt	Wt	0.287 ± 0.12	0.337 ±0.12
Wt	Wt	Mut	0.264 ± 0.10	0.288 ± 0.12
Wt	Mut	Wt	0.268 ± 0.08	0.313 ± 0.13
Mut	Wt	Wt	0.148 ± 0.06	0.229 ± 0.08
Mut	Mut	Wt	0.128 ± 0.09	0.079 ± 0.08
Mut	Wt	Mut	0.174 ± 0.07	0.223 ± 0.07
Wt	Mut	Mut	0.224 ± 0.03	0.323 ± 0.11
Mut	Mut	Mut	0.081 ± 0.04	0.062 ± 0.05
	White Choteau		0.301 ± 0.06	
	White Vida		0.296 ± 0.04	
	Glenn		0.247 ± 0.05	
	Mountrail (Durum)		0.068 ± 0.03	
	#07OR1074		0.043 ± 0.02	

2. Determine expression levels of each PPO gene among our parental lines to determine the most important PPO genes in early generation selection.

Prior to this study, DNA mutations in three of the five PPO genes in line 1074 relative to our Montana adapted parent varieties were known, but the extent to which each of the three genes contributes to total PPO activity was unknown. To determine how much each PPO gene contributes to noodle darkening we measured expression levels of each PPO gene. This was accomplished by growing replicated trials of the parental genotypes in the greenhouse and sampling seeds during mid-grain fill. Mid grain fill is when past research studies have indicated that PPO genes are at peak expression. In our experiments we measured gene expression using the relatively new technique of RNA sequencing in which all expressed genes are identified and quantified (**Figure 1**). We anticipated finding that one or two of the PPO genes predominate in expression levels and are therefore more important to focus upon in early generation selection. The results of the expression analysis reveal that genes PPO-A1 and PPO-D1 predominate in expression levels compared to the other PPO genes. Additionally, PPO-A1, PPO-A2, and PPO-D1 expression levels were lower in the nil PPO line 1074 compared to Montana adapted spring wheat lines further demonstrating that the incorporation of desirable low PPO alleles from line 1074 into Montana adapted wheat varieties will minimize PPO levels affecting end product quality.

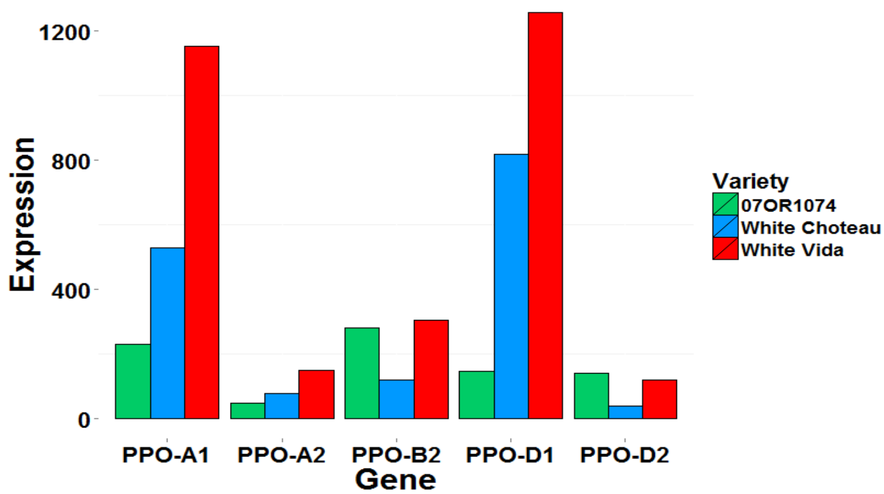


Figure 1. Expression levels of PPO genes in White Choteau, White Vida and mutant PPO line 1074.

3. Conduct field experiments and end product quality analyses of spring and winter wheat populations segregating for PPO activity.

As noted in **Table 1**, we have two populations of spring wheat and three populations of winter wheat that were planted in Arthur H. Post Field Research Center and Montana State University greenhouses respectively. Each population consists of roughly 250 individual lines. Because we can't plant winter wheat until October 2014, we will only be able to begin to measure initial end product quality on the spring wheat populations in the remainder of FY2014. The spring wheat populations were harvested and then the seed will be subjected to initial end product quality analysis. Total PPO activity, seed size parameters, total protein, ash and moisture content was measured on seeds from each plot. In the remainder of FY2014 initial end product quality testing will begin with pooling of several lines within each genotypic group to create replicate groups in order to estimate and effectively minimize background variability. Both white salted Chinese noodles and whole-wheat Chinese white salted noodles will be prepared for each pooled genotypic group. End product quality testing will begin with cleaning and flour milling of samples of seeds from each of the PPO genotypic classes. Flour milling will be assessed by measuring flour yield (proportion of flour obtained from seeds), flour ash, and flour color. Flour will then be used in noodle color assessments with noodle color measured before and after a holding period. The holding period is an cereal quality industry standard test used to allow the PPO that is present to develop off colors. The creation and testing of noodles is essential to accurately determine the relative value of the PPO mutations that we have identified. Since total PPO activity in seeds is only predictive of noodle color off colors, we will compare noodle end product quality for white and whole-wheat noodles with total seed PPO activity and the genotype of each of the three PPO genes. This will result in recommendations for which PPO mutations are essential to have in varieties useful in the preparation of high quality noodles.

Summary

We identified a null PPO genotype and used this unadapted (1074) line in crosses to Montana spring and winter wheat varieties. White Vida and White Choteau spring wheat populations, each containing roughly 250 F_3 derived lines, created by crossing either White Vida or White Choteau with nil PPO parental line 1074 (see **Table 1**) were planted at the Montana State University Arthur H. Post Field Research Center in near Bozeman, MT in spring 2013. Segregation analysis of spring and winter wheat populations segregating for three PPO genes was finished (**Table 2**) which shows a large reduction in total PPO activity among the offspring possessing mutant PPO genes at all three loci (0.081 absorbance) compared to the Choteau (0.301) and Vida (0.296) parents. In addition to segregation analysis expression analysis was completed which demonstrates that genes PPO-A1 and PPO-D1 predominate in expression levels compared to the other PPO genes. Additionally, PPO-A1, PPO-A2, and PPO-D1 expression levels were lower in the nil PPO line 1074 compared to Montana adapted spring wheat lines. The spring wheat populations were harvested and then the seed is currently being subjected to end product quality analysis. Total PPO activity, seed size parameters, total protein, ash and moisture content was measured on seeds from each plot and genotypic groups are currently being pooled to create replicate groups in order to estimate and effectively minimize background variability in end product quality measurements. White salted chinese noodles and whole-wheat Chinese white salted noodles will be prepared for each pooled genotypic group and undergo end product quality testing to produce recommendations for which PPO mutations are essential to have in wheat varieties useful in the preparation of high quality noodles.

Funding Summary

No funds other than those from the MWBC are supporting this project.

MWBC FY2015 Grant Submission Plans

We plant to submit a grant proposal to allow us to complete end product quality analysis of the spring wheat populations and PPO segregation on the winter wheat populations. The 2013 spring wheat field experiments were planted with a very small amount of seed and a planting in 2014 would allow us to replicate our results and make final recommendations to breeders. The PPO segregation conducted on the winter wheat populations would allow us to test whether the low PPO alleles behave the same in those populations and to create low PPO winter wheat genotypes useful in Phil Bruckner's breeding program.

Midyear Report of the Project is on a separate disk.
(CD has photo of Kent McVay spreading fertilizer)

GRANTS: 4W4635, 4W4636, 4W4637, 4W4638, 4W4639, 4W4640

TITLE: Evaluation of various materials and practices contributing toward economic crop production under flexible, continuous and other cropping systems in Montana.

TIME PERIOD: July 1, 2013 to June 30, 2014

PERSONNEL: Research scientists at the following AES Research Centers:

1. Southern Agricultural Research Center (SARC) - Huntley
   Kent A. McVay, Crop Scientist & Project Coordinator

2. Northern Agricultural Research Center (NARC) - Havre
   Peggy Lamb, Crop Scientist

3. Central Agricultural Research Center (CARC) - Moccasin
   Dave Wichman, Superintendent/Crop Scientist

4. Eastern Agricultural Research Center (EARC) - Sidney
   Joyce L. Eckhoff, Crop Scientist

5. Northwestern Agricultural Research Center (NWARC) - Kalispell
   Bob Stougaard, Superintendent/Weed Scientist

6. Western Triangle Ag Research Center (WTARC) - Conrad
   Gadi Reddy, Superintendent/Entomologist

COOPERATORS: Research Associates, Assistants and Technicians at the above research centers; and cooperating producers hosting off-station research trials on farms across Montana.

OBJECTIVES:

1. To evaluate the effects of differing systems on crop and variety performance under diverse environments represented across the Montana Agricultural Experiment Station - Research Center network.

2. To evaluate the potential fit of other materials, concepts and techniques with various cropping systems employed for cereal crop production.

FY2014 Montana Wheat and Barley Compliance Midyear Report

Title (4W4617):

Soil Sampling Equipment for Field Scale and Small Plot Research On- and Off-Station at Northern Agricultural Research Center

Principal Investigators:

Peggy F. Lamb, Research Scientist, Northern Ag Research Center, Havre
Darrin L. Boss, Superintendent, Northern Ag Research Center, Havre

Objectives:

The objective is to a purchase a hydraulic soil sampling machine designed to mount on a 6x6 utility vehicle such as a Polaris Ranger, John Deere Gator, or similar six wheel utility vehicle and also the UTV to mount the sampler in.

Results:

Bid solicitation for the hydraulic soil sampling machine will be submitted by the end of February. Once a soil sampling component meeting specifications is identified, then bid solicitation for the UTV will be submitted. By doing this, we will be certain that both pieces of the package fit well together as one unit. The following photos depict examples only of the proposed soil sampling equipment.

Summary:

Increased fertility, soil health and cropping systems research on- and off-station, in small plot and field scale scenarios, requiring soil samples to be taken on a per plot basis has necessitated this equipment purchase.

Funding Summary:

Expenditure information for grant index 4W4617 is to be provided by Montana State University, Office of Sponsored Programs. There is no other grant support for this project, however there will be additional matching funds used from existing Northern Ag Research Center designated accounts to fulfill the entire purchase price.

MWBC FY2015 Grant Submission Plans:

This equipment grant is for a onetime purchase, so it will not be resubmitted in FY2015.

FY2014 Montana Wheat and Barley Compliance Midyear Report

Title (4W4625):

Weather Data Collection for Producers in North Central Montana

Principal Investigators:

Peggy F. Lamb, Research Scientist, Northern Ag Research Center, Havre
Darrin L. Boss, Superintendent, Northern Ag Research Center, Havre

Objectives:

The objective is establish a permanent computerized weather station to electronically collect continuous real time climatic data year-round to be accessed via the internet or smart phone.

Results:

Bid solicitation for a web compatible, computerized weather station to be utilized on-station at Northern Ag Research Center and easily accessed by growers, will be submitted by the end of February. Accurate weather data will enhance the interpretation of on-station cereal research and the associated development of crop performance databases over time.

Summary:

Once installed, real-time weather will be available to Montana crop producers and the general public via the internet. The web based weather station will also give producers current information on soil and ambient temperatures, evapotranspiration, precipitation and other important data necessary to schedule seeding and time irrigation. Summary results of the data collected by this weather station will be utilized and included in the on-station research reports from Northern Ag Research Center.

Funding Summary:

Expenditure information for grant index 4W4625 is to be provided by Montana State University, Office of Sponsored Programs. There is no other grant support for this project, however there will be additional matching funds used from existing Northern Ag Research Center designated accounts to fulfill the entire purchase price.

MWBC FY2015 Grant Submission Plans:

This equipment grant is for a onetime purchase, so it will not be resubmitted in FY2015.

TITLE: Prebreeding for Root Health in Montana's Wheat (Grant# 4W4614)

PRINCIPLE INVESTIGATORS: Alan Dyer, Phil Bruckner

OBJECTIVES:

- Develop molecular markers for root lesion nematode resistance associated with wheat land race Persia 20.
- Evaluate RLN and FCR resistant winter wheat lines for agronomic traits.
- Evaluate Yellowstone/GS50a, BC_1F_4 progeny for root lesion nematode resistance.
- Advance resistances to RLN, FCR, and CEP in spring and winter wheat lines.

RESULTS:

DEVELOP MOLECULAR MARKERS FOR ROOT LESION NEMATODE RESISTANCE ASSOCIATED WITH WHEAT LAND RACE PERSIA 20.

This objective seeks to identify molecular markers (single nucleotide polymorphisms) linked to quantitative trait loci (QTL) for resistance to the root lesion nematode (RLN) *Pratylenchus neglectus*. Previous disease screening of nematode resistant materials identified 6 wheat lines as promising sources of resistance including a land race "Persia 20." The resistance from this land race has since been introduced into low polyphenol oxidase (ppo) lines of the winter wheat cultivar Yellowstone (lines MT08185 and MT08184) using the backcross breeding method. In February 2012, 200 BC_1F_3 progeny lines (MT08185//MT08184/Persia 20) from these crosses were screened for resistance using previously established protocols. Final results showed that RLN populations ranged from 55 to 340 *P. neglectus* per plant with no significant difference among entries (ANOVA, p=0.20). However, when analyzed alone, significant differences were clearly evident between the susceptible (MTO8184) and resistant parents (Perisa 20) (two-sided t test, p-value <0.001). Final average RLN populations for the parents were 236 for MT08184 and 115 for Persia 20. These results suggested that the parental lines were indeed resistant and susceptible to RLN and the lack of detectable difference among progeny lines was due to the genetic heterogeneity of the early breeding materials rather than due to lack of resistance.

To improve separation between entries, a subset of the 200 initially screened lines was chosen based on past performance as compared to the resistant and susceptible controls. The more advanced BC_1F_4 lines (seed derived from BC_1F_3 plants harvested in 2012) would contain 50% less of the genetic heterogeneity present in the BC_1F_3 lines and therefore should yield better results. After a thorough analysis of the performance of each lines in the previous phenotypic screen, 28 "susceptible" and 27 "resistant" progeny lines were chosen for a second RLN resistance trial which is currently ongoing. In this second trial, there are 12 replicates as opposed to the initial 5 in the first trial. So far, five of these replicates have been examined and nematodes counted. The results again indicated that parents are indeed resistant and susceptible with the final populations per plant averaging 903 RLN per plant for Yellowstone and 248 for Persia 20 (two-sided p-value=0.016, from a two-sample t-test). Results for the progeny are still unclear but very promising *(p=0.052).* Completion of the remaining replicates should clearly identify resistant progeny lines in the next few weeks.

EVALUATE FCR RESISTANT WINTER WHEAT LINES FOR AGRONOMIC TRAITS.

Root Lesion Nematode Resistance: The 55 progeny lines screened above were also entered into a replicated yield trial along with six checks (Colter, Decade, Jagalene, CDC Falcon, Yellowstone and Persia 20) to evaluate their agronomic performance. The experiment utilized a randomized complete block design consisting of four blocks. Entries were planted early October 2012 in single row plots in a field that had been previously planted to non-host crops in order to mitigate the potential influence of RLN and allow the lines to reach their full yield potential. Plots were harvested in August 2013 and heading date, plant height, yield, test weight and percent protein were recorded for each entry. All data was subjected to analysis of variance as well as regression analysis using SAS statistical software to identify associations between RLN resistance and agronomic traits that could be barriers to the development of RLN resistant winter wheat cultivars.

Analysis of data from the 2013 replicated yield trial indicated significant differences in means for heading date, plant height, yield, test weight and % protein among entries (all $p<0.001$ **see Figure 1** on the next page). Many of the selected RLN resistant progeny lines performed better than or equal to the widely grown checks for yield, test weight and protein. No significant correlations were found between RLN resistance of the progeny lines (as defined by reproductive factor) and any of the measures of agronomic performance. These promising results suggest that there are no penalties associated with resistance genes for *P. neglectus*. However, overall progeny lines were significantly taller than the widely grown checks. Such a height difference would be an undesirable trait for Montana winter wheat growers. Therefore, additional crosses of selected resistant lines to Yellowstone will be necessary

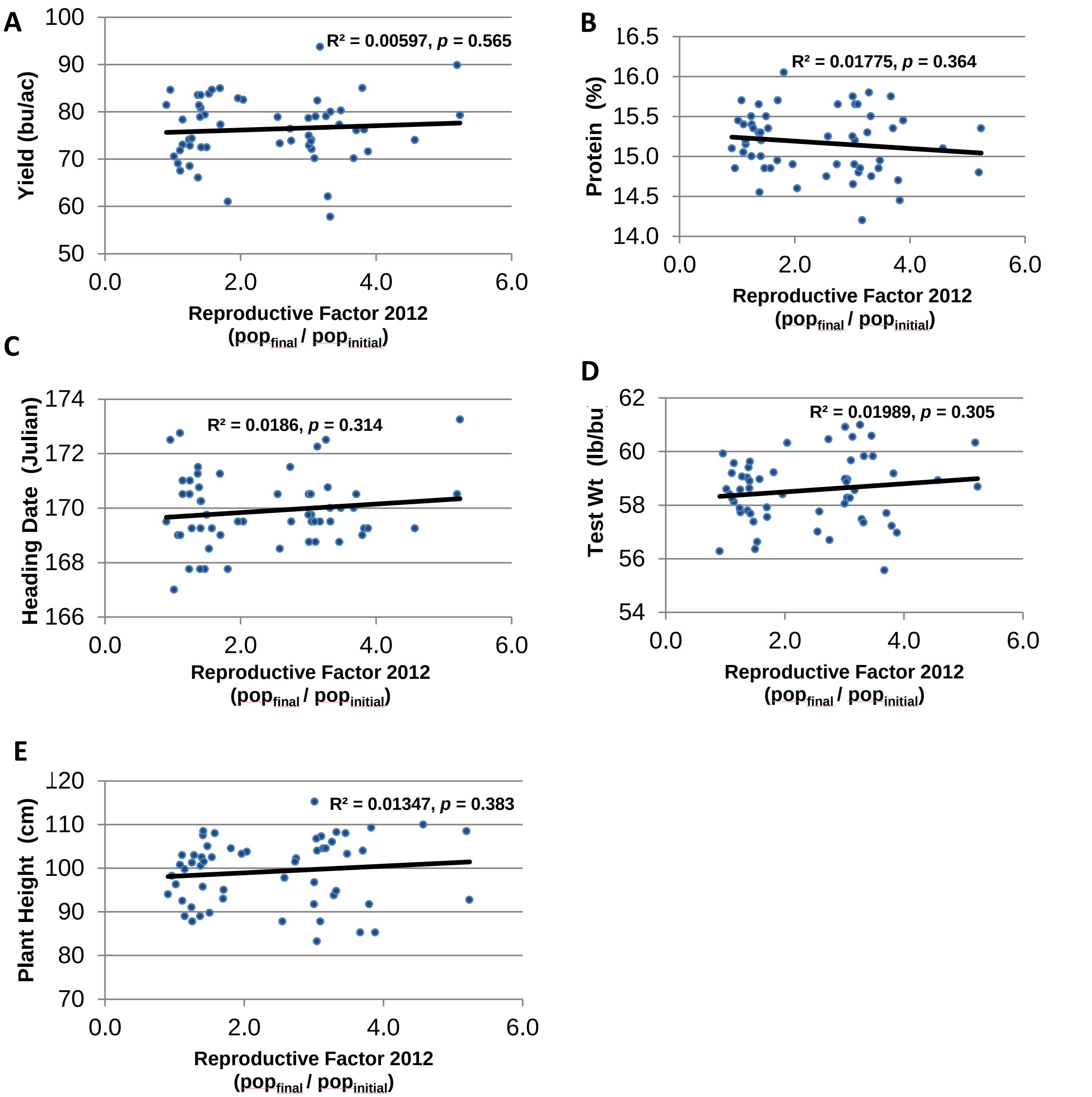


Figure 1. Replicate Yield Trails for Root Lesion Nematode Resistance. The figures show A) yield, B) protein C) heading date, D) test weight and E) plant height for each of 54 BC_1F_4 lines grown under low nematode pressure plotted against their nematode resistance (low reproductive factor). The low R^2 and high *p*-values suggest there is no linkage between resistance and decreases in yield, protein or other desirable trait.

in order to develop a nematode-resistant winter wheat adapted for large-scale production. The necessity of additional backcrosses underscores our desire to develop molecular markers for facilitated introgression of resistance genes.

Fusarium crown rot resistance. In the winter of 2011, 7 CIMMYT lines were screened for Fusarium crown rot (FCR) resistance using a seedling greenhouse assay. The two best performing lines (CR-2 and CR-3) were entered into the MSU winter wheat breeding program where they were introgressed into a low ppo selection of Yellowstone winter wheat (MT08184) by Phil Bruckner and Jim Berg. The resulting 547 BC_1F_4 lines of MT08184*2/CR-2 and MT08184*2/CR-3 were then returned for initial disease resistance screening. Due to the large number of entries and limited greenhouse space, a more rapid crown depth screening was completed to narrow the number of entries for additional screening in field and greenhouse trials. A published report negatively correlated crown depths with disease resistance and our own trials confirmed that a shallow crown depth was associated with reduced FCR infection and Fusarium related yield losses. Figure 2a shows the crown depth distribution for progeny from MT08184*2/CR-2; fig. 2b shows the crown depth distribution for MT08184*2/CR-3.

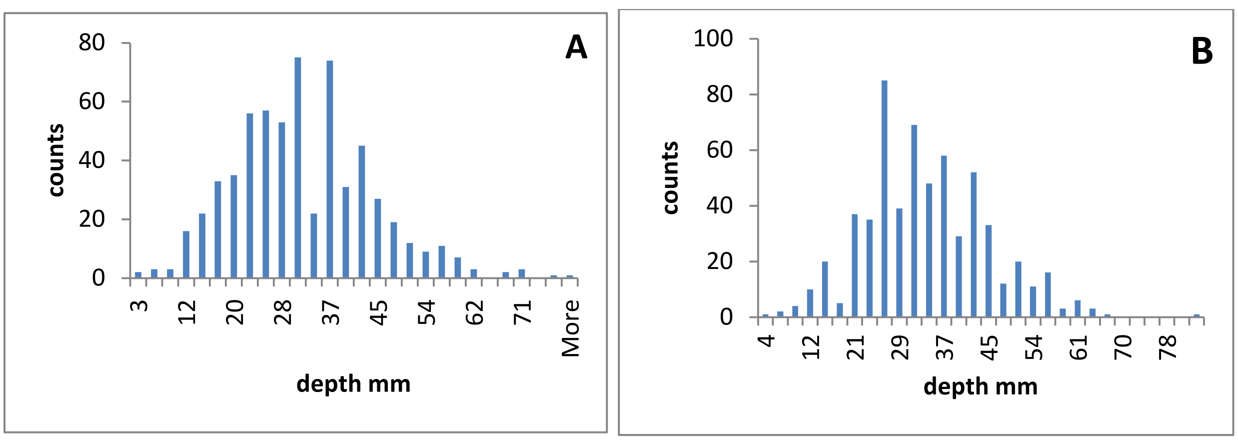


Figure 2. Crown Depth variation displayed from crosses with CR2 (A) and CR3(B). Crown depths are negatively correlated to Fusarium susceptibility and were used as an initial disease susceptibility screen.

For agronomic assessments, the 25 progeny with the shallowest mean crown depth from each MT08184*2/CR-2 and MT08184*2/CR-3 along with the 10 progeny from each cross with the deepest crown depths were selected for the 2013-2014 field evaluations. On November 14, 2013 the selected progeny lines were planted in paired inoculated and non-inoculated plots at the MSU Lutz Farm. Inoculation was performed in furrow with 15 grams of *Fusarium culmorum* infested oat kernels. Planting was done with a Kubota B1700 tractor and a 4 row cone seeder with 1 foot centers, 10 feet long rows.

The plots will be observed for agronomic and disease resistance data during the summer of 2014 and analyzed for linkages between the two that may be barriers to the development of resistant cultivars.

EVALUATE YELLOWSTONE/GS50A, BC_1F_4 PROGENY FOR ROOT LESION NEMATODE RESISTANCE.

Due to reduced funding and limited greenhouse space, this portion of the project has been delayed. Our previous work has shown GS50a was not as promising a resistance source as Persia 20 and therefore not as likely to provide a useful source of resistance. When time and space permits, these progeny lines will be evaluated for RLN resistance in greenhouse assays.

ADVANCE RESISTANCES TO ROOT LESION NEMATODE, FUSARIUM CROWN ROT AND CEPHALOSPROIUM STRIPE IN SPRING AND WINTER WHEAT LINES

Additional useful resistances to root lesion nematodes, Fusarium crown rot, cereal cysts and Cephalosporium stripe are available for incorporation into Montana adapted wheat lines. Both root lesion nematodes and Fusarium crown rot are important diseases in Montana while Cephalosporium stripe and cereal cysts are issues of growing concern. The purpose of this objective is to conduct the preliminary crosses for these materials both for immediate cultivar development through BC_1 breeding strategy and for molecular characterization of resistance through advancing of F_1 lines. The crossing strategies chosen are described in Table 2 (at the end of this report). Below is a description of current status for each disease resistance.

Root Lesion Nematode Resistance. In 2012, 30 winter and spring wheat lines from CYMMIT were screened for resistance to root lesion nematodes. Five lines -Persia 20, spring wheat line 'Nema 19' and winter wheat lines 'Nema 50,' 'Nema 57,' and 'Nema 58,' performed exceptionally well (See Table 1). Besides Persia 20, these four additional sources of resistance represent a valuable resource for future cultivar development. Therefore their resistances are being advanced into Montana's top-performing spring and winter wheat lines via a $BC_1$and F_1 breeding strategies. This will allow us to rapidly develop new resistant cultivars incorporating this useful resistance. Initial crosses have been made and the F_1 progeny are being advanced to establish an F_2 population for genetic studies and will be backcrossed to its appropriate recurrent parent for rapid incorporation into Montana adapted lines (See Table 2). All F_1 crosses are expected to completed by March 2014.

Table 1. Root lesion nematode resistance levels of susceptible cultivar 'Yellowstone' and the top 5 resistant lines.

Cultivar	(Average Nema. Pop.)
Yellowstone	721.3
Persia 20	124.3
Nema 19	54.3
Nema 50	40.7
Nema 57	36.0
Nema 58	34.3

Fusarium Crown Rot Crosses. Three spring wheat resistant lines (2-49, CR2 and CR3) have been selected for their high level of resistance to Fusarium crown rot disease. They have been crossed with two Montana spring wheat cultivars, Duclair and McNeal. The F_1 seeds are currently growing and will be backcrossed to Duclair and McNeal this February.

Cephalosporium Stripe Crosses. Four winter wheat lines resistant to *Cephalosporium gramineum* (CEP) provided by Dr. Tim Murray will be crossed to cv. Judee. The plants have just completed vernalization and will be crossed in late winter.

SUMMARY:

Disease screening and molecular characterization of the Persia 20/Yellowstone cross are progressing well with progeny lines soon to be identified. Evaluation of these lines for agronomic characters has indicated no linkage between resistance and protein or yield data, but all progeny are taller than desired and will need to be advance through additional backcrosses before cultivar selection can proceed. Initial screen for Fusarium crown rot has been completed and the remaining lines have been planted in the field for additional evaluation for disease resistance and agronomic data. Disease evaluation of Yellowstone/GS50a progeny has been delayed due to limited greenhouse space.

Advancing additional sources of resistance for Fusarium crown rot, root lesion nematodes and Cephalosporium stripe are progressing and are expected to be past the initial crosses by this spring at which point progeny lines will be advanced to homozygosity through the strategy of single seed descents.

FUNDING SUMMARY:

Designated funds and MWBC funding have been the primary source of funding for this work. In the coming year additional funds will be sought from the Montana Board of Research and Commercialization Technology (MBRCT) but previous attempts from this state agency have been unsuccessful.

MWBC FY2014 GRANT SUBMISSION PLANS:

Renewal of this project will be sought to fund advancing and screening of these resistant breeding materials into locally adapted spring and winter wheat backgrounds.

TABLE 2. CROSSING PLAN. Crosses will either involve F_1 or $Backcross_1$ strategies before being advanced to homozygosity. Grayed-in cells indicate crosses that will be made along with the breeding method(s) to be used (F_1 or BC) depending on plans for molecular assessment (F_1) and cultivar development (BC).

				Winter Wheat	Spring Wheat	
				Judee	Duclair	McNeal
Nematode Resistance	SW	Nema 19	RLN VI		F_1 | BC	F_1 | BC
	WW	Nema 50	RLN VII	F_1		
	WW	Nema 57	RLN IV	F_1		
	WW	Nema 58	RLN V	F_1 | BC		
FCR Resistance	SW	2-49	FCR I		BC	BC
	SW	CR2	FCR II		BC	BC
	SW	CR3	FCR III		BC	BC
Cephalosporium Resistance	WW	TML 1	CEP I	BC		
	WW	TML 2	CEP II	BC		
	WW	TML 3	CEP III	BC		
	WW	TML 4	CEP IV	BC		

Title: Characterization of new sources of the solid stem trait in wheat (4W4619)

Principal Investigators:
Jack Martin and Mike Giroux, Plant Sciences and Plant Pathology, MSU-Bozeman

Objective 1: Evaluate the inheritance of the solid stem trait in segregating populations of spring wheat.

Objective 2: Obtain more extensive agronomic evaluation of potential new solid stem sources.

Results:

The hollow stemmed variety Alpowa was treated with a mutagen. This produced mutations in many genes affecting agronomic traits. Agronomic traits were measured on lines derived from this population. Nearly all lines had hollow stems but a small minority showed some degree of stem solidness at the bottom internode. Five parents that showed solid stems at the bottom internode in a preliminary trial were crossed to three parents, Alpowa, White Vida and White Choteau. Alpowa is the parent source of the five solid stem parent lines. White Vida and White Choteau are white seeded versions of the widely grown varieties Vida and Choteau, respectively. Thirteen of the possible fifteen crosses were grown as spaced F2 plants in the field during 2013. Solid stem score was measured from a single stem from single F2 plants on a 1 (hollow) to 5 (solid) basis on all internodes (usually 5). The number of plants from each cross varied from 120 to 198. The mean values and the segregation patterns from these crosses can help determine the mode of inheritance of the solid stem trait. One possibility is that the mutation conferring solid stem in the parents is in the same gene as in the currently grown solid stem varieties such as Choteau. Another possibility is that the mutation in the parents is in a different gene than that found in varieties such as Choteau.

Average stem score values for each internode were computed (Table 1). One observation is that the stems become more solid moving from the top (internode 1) to the bottom (internode 5) of the stem. As expected crosses to the solid stemmed White Choteau were most solid while crosses to hollow stemmed Alpowa were least solid, and crosses to White Vide were intermediate. Crosses of all five novel solid stem sources showed similar segregation patterns when crossed to the three common parents. Crosses to White Chotesu showed the F2 plants had solid stems. See Figure 1 for an example. If two different genes were segregating we would have seen a bimodal distribution. This lends support to the hypothesis that the mutation in the novel solid stem sources is in the same gene as that found in White Choteau. Crosses to Alpowa showed the distribution of F2 plants was symmetric with most plants being intermediate in solidness. See Figure 1 for an example. These results are also consistent with the hypothesis of a single gene segregating.

Four of the five novel solid stemmed parents plus important check varieties were evaluated in a larger replicated trial under solid seeded conditions. Several agronomic traits were measured in addition to solid stem score (Table 2). The novel solid stem parents were obviously not as solid as White Choteau, but they were more solid than Alpowa. This may not be too surprising since Choteau is the result of several cycles of breeding for the solid stem trait and most likely has accumulated several genes that affect stem solidness. The novel solid stem sources have lower grain yield than Alpowa and the other check varieties. They also tend to be later in maturity and higher in grain protein than Alpowa. The higher grain protein probably reflects that these parent lines have lower grain yield.

Based on the performance of the solid stem parents themselves, the segregation patterns, and mean values of the crosses, six crosses were chosen to advance in the greenhouse this winter. These six crosses involve RJ380 and RJ646 in crosses with Alpowa, Vida and White Choteau. These will be advanced to near homozygosity. Molecular markers will be developed to track the segregating mutation conferring solid stem. Ultimately the near homozygous lines will be evaluated to determine the relationship between stem solidness and agronomic traits.

Summary:

Five potential solid stem parents derived from a mutagenized population were crossed to a hollow, semi-solid stem and solid stem parent. Solid stem score was recorded from individual plants in segregating populations. The stems were progressively more solid moving from the top to the base of the plant. Segregation patterns were similar for the five parents. The mutation conferring the solid stem trait in these parents is probably in the same gene as is in currently grown solid stem varieties. The solid stem sources were not as solid as the most widely grown variety, Choteau. This is not surprising since Choteau is the result of several cycles of selection for the solid stem trait. Six crosses were chosen to advance to near homozygosity.

Funding Summary:

There are no other outside funding sources supporting this project.

FY2015 MWBC Grant Submission Plans:

We plan to submit a proposal for FY 2015.

Table 1. Solid stem score (1 hollow to 5 solid) for five internodes from single F2 plants for novel solid stem sources crossed to Alpowa (A), White Choteau (WC), or White Vida (WV).

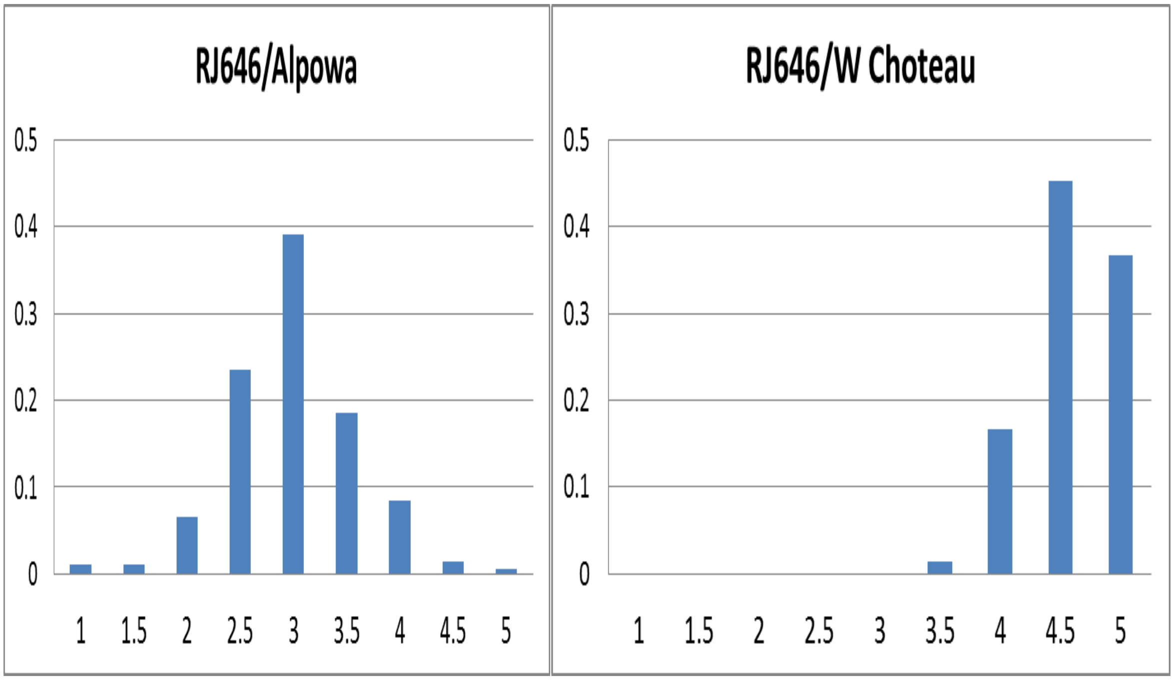
Cross	Internode					
	1	2	3	4	5	Mean
AxRJ164	1.16	1.98	1.50	3.30	3.84	2.35
AxRJ380	1.27	2.03	1.87	4.02	4.34	2.70
AxRJ646	1.37	2.93	2.86	3.51	3.85	2.82
AxRJ83	1.10	2.67	1.59	3.86	3.90	2.61
WCxRJ164	3.39	4.61	4.48	4.69	4.73	4.36
WCxRJ380	4.33	4.94	4.86	4.83	4.94	4.76
WCxRJ6	4.21	4.75	4.85	4.86	4.82	4.68
WCxRJ646	2.94	4.90	4.85	4.79	4.79	4.41
WCxRJ83	2.47	4.37	4.24	4.48	4.75	4.00
WVxRJ164	1.74	2.47	2.39	3.48	3.67	2.73
WVxRJ6	1.75	2.07	1.86	3.15	3.70	2.42
WVxRJ646	1.29	2.16	2.38	2.78	3.10	2.25
WVxRJ83	1.66	2.21	2.18	3.32	3.95	2.64

Table 2. Mean values for average internode stem score and several agronomic traits for novel solid stem sources and important check varieties.

Entry	Stem score[1]	Yield (bu/a)	Heading (d after Jan 1)	Maturity (d after Jan 1)	Protein (%)	Height (in)	Kernel weight (mg)
Solid stem parents							
RJ6	3.0	29.5	192.5	224.8	14.6	25.5	34.2
RJ164	1.9	25.7	194.0	227.5	15.9	28.5	34.6
RJ380	2.2	37.7	192.5	225.8	13.3	30.0	37.1
RJ646	1.7	59.4	192.3	224.0	14.5	30.0	34.0
Check entries							
Alpowa	1.0	72.0	192.0	223.5	12.5	29.0	35.4
Choteau	4.6	58.9	190.8	222.5	15.4	30.0	33.9
Vida	1.3	69.6	192.0	224.3	14.8	31.8	35.9
Reeder		61.8	191.5	225.8	15.5	31.5	34.9
LSD(0.05)	2.0	11.8	1.7	2.7	0.6	1.4	2

[1] Average of 5 internodes from 1 (hollow) to 5 (solid).

Figure 1. Relative frequency for average internode score (1 hallow 5 solid) from approximately 200 F2 single plants from cross of novel solid stem source with Alpowa and White Choteau.



FY2014 Mid Report

Title (W4610): A new strategy to create broad-spectrum resistance to biotrophic pathogens in wheat

Principal Investigator: Li Huang

Objectives:

1) Identify wheat genes that biotrophic pathogens target for their nutrient uptake.
2) Identify mutants on the target genes in wheat cultivar Alpowa.

Results: In a recent search of wheat ESTs we identified the top three homologs for one of the six host- target genes, *Arabidopsis COP9* sinalosome (*AtCOP9*) mentioned in the Mukhtar et al. (2011) paper. *Arabidopsis COP9* is a component of a multisubunit nuclear regulator that is a repressor of photomorphenesis (Chamovit et al., 1996). The COP9 complex is also shown to be positively involved in the *N*-gene mediated resistance to tobacco mosaic virus (Liu et al., 2002) and negatively involved in the defense responses to the bacterium *Pseudomonas syringae* and the biotrophic oomycete *Hyaloperonospora arabidopsodis* (Mukhtar et al., 2011). The three wheat homologs are located on the homeologous loci of the long arms of chromosomes 2A, 2B and 2D, and are referred thereafter as group 2-long arm *COP9* (G2L-*COP9*) homeologs. Further sequence searches of the International Wheat Genome Sequencing Consortium (IWGSC) genomic DNA sequence database identified additional sequences homologous to *AtCOP9* on wheat chromosomes 2D short arm and 4D long arm. The G2L-*COP9* homeologs share up to 89% with the 2DS-homolog and 67% with the 4DL-homolog. The full length genomic DNA sequence of each G2L-*COP9* was isolated and sequence comparisons among the three G2L-*COP9* sequences revealed ≥ 99% similarity in the exons among the three homeologs, with variation found mainly in the non-translated regions. Our preliminary and proposed experiments focus only on the three G2L-*COP9* homeologs.

<u>Expressions of the G2L-*COP9* homeologs correlated with rust pathogenesis</u>

Gene expression analysis via real-time PCR on a conserved region among the G2L-*COP9* homeologs using RNA samples collected from leaves of the spring wheat variety Alpowa inoculated with leaf rust isolate PBJL or buffer at 0, 1, 2, 3, 5, 8 and 10 days post inoculation (dpi) indicated that the genes were almost unchanged from 0 to 10 dpi in Alpowa with buffer inoculation (Fig. 1). However, with leaf rust inoculation, the genes were upregulated starting at 5 dpi, the time point when leaf rust spores started sporulating in Alpowa, and continue to increase at 8 dpi when Alpowa was fully infected and G2L-*COP9* expression remained high at 10 dpi. Further real-time PCR analysis of expression in an additional pair of near-isogenic lines of cultivar Scholar +*Lr47*/- *Lr47*, indicated that the genes were up-regulated only in successful infection of susceptible lines, but decreased in resistant lines (Fig. 2).

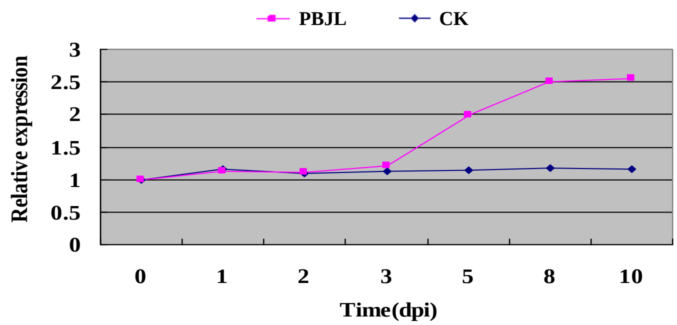


Figure 1. Relative expression of the Alpowa G2L-*COP9* homeologs. Alpowa inoculated with buffer was referred as CK, and inoculated with leaf rust PBJL was referred as PBJL. Gene expression at 0 dpi was normalized as 1, and the remaining time points of the CK and PBJL were relative to the corresponding expression at 0 dpi.

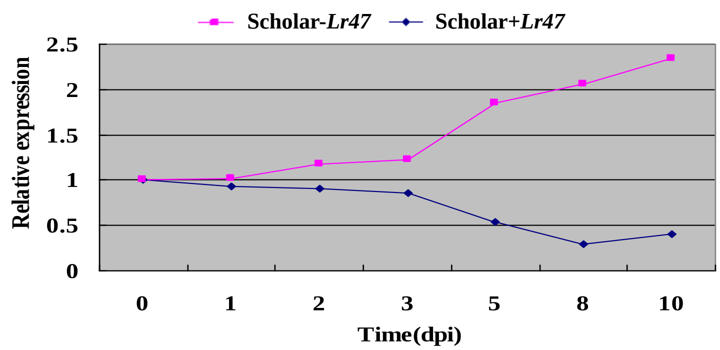


Figure 2. Relative expression of G2L-*COP9* homeologs in near-isogenic lines with or without the leaf rust resistance gene *Lr47* in cultivar Scholar background. Gene expression at 0 dpi was normalized as 1, and the remaining time points of the Scholar+*Lr47* and Scholar-*Lr47* were relative to the corresponding expression at 0 dpi.

Financial Narrative: Expenditures are detailed by major category grouping below. The remaining $44,592.69 will be spent for oncoming invoices on RNAseq, student salaries and greenhouse rental.

Salaries	$801.34
Lab supplies	$4,124
Total:	$4,925.34

Supporting Funding: $50,000 from MWBC, none from any other sources for the same project.

MWBC FY2015 Grant Submission Plans: The reported project funded by MWBC is in the early stage of research and funding. We intend to submit a proposal to USDA using the preliminary results generated from this project. We will be seeking more support to continue the project. Successes in the proposed project will not only produce a new category of resistance material for resistance breeding, but also gain insightful understandings on how biotrophic pathogens manipulate host machinery for their nutrient uptake. There is a great potential for extramural funding for the advanced stage of the project.

FY2014 Montana Wheat and Barley Compliance Midyear Report

Soil nutrient analysis for cutting edge agronomic studies: Purchase of a new Lachat Quickchem flow injection analysis system (grant number W4603)

Principal Investigators: Stephanie Ewing, Jack Brookshire

Collaborator:
Jane Klassen, Associate Research Professor/Analyst, LRES Environmental Analysis Laboratory

Objective: Precise, accurate and efficient analysis of soil nutrients (nitrate, ammonium, phosphate) for agronomic studies in Montana.

The Environmental Analysis Laboratory in the Department of Land Resources and Environmental Science had been relying on an aging and outdated instrument for soil nutrient analyses; this instrument had sustained very high sample throughput for about twenty years. At the same time that this instrument was starting to show its age in terms of mounting repairs and outdated software, we were seeing increasing sample numbers as a growing cohort of faculty undertook agricultural research projects with a variety of funding sources including MWBC. In LRES, multiple faculty members and affiliated research groups use this analytical capability on a monthly to weekly basis in support of agronomic studies in Montana (e.g., Jones, Engel, Ewing, Maxwell, Miller).

Results

MWBC funding was in place by September 18, 2013. Following informational conversations and meetings with likely users (to confirm appropriate instrument specifics), and MSU's purchasing process, the MSU purchase order was completed on January 13, 2014. Instrument installation and training are expected to occur within a month.

Summary

With completion of the purchasing and installation processes for this Lachat Quickchem system, LRES and MSU will now have the benefit of excellent and efficient analytical capability for soil nutrient studies.

Funding Summary

The final quote from Lachat for this purchase is $67,587.36 (please see the attached quote). We await the final assessment upon installation of the instrument, but this total may reflect our total expenditure under this grant (of the $70,000 award).

Headquarters/Purchase Orders:
P.O. Box 608, Loveland CO 80539-0608
Tel: (800) 247-7613
Fax: (970) 461-3919
email: sales@lachatinstruments.com

Remittance:
2207 Collections Center Drive
Chicago, IL 60693

HACH® Be Right™

LACHAT INSTRUMENTS BRAND PRICE QUOTATION

TO:
Jane Klassen
Environmental Analytical Lab
Montana State University
824 Leon Johnson Hall
Bozeman, MT 59717
Phone: 406-994-5703
Email: jane.klassen@montana.edu

Quote # 22364 Rev1
Date: 1/9/2014
Salesperson: SS/John Puryear
Prepared By: Heather Johnston
Proposed Shipping Date: 2-4 Weeks ARO
F.O.B. Shipping Point
To be shipped via: Best Way
Expiration: 1/14/2014

QTY.	DESCRIPTION		UNIT PRICE	EXTENDED AMOUNT
1	**QC85S2X3**	**QuikChem 8500 Series 2 FIA+, includes:**	$49,637.00	$49,637.00
	1 - A58102	**System Unit with built-in leak detector/failure alert system**		
	3 - A58008	**Analytical Channel with high performance injection valve**		
	1 - A85137	**ASX-500 Series XYZ Auto Sampler**		
	1 - A85140	**RP-100 Reagent Pump, 16 Tubes**		
	1 - A85025	**Accessories Kit**		
	LIMETH	**Methods Manual**		
	85204	**QC8500 Packaging Set**		
	14011L	**Power Strip**		
	Additional required items:			
1	**A85080**	**Omnion 3.0 Software**	$3,203.00	$3,203.00
1	**85255**	**HP Small Form CPU & 19" Monitor**	$1,546.00	$1,546.00
2	**A85132**	**Software Controlled Heater Apparatus including 175CM and 650CM Insert**	$1,157.00	$2,314.00
	(Required for ammonia, cyanide, TKN, phos, sodium chlorate or sulfide)			
1	**A89103**	**PDS200 Dilutor**	$6,995.00	$6,995.00
1	**50151**	**Sipper Cap Start Up Kit**	$135.00	$135.00
	Analytical Manifolds:			
1	**E12-107-04-1-J**	**NITRATE NITRITE IN KCL EXTRACTS SOIL**	$1,601.00	$1,601.00
1	**E12-115-01-1-Q**	**PHOSPHOROUS, 0.5M NaHCO3 SOIL EXTRACTION**	$1,601.00	$1,601.00
1	**E90-107-06-3-A**	**LACHAT MANIFOLD, AMMONIA, MULTI SOIL EXTRA**	$1,387.00	$1,387.00
1	**E12-206-00-1-A**	**UREA IN 2M KCL EXTRACTS OF SOILS**	$1,025.00	$1,025.00
		Sub-Total:		**$69,444.00**
		Less University Discount		**($4,166.64)**
1	**START UP**	**Installation by sales representative**	$750.00	$750.00
1	**TRNFAC2**	**Training, Factory-based, 2 Day, QC8500 FIA+, Omnion 3.0**	$1,000.00	$1,000.00
	Training on system installation, operation, maintenance and troubleshooting. Note: training course expires one (1) year after invoicing.			
		Packing & Handling fee (41LI):	$175.00	**$175.00**
		Shipping Charge:		**$250.00**
		TOTAL:		**$67,452.36**
	Prepared Reagent Options:	+ $135.00 for second	sipper cap	67587.36
1	**52901**	**Chloride Reagent Set**	$77.89	$77.89
1	**52902**	**Phosphate Reagent Set**	$83.45	$83.45
1	**52903**	**Nitrate Reagent Set**	$88.95	$88.95
1	**52904**	**Ammonia Reagent Set**	$126.00	$126.00
1	**52905**	**TKN Reagent Set**	$185.00	$185.00

Prepared By: Heather Johnston

Headquarters/Purchase Orders:
P.O. Box 608, Loveland CO 80539-0608
Tel: (800) 247-7613
Fax: (970) 461-3919
email: sales@lachatinstruments.com

Remittance:
2207 Collections Center Drive
Chicago, IL 60693

HACH® Be Right™

LACHAT INSTRUMENTS BRAND PRICE QUOTATION

TO:
Jane Klassen
Environmental Analytical Lab
Montana State University
824 Leon Johnson Hall
Bozeman, MT 59717
Phone: 406-994-5703
Email: jane.klassen@montana.edu

Quote # 22364 Rev1
Date: 1/9/2014
Salesperson: SS/John Puryear
Prepared By: Heather Johnston
Proposed Shipping Date: 2-4 Weeks ARO
F.O.B. Shipping Point
To be shipped via: Best Way
Expiration: 1/14/2014

QTY.	DESCRIPTION		UNIT PRICE	EXTENDED AMOUNT
1	52906	Cyanide Reagent Set	$217.00	$217.00
1	52910	TKP Reagent Set	$183.00	$183.00
1	52975	Ammonia Preserved Reagent Set	$174.00	$174.00
1	50151	Sipper Cap Start Up Kit I will add this to the total.	$135.00	$135.00
	Service Options:			
1	FSPQC8500	Field Service Partnership (1 year) & One On-Site PM Visit	$5,458.00	$5,458.00
1	BSPQC8500	Factory Service Partnership (1 year)	$4,558.00	$4,558.00

NOTES: Full payment is not contingent upon completion of installation.

Warranty - One (1) Year Parts and Labor

This system is delivered on a large pallet which requires a lift gate. Please indicate if you do not have a loading dock or lift gate at the delivery point. In this case, special equipment from the trucking company would be required to unload the goods.

All purchases of Hach Company products and/or services are expressly and without limitation subject to Hach Company Terms & Conditions of Sales ("Hach TCS"), incorporated herein by reference and published on Hach Company's website at www.hach.com/terms. Hach TCS are contained directly and/or by reference in Hach's offer, order acknowledgement and invoice documents. The first of the following acts constitutes an acceptnace of Hach's offer and not a counteroffer and creates a contract of sale ("Contract") in accordance with the Hach TCS: (i) Buyer's issuance of a purchase order document against Hach's offer; (ii) acknowledgement of Buyer's order by Hach; or (iii) commencement of any performance by Hach pursuant to Buyer's order. Provisions contained in Buyer's purchase documents (including electronic commerce interfaces) that materially alter, add to or subtract from the provisions of the Hach TCS are not part of the Contract.

Prepared By: Heather Johnston

TERMS & CONDITIONS OF SALE FOR HACH COMPANY PRODUCTS AND SERVICES

This document sets forth the Terms & Conditions of Sale for goods manufactured and/or supplied, and services provided, by Hach Company of Loveland, Colorado ("Hach") and sold to the original purchaser thereof ("Buyer"). Unless otherwise specifically stated herein, the term "Hach" includes only Hach Company and none of its affiliates. Unless otherwise specifically stated in a previously-executed written purchase agreement signed by authorized representatives of Hach and Buyer, these Terms & Conditions of Sale establish the rights, obligations and remedies of Hach and Buyer which apply to this offer and any resulting order or contract for the sale of Hach's goods and/or services ("Products").

1. APPLICABLE TERMS & CONDITIONS: These Terms & Conditions of Sale are contained directly and/or by reference in Hach's offer, order acknowledgment, and invoice documents. The first of the following acts constitutes an acceptance of Hach's offer and not a counteroffer and creates a contract of sale ("Contract") in accordance with these Terms & Conditions: (i) Buyer's issuance of a purchase order document against Hach's offer; (ii) acknowledgement of Buyer's order by Hach; or (iii) commencement of any performance by Hach pursuant to Buyer's order. Provisions contained in Buyer's purchase documents (including electronic commerce interfaces) that materially alter, add to or subtract from the provisions of these Terms & Conditions of Sale are not a part of the Contract.

2. CANCELLATION: Buyer may cancel goods orders subject to fair charges for Hach's expenses including handling, inspection, restocking, freight and invoicing charges as applicable, provided that Buyer returns such goods to Hach at Buyer's expense within 30 days of delivery and in the same condition as received. Buyer may cancel service orders on ninety (90) day's prior written notice, and refunds will be prorated based on the duration of the service plan. Inspections and re-instatement fees may apply upon cancellation or expiration of service programs.

3. DELIVERY: Delivery will be accomplished FCA Hach's facility located in Ames, Iowa or Loveland, Colorado, United States (Incoterms 2010). For orders having a final destination within the U.S., legal title and risk of loss or damage pass to Buyer upon transfer to the first carrier. For orders having a final destination outside the U.S., legal title and risk of loss or damage pass to Buyer when the Products enter international waters or airspace or cross an international frontier. Hach will use commercially reasonable efforts to deliver the Products ordered herein within the time specified on the face of this Contract or, if no time is specified, within Hach's normal lead-time necessary for Hach to deliver the Products sold hereunder. Upon prior agreement with Buyer and for an additional charge, Hach will deliver the Products on an expedited basis. Standard service delivery hours are 8 am – 5 pm Monday through Friday, excluding holidays.

4. INSPECTION: Buyer will promptly inspect and accept any Products delivered pursuant to this Contract after receipt of such Products. In the event the Products do not conform to any applicable specifications, Buyer will promptly notify Hach of such nonconformance in writing. Hach will have a reasonable opportunity to repair or replace the nonconforming product at its option. Buyer will be deemed to have accepted any Products delivered hereunder and to have waived any such nonconformance in the event such a written notification is not received by Hach within thirty (30) days of delivery.

5. PRICES & ORDER SIZES: All prices are in U.S. dollars and are based on delivery as stated above. Prices do not include any charges for services such as insurance; brokerage fees; sales, use, inventory or excise taxes; import or export duties; special financing fees; value added taxes; income or royalty taxes imposed outside the U.S.; consular fees; special permits or licenses; or similar charges imposed upon the production, sale, distribution, or delivery of Products hereunder. Buyer will either pay any and all such taxes and charges or provide Hach with acceptable exemption certificates, which obligation survives performance under this Contract. Hach reserves the right to establish minimum order sizes and will advise Buyer accordingly.

6. PAYMENTS: All payments must be made in U.S. dollars. For Internet orders, the purchase price is due at the time and in the manner set forth at www.hach.com. Invoices for all other orders are due and payable (1) NET 30 DAYS from date of the invoice without regard to delays for inspection or transportation, with payments to be made by check to Hach at the above address or by wire transfer to the account stated on the front of Hach's invoice. In the event payments are not made or not made in a timely manner, or (2) for customers with no established credit, Hach may require cash or credit card payment in advance of delivery. Hach may, in addition to all other remedies provided at law, either: (1) declare Buyer's performance in breach and terminate this Contract for default; (2) withhold future shipments until delinquent payments are made; (3) deliver future shipments on a cash-with-order or cash-in-advance basis even after the delinquency is cured; (4) charge interest on the delinquency at a rate of 1-1/2% per month or the maximum rate permitted by law, if lower, for each month or part thereof of delinquency in payment plus applicable storage charges and/or inventory carrying charges; (5) repossess the Products for which payment has not been made; (6) recover all costs of collection including reasonable attorney's fees; or (7) combine any of the above rights and remedies as is practicable and permitted by law. Buyer is prohibited from setting off any and all monies owed under this from any other sums, whether liquidated or not, that are or may be due Buyer, which arise out of a different transaction with Hach or any of its affiliates. Should Buyer's financial responsibility become unsatisfactory to Hach in its reasonable discretion, Hach may require cash payment or other security. If Buyer fails to meet these requirements, Hach may treat such failure as reasonable grounds for repudiation of this Contract, in which case reasonable cancellation charges shall be due Hach. Buyer grants Hach a security interest in the Products to secure payment in full, which payment releases the security interest but only if such payments could not be considered an avoidable transfer under the U.S. Bankruptcy Code or other applicable laws. Buyer's insolvency, bankruptcy, assignment for the benefit of creditors, or dissolution or termination of the existence of Buyer, constitutes a default under this Contract and affords Hach all the remedies of a secured party under the U.C.C., as well as the remedies stated above for late payment or non-payment.

7. LIMITED WARRANTY: Hach warrants that Products sold hereunder will be free from defects in material and workmanship and will conform to any express written warranty pertaining to the specific goods purchased, which for most Hach instruments is for a period of twelve (12) months from delivery. Hach warrants that services furnished hereunder will be free from defects in workmanship for a period of ninety (90) days from the completion of the services. Parts provided by Hach in the performance of services may be new or refurbished parts functioning equivalent to new parts. Any non-functioning parts that are repaired by Hach shall become the property of Hach. No warranties are extended to consumable items such as, without limitation, reagents, batteries, mercury cells, and light bulbs. **All other guarantees, warranties, conditions and representations, either express or implied, whether arising under any statute, law, commercial usage or otherwise, including implied warranties of merchantability and fitness for a particular purpose, are hereby excluded**. The sole remedy for Products not meeting this Limited Warranty is replacement, credit or refund of the purchase price. This remedy will not be deemed to have failed of its essential purpose so long as Hach is willing to provide such replacement, credit or refund.

8. INDEMNIFICATION: Indemnification applies to a party and to such party's successors-in-interest, assignees, affiliates, directors, officers, and employees ("Indemnified Parties"). Hach is responsible for and will defend, indemnify and hold harmless the Buyer Indemnified Parties against all losses, claims, expenses or damages which may result from accident, injury, damage, or death due to Hach's breach of the Limited Warranty. This indemnification is provided on the condition that the Buyer is likewise responsible for and will defend, indemnify and hold harmless the Hach Indemnified Parties against all losses, claims, expenses or damages which may result from accident, injury, damage, or death due to the negligence or misuse or misapplication of any goods or services by the Buyer or any third party affiliated or in privity with Buyer.

9. PATENT PROTECTION: Subject to all limitations of liability provided herein, Hach will, with respect to any Products of Hach's design or manufacture, indemnify Buyer from any and all damages and costs as finally determined by a court of competent jurisdiction in any suit for infringement of any U.S. patent (or European patent for Products that Hach sells to Buyer for end use in a member state of the E.U.) that has issued as of the delivery date, solely by reason of the sale or normal use of any Products sold to Buyer hereunder and from reasonable expenses incurred by Buyer in defense of such suit if Hach does not undertake the defense thereof, provided that Buyer promptly notifies Hach of such suit and offers Hach either (i) full and exclusive control of the defense of such suit when Products of Hach only are involved, or (ii) the right to participate in the defense of such suit when products other than those of Hach are also involved. Hach's warranty as to use patents only applies to infringement arising solely out of the inherent operation of the Products according to their applications as envisioned by Hach's specifications. In case the Products are in such suit held to constitute infringement and the use of the Products is enjoined, Hach will, at its own expense and at its option, either procure for Buyer the right to continue using such Products or replace them with non-infringing products, or modify them so they become non-infringing, or remove the Products and refund the purchase price (prorated for depreciation) and the transportation costs thereof. The foregoing states the entire liability of Hach for patent infringement by the Products. Further, to the same extent as set forth in Hach's above obligation to Buyer, Buyer agrees to defend, indemnify and hold harmless Hach for patent infringement related to (x) any goods manufactured to the Buyer's design, (y) services provided in accordance with the Buyer's instructions, or (z) Hach's Products when used in combination with any other devices, parts or software not provided by Hach hereunder.

10. TRADEMARKS AND OTHER LABELS: Buyer agrees not to remove or alter any indicia of manufacturing origin or patent numbers contained on or within the Products, including without limitation the serial numbers or trademarks on nameplates or cast, molded or machined components.

11. SOFTWARE. All licenses to Hach's separately-provided software products are subject to the separate software license agreement(s) accompanying the software media. In the absence of such terms and for all other software, Hach grants Buyer only a personal, non-exclusive license to access and use the software provided by Hach with Products purchased hereunder solely as necessary for Buyer to enjoy the benefit of the Products. A portion of the software

may contain or consist of open source software, which Buyer may use under the terms and conditions of the specific license under which the open source software is distributed. Buyer agrees that it will be bound by any and all such license agreements. Title to software remains with the applicable licensor(s).

12. NONDISCLOSURE AND NON-USE OF PROPRIETARY INFORMATION: “Proprietary Information” means any information, technical data or know-how in whatever form, including, but not limited to, documented information, machine readable or interpreted information, information contained in physical components, mask works and artwork, which Hach considers proprietary or Proprietary, including but not limited to Hach’s service and maintenance manuals. Buyer and its customers, employees and agents will keep confidential all such Proprietary Information obtained directly or indirectly from Hach and will not transfer or disclose it without Hach’s prior written consent, or use it for the manufacture, procurement, servicing or calibration of Products or any similar products, or cause such products to be manufactured, serviced or calibrated by or procured from any other source, or reproduce or otherwise appropriate it without Hach’s prior written consent. All such Proprietary Information remains property of Hach. No right or license is granted hereby to Buyer or its customers, employees or agents, expressly or by implication, with respect to the Proprietary Information or any patent, patent application or other proprietary right of Hach, except for the limited use licenses implied by law.

13. CHANGES AND ADDITIONAL CHARGES: Hach reserves the right to make changes in design or additions or improvements to any products of the same general class as Products being delivered hereunder without liability or obligation to incorporate such changes, additions or improvements to Products ordered by Buyer unless specifically agreed upon in writing reasonably in advance of such Products’ delivery date. Services which must be performed as a result of any of the following conditions are subject to additional charges for labor, travel and parts: (a) equipment alterations not authorized in writing by Hach; (b) damage resulting from improper use or handling, accident, neglect, power surge, or operation in an environment or manner in which the instrument is not designed to operate or is not in accordance with Hach’s operating manuals; (c) the use of parts or accessories not provided by Hach; (d) damage resulting from acts of war, terrorism or nature; or (e) services outside standard business hours.

14. SITE ACCESS / PREPARATION / WORKER SAFETY / ENVIRONMENTAL COMPLIANCE: In connection with services provided by Hach, Buyer agrees to permit prompt access to equipment. Buyer assumes full responsibility to back-up or otherwise protect its data against loss, damage or destruction before services are performed. Buyer is the operator and in full control of its premises, including those parts of the premises where Hach employees or contractors are performing service, repair and maintenance activities. Buyer will ensure that all necessary measures are taken for safety and security of working conditions, sites and installations during the performance of services. Buyer is the generator of any wastes, including without limitation hazardous wastes, resulting from such services, repair and maintenance. Buyer is solely responsible to arrange for the disposal of any wastes at its own expense. Buyer will, at its own expense, provide Hach employees and contractors working on Buyer’s premises with all information and training required under applicable safety compliance regulations and Buyer’s policies. If the instrument to be serviced is in a Confined Space, as that term is defined under OSHA regulations, Buyer is solely responsible to make it available to be serviced in an unconfined space. Hach service technicians will not work in Confined Spaces. In the event that a Buyer requires Hach employees or contractors to attend safety or compliance training programs provided by Buyer, Buyer will pay Hach the standard hourly rate and expense reimbursement for such training attended. The attendance at or completion of such training does not create or expand any warranty or obligation of Hach and does not serve to alter, amend, limit or supersede any part of this Contract.

15. LIMITATIONS ON USE: Buyer will not use any Products for any purpose other than those identified in Hach’s catalogs and literature as intended uses. Unless Hach has advised the Buyer in writing, in no event will Buyer use any Products in drugs, food additives, food or cosmetics, or medical applications for humans or animals. In no event will Buyer use in any application any Product that requires FDA 510(k) clearance unless and only to the extent the Product has such clearance. Any warranty granted by Hach is void if any goods covered by such warranty are used for any purpose not permitted hereunder.

16. EXPORT AND IMPORT LICENSES AND COMPLIANCE WITH LAWS: Unless otherwise specified in this Contract, Buyer is responsible for obtaining any required export or import licenses. Hach represents that all Products delivered hereunder will be produced and supplied in compliance with all applicable laws and regulations. Buyer will comply with all laws and regulations applicable to the installation or use of all Products, including applicable import and export control laws and regulations of the U.S., E.U. and any other country having proper jurisdiction, and will obtain all necessary export licenses in connection with any subsequent export, re-export, transfer and use of all Products and technology delivered hereunder. Buyer will not sell, transfer, export or re-export any Hach Products or technology for use in activities which involve the design, development, production, use or stockpiling of nuclear, chemical or biological weapons or missiles, nor use Hach Products or technology in any facility which engages in activities relating to such weapons. Buyer will comply with all local, national, and other laws of all jurisdictions globally relating to anti-corruption, bribery, extortion, kickbacks, or similar matters which are applicable to Buyer’s business activities in connection with this Contract, including but not limited to the U.S. Foreign Corrupt Practices Act of 1977, as amended (the “FCPA”). Buyer agrees that no payment of money or provision of anything of value will be offered, promised, paid or transferred, directly or indirectly, by any person or entity, to any government official, government employee, or employee of any company owned in part by a government, political party, political party official, or candidate for any government office or political party office to induce such organizations or persons to use their authority or influence to obtain or retain an improper business advantage for Buyer or for Hach, or which otherwise constitute or have the purpose or effect of public or commercial bribery, acceptance of or acquiescence in extortion, kickbacks or other unlawful or improper means of obtaining business or any improper advantage, with respect to any of Buyer’s activities related to this Contract.

17. FORCE MAJEURE: Hach is excused from delays in delivery and performance of other contractual obligations under this Contract caused by acts or omissions that are beyond the control of Hach, including but not limited to Government embargoes, blockages, seizures or freeze of assets, delays or refusals to grant an export or import license or the suspension or revocation thereof, or any other acts of any Government; fires, floods, severe weather conditions, or any other acts of God; quarantines; labor strikes or lockouts; riots; strife; insurrections; civil disobedience or acts of criminals or terrorists; war; material shortages or delays in deliveries to Hach by third parties. In the event of the existence of any force majeure circumstances, the period of time for delivery, payment terms and payments under any letters of credit will be extended for a period of time equal to the period of delay. If the force majeure circumstances extend for six months, Hach may, at its option, terminate this Contract without penalty and without being deemed in default or in breach thereof.

18. NON ASSIGNMENT AND WAIVER: Buyer will not transfer or assign this Contract or any rights or interests hereunder without Hach’s prior written consent. Failure of either party to insist upon strict performance of any provision of this Contract, or to exercise any right or privilege contained herein, or the waiver of any breach of the terms or conditions of this Contract will not be construed as thereafter waiving any such terms, conditions, rights, or privileges, and the same will continue and remain in force and effect as if no waiver had occurred.

19. LIMITATION OF LIABILITY. **None of the Hach Indemnified Parties will be liable to Buyer under any circumstances for any special, treble, incidental or consequential damages, including without limitation, damage to or loss of property other than for the Products purchased hereunder; damages incurred in installation, repair or replacement; lost profits, revenue or opportunity; loss of use; losses resulting from or related to downtime of the products or inaccurate measurements or reporting; the cost of substitute products; or claims of Buyer’s customers for such damages, howsoever caused, and whether based on warranty, contract, and/or tort (including negligence, strict liability or otherwise). The total liability of the Hach Indemnified Parties arising out of the performance or nonperformance hereunder or Hach’s obligations in connection with the design, manufacture, sale, delivery, and/or use of Products will in no circumstance exceed in the aggregate a sum equal to twice the amount actually paid to Hach for Products delivered hereunder.**

20. APPLICABLE LAW AND DISPUTE RESOLUTION: The construction, interpretation and performance hereof and all transactions hereunder shall be governed by the laws of the State of Colorado, without regard to its principles or laws regarding conflicts of laws. If any provision of this Contract violates any Federal, State or local statutes or regulations of any countries having jurisdiction of this transaction, or is illegal for any reason, said provision shall be self-deleting without affecting the validity of the remaining provisions. Unless otherwise specifically agreed upon in writing between Hach and Buyer, any dispute relating to this Contract which is not resolved by the parties shall be adjudicated in order of preference by a court of competent jurisdiction (i) in the State of Colorado, U.S.A. if Buyer has minimum contacts with Colorado and the U.S., (ii) elsewhere in the U.S. if Buyer has minimum contacts with the U.S. but not Colorado, or (iii) in a neutral location if Buyer does not have minimum contacts with the United States.

21, ENTIRE AGREEMENT & MODIFICATION: These Terms & Conditions of Sale constitute the entire agreement between the parties and supersede any prior agreements or representations, whether oral or written. No change to or modification of these Terms & Conditions shall be binding upon Hach unless in a written instrument specifically referencing that it is amending these Terms & Conditions of Sale and signed by an authorized representative of Hach. Hach rejects any additional or inconsistent Terms & Conditions of Sale offered by Buyer at any time, whether or not such terms or conditions materially alter the Terms & Conditions herein and irrespective of Hach’s acceptance of Buyer’s order for the described goods and services.

MONTANA WHEAT AND BARLEY COMMITTEE
MIDYEAR PROGRESS REPORT – FY2014

PROJECT TITLE: Winter Wheat Breeding/Genetics (4W4602)

PRINCIPAL INVESTIGATOR: Phil Bruckner, Plant Sciences & Plant Pathology Dep., Bozeman

OBJECTIVES:

1. Develop improved cultivars of winter wheat adapted to Montana climatic conditions and cropping systems, which possess superior on-farm production characteristics (grain yield, winter hardiness, adequate and durable pest resistance, stress tolerance, agronomic characteristics) and superior end-use qualities.

2. Isolate, as much as possible, our foreign wheat customers from variations in wheat performance by development and release of suitable cultivars and production research to develop strategies to maximize quality consistency for wheat produced in Montana.

3. Investigate environmental, genetic, and management factors that influence wheat productivity and end-use in Montana

4. Coordinate Montana statewide winter wheat variety testing program and provide long-term performance data necessary for cultivar release decisions, variety recommendations, and producer management decisions.

RESULTS:

1. 2012-2013 season. Conditions were variable at testing sites with dry fall planting conditions and variable growing season precipitation. Growing season precipitation was above average at Havre, Sidney and Williston but below normal at other testing sites. Severe stripe rust at Kalispell (ave. 77% infection) reduced yield of some susceptible entries to less than 30 bu/acre with test weights in the 40 t0 50 lb/bu range. Winterkill was severe at Sidney and Williston averaging 23 and 25% survival, respectively. Cutting by wheat stem sawfly was evident but not extreme at Havre (10%) but severe at Loma. These conditions provided excellent evaluation and selection conditions for winter wheat cultivars. On a state basis, harvested winter wheat acreage for 2012 was 1.9 million acres averaging ~43 bu/acre (total production ~81.7 million bushels). Leading cultivars were Yellowstone (23.5%), Genou (14.0%), AP503 CL2 (6.9%), Decade (6.0%), CDC Falcon (5.1%), Rampart (4.5%), and Jerry (4.4%).
2. Breeding program.
   - In 2013, 254 crosses were added to the germplasm base with emphasis on incorporation of disease resistance and adaptation traits [176 topcross, 78 single cross].
   - The Intrastate Yield Trial was planted at eight and harvested at seven locations (Sidney hailed out). Winter conditions were moderate at all testing sites except Sidney and Williston (23% & 25% mean survival). Stripe rust was severe at Kalispell (mean severity 16 July, 77%). Timely precipitation resulted in high grain yields, averaging 74 bu/acre across seven testing sites and ranging from 54 bu/acre at Williston to 92 bu/acre at Kalispell (Table 1). Average grain yield ranged from 85 bu/acre for MT1138 to 61 bu/acre for MTS0832. Under severe stripe rust infection at Kalispell, grain yields ranged from139 bu/acre for Promontory to19 bu/acre for MTS0832.

Table 1. 2013 Intrastate Winter Wheat Test: Multi-Location Yield (bu/a)

	Cultivar/Line	Bozeman LAT	Havre LAT	Sidney Hailed	Williston RCB	Kalispell LAT	Moccasin LAT	Huntley LAT	Conrad LAT	7 Loc Avg.
	lattice efficiency	184%	245%	out		102%	120%	114%	265%	
	MT1138	89.8	65.8		**66.4***	**130.4***	**72.1****	67.8	**99.6***	**84.6****
	MTCL1131	90.1	71.6		**69.8***	120.5	**71.2***	63.0	**103.2***	**84.2***
	Yellowstone	**94.5***	66.9		**70.5***	**124.2***	66.4	65.4	**95.8***	**83.4***
	Colter	87.8	63.7		**76.0***	**129.8***	59.8	66.8	**94.5***	**82.6***
d	**MT1091**	86.3	68.5		**78.2****	112.7	**67.8***	64.6	**97.7***	**82.3***
	MT0978	**90.9***	74.6		**61.5***	**125.0***	61.6	67.8	**94.1***	**82.2***
	MT1117	84.2	67.9		**59.7***	**131.1***	**70.1***	64.2	**94.9***	**81.7***
	MT1090	**91.5***	66.6		**74.7***	111.8	**67.4***	66.4	90.8	**81.3***
	MTW08168	**92.7***	71.4		**62.5***	121.5	62.9	59.2	**98.4***	**81.2***
	MT1108	87.3	70.4		**61.8***	122.8	**68.3***	62.5	**94.6***	**81.1***
d	**Curlew**	**97.2***	73.6		50.8	122.5	55.0	**71.0***	89.8	**80.0***
	Promontory	**94.0***	65.9		46.6	**138.5****	56.3	65.9	92.1	**79.9***
	MT1113	**92.3***	67.3		**58.6***	112.6	65.7	**72.0***	89.7	**79.7***
	MT1078	**97.6***	74.1		39.0	106.6	60.7	**75.2***	**104.2****	**79.6***
d	**MT1105**	88.6	67.2		**60.5***	104.1	**70.7***	68.0	**96.7***	**79.4***
d	**MT1156**	89.8	69.5		**63.3***	112.3	62.7	67.6	90.9	**79.4***
d	**MT1102**	**91.6***	70.8		**60.6***	106.4	64.3	63.2	**98.1***	**79.3***
	SY Clearstone 2CL	81.8	74.8		50.2	117.8	**71.0***	63.9	**95.2***	**79.2***
	MTS1024	**91.3***	72.1		47.7	117.1	62.2	**72.2***	90.1	**79.0***
	MT1143	**93.8***	71.5		52.0	105.5	63.5	68.8	**95.9***	**78.7***
	SY Wolf	**97.8****	71.5		53.4	115.2	56.4	64.6	91.2	**78.6***
d	**MT10116**	86.3	69.4		**58.1***	109.2	61.1	70.0	**95.5***	**78.5***
d	**MT1092**	86.6	65.6		48.5	114.8	**67.9***	67.2	**96.6***	**78.2***
d	**Art**	**93.8***	60.9		24.6	**123.2***	**68.1***	**72.6***	**101.9***	**77.9***
	Jagalene	**96.8***	62.4		43.4	107.8	61.8	**75.1***	**94.9***	**77.5***
	Cowboy	**90.5***	**82.7****		53.2	71.3	61.6	**77.1****	**97.8***	**76.3***
	Warhorse	87.7	70.0		54.3	115.4	60.2	62.7	79.6	**75.7***
d	**Overland**	89.4	69.6		44.3	79.9	**69.6***	**75.3***	**98.0***	**75.2***
d	**Robidoux**	**90.2***	60.7		40.5	120.7	58.1	65.6	89.1	**75.0***
d	**MT1137**	84.4	62.3		**67.4***	72.6	**67.4***	62.5	**94.5***	**73.0***
	WB-Quake	76.7	71.2		**59.5***	110.3	58.6	55.8	77.7	**72.8***
	MTS0826-63	80.5	70.0		49.4	107.0	47.6	63.1	84.6	**71.7***
	Radiant	74.9	65.7		52.2	114.0	44.6	59.4	81.4	70.3
	Judee	81.8	72.7		37.4	106.6	48.3	61.8	78.8	69.6
	Decade	89.0	67.4		**57.1***	42.4	61.3	**71.2***	89.4	68.3
d	**Norris (CL)**	85.8	64.8		**60.1***	73.0	52.8	62.0	79.8	68.3
	Ledger	79.0	63.4		43.9	99.3	48.9	60.3	82.7	68.2
	McGill	83.9	62.1		36.1	77.3	66.2	62.0	88.3	68.0
	Broadview	78.3	69.1		52.8	61.3	54.7	65.9	89.8	67.4
	CDC Falcon	80.2	58.2		45.8	76.6	59.2	67.1	83.8	67.3
d	**Accipiter**	74.9	64.7		**63.0***	64.1	52.7	62.1	84.3	66.5
d	**WB-Matlock**	76.1	68.6		37.8	59.8	58.8	64.4	88.9	64.9
	Jerry	79.0	63.6		**65.2***	43.0	58.6	61.4	80.8	64.5
	Rampart	74.3	66.7		49.9	85.9	45.2	53.5	75.6	64.4
d	**Bynum (CL)**	81.4	69.2		41.8	85.8	38.5	55.2	75.6	63.9
	Genou	78.4	70.6		52.0	57.4	47.3	56.8	74.7	62.5
	Bearpaw	82.7	68.7		48.5	31.1	58.2	61.9	82.5	61.9
	Carter	82.7	61.3		50.9	26.9	57.3	64.7	89.8	61.9
d	**MTS0832**	75.7	74.2		**62.9***	18.9	55.6	62.6	74.9	60.7
	Average	**86.4**	**68.2**		**54.4**	**91.5**	**60.1**	**65.3**	**90.0**	**74.4**
	LSD (0.05)	**7.5**	**6.7**		**21.7**	**15.6**	**5.7**	**6.9**	**10.7**	**13.0**
	C. V. (%)	**4.9**	**5.5**		**24.6**	**9.6**	**5.4**	**7.0**	**6.7**	**16.6**
	P-value (Varieties)	**<.0001**	**<.0001**		**0.0010**	**<.0001**	**<.0001**		**<.0001**	**<.0001**

d = cultivars/lines dropped for 2014 test

- The highest yielding lines in the Intrastate trial over the past five years are shown in Table 2. Of note is that Yellowstone has shown excellent yields in all years. 2013 releases Colter and MTW08168 have been in the elite yield group since 2011. Yellowstone has the highest statewide yield average of all lines over the past nine years and has averaged 64.9 bu/a over 194 trials during that period, 9.3% and 7.2% higher than CDC Falcon and Jagalene, respectively.

Table 2a. 10 highest yielding winter wheat lines at 7 locations in the 2013 Montana Intrastate Trial.

MT1138 (85)	MTCL1131 (84)	Yellowstone (83)	Colter (83)	MT1091 (82)
MT0978 (82)	MT1117 (82)	MT1090 (81)	MTW08168 (81)	MTS1108 (81)

Table 2b. 10 highest yielding winter wheat lines at 8 locations in the 2012 Montana Intrastate Trial.

MT1090 (70)	Colter (68)	MT1078 (66)	Yellowstone (66)	MTW08168 (65)
MT10116 (65)	MT1091 (64)	SY Clearstone (64)	MT1092 (64)	MTS1024 (64)

Table 2c. 10 highest yielding winter wheat lines at 7 locations in the 2011 Montana Intrastate Trial.

Colter (83)	Yellowstone (81)	MTW08168 (80)	MT0978 (80)	Promontory (79)
MT0990 (79)	MT08146 (79)	Warhorse (77)	MT08189 (76)	Curlew (76)

Table 2c. 10 highest yielding winter wheat lines at 6 locations in the 2010 Montana Intrastate Trial.

Yellowstone (94)	Overland (94)	MT0871 (93)	MTS0819 (92)	Settler CL (91)
MT0890 (91)	Promontory (90)	MT0861 (89)	Hyalite (89)	Wahoo (88)

Table 2d. 10 highest yielding winter wheat lines at 7 locations in the 2009 Montana Intrastate Trial.

Yellowstone (78)	MT0495 (75)	Pryor (72)	NI04421 (72)	Neeley (71)
Curlew (71)	BZ9W02-2051 (71)	Wahoo (71)	CDC Falcon (71)	MT0742 (71)

Table 2e. 10 highest yielding winter wheat lines at 7 locations in the 2008 Montana Intrastate Trial.

Accipiter (67)	MT0495 (67)	Pryor (67)	Decade (67)	CDC Falcon (66)
Yellowstone (65)	Wahoo (64)	Jagalene (64)	MTS04114 (63)	MTS0531 (63)

- Average grain yields over the past 4 years in the Intrastate trial (28 location-years) for the 5 highest yielding lines were Yellowstone, 80.0 bu/acre; Promontory, 76.9 bu/acre; Curlew, 74.1 bu/acre; Warhorse, 73.9 bu/acre; and Robidoux, 72.7 bu/acre ($LSD_{0.05}$=6.2 bu/acre). Robidoux has unacceptably bread quality and will not be recommended for Montana production.
- Breeder seed was increased at Bozeman for MT1090 and MTS9720. Warhorse, Colter, and WB3768 (MTW08168) were approved for release and foundation seed was released to seed growers fall, 2013. Multiplication and purification headrows sets were planted and harvested for MT1108, MT1138, MTS0826-63, MT1113 and MT1117. M&P sets MT1102, MT1137, and MT1143 were discarded.
- Off-station yield trials were conducted at additional 17 sites (14 sites harvested). Average yield in off-station trials ranged from 63 bu/acre (Overland) to 48 bu/acre (MTS0832). Overland, MT1090, MTS1024, MT0978, Jagalene, Yellowstone, MTW08168 and SY Clearstone 2CL performed best across sites.
- A 36 entry advanced yield trial was planted and harvested at six locations. Average yield ranged from 50 bu/acre at Huntley to 87 bu/acre at Conrad. **Five hollow-stem, one forage, two solid-stem, and one Clearfield experimental lines were selected for further testing and initial seed purification.**
- A 64 entry Preliminary A yield trial was planted and harvested at four locations. Yield of entries ranged from 59 to 80 bu/acre. **26 MT experimental lines were selected [2 Clearfield, 1 hard white] for additional testing**.

- A 49 entry Preliminary Sawfly yield trial was planted and harvested at four locations. Yield of entries ranged from 42 to 56 bu/acre. Cutting by wheat stem sawfly was significant at Loma. **Eleven solid stem lines (2 Clearfield) were retained in upper level sawfly trials**.
- Segregating populations were planted at Fort Ellis, Williston, Havre, and Bozeman. Mass selection against extreme height was implemented by trimming a top layer of heads from each population with an electric hedge trimmer prior to selection for other traits. Heads were selected from each population and bulked to produce improved populations. Approximately 15,000 heads were selected from F_5 populations at Havre and Bozeman to generate F_6 head rows in 2014. Populations were severely infested with stem and stripe rust at Fort Ellis allowing effective mass selection for resistance [24 populations were passed over a gravity table to retain the plumpest fraction for planting].
- 1122 lines were evaluated for agronomic potential in single-replicate observation nurseries (SROA, B) planted at Bozeman, Havre, Conrad, and Moccasin. Based on agronomic performance and early-generation quality screening, **112 lines were harvested and 60 lines subsequently selected for preliminary yield testing. These selections included 6 hard white selections, 3 forage lines, and 1 Clearfield line.**
- 536 solid-stemmed lines were evaluated for stem solidness and agronomic potential in a single-replicate observation nursery (SFO) at Bozeman, Conrad, and Havre. **Based on stem solidness, resistance to sawfly cutting, agronomic potential, and end-use quality evaluation, 64 solid-stemmed lines were harvested with 30 lines being subsequently selected for preliminary yield testing.**

24,552 single rows and head rows were evaluated at Bozeman and Fort Ellis for stem solidness, agronomic potential, and productivity (**Table 3)**. 2837 rows were selected, harvested, and further evaluated. 347 lines were discarded based on poor grain protein, kernel characteristics, or miscellaneous reasons. 1417 hollow-stem and 636 solid-stem lines were selected for plot evaluation and pest and end-use quality screening in 2014. All selected head rows have been screened for grain protein and PPO, and will be subsequently screened for SDS-sedimentation.

Table 3. Summary of headrow evaluation, selection, & disposition in 2013.

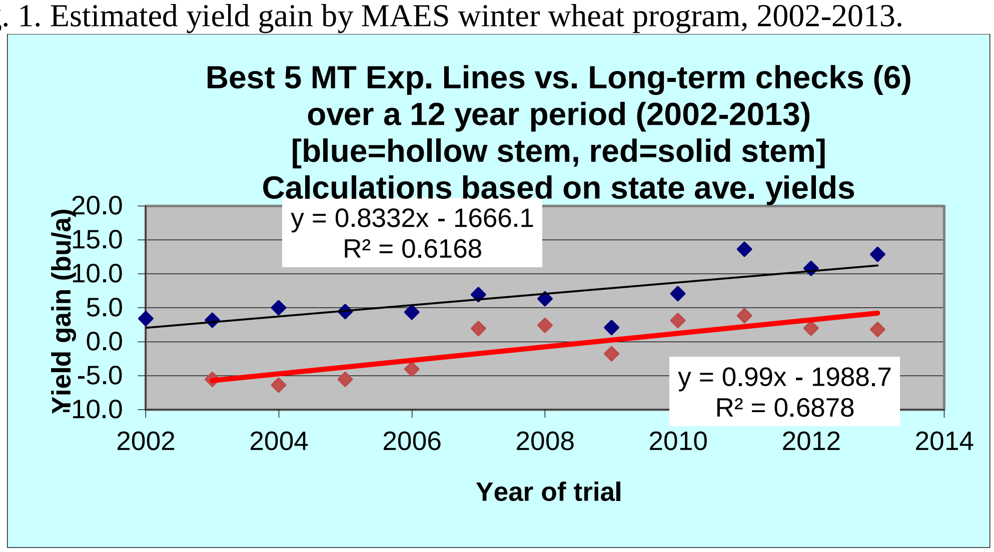
Block	Type	Total	Harvested	checks	Tentative Selections	Protein DISCARD	Hollow seln advanced	Solid seln advanced
A	Clearfield	1324	163	3	160	32	88	40
B	SAWFLY-F6	2520	268	6	262	41		221
C	SAWFLY-F6	2014	274	5	269	12		257
C	SAWFLY-F7	506	37	1	36	6		30
D	SAWFLY-F7	1192	98	3	95	7		88
D	REGULAR-misc	1028	120	2	118	20	98	
D	F1 rows	147	147	6	141			
E	REGULAR-F6	3576	393	8	385	67	318	
F	REGULAR-F6	2250	286	6	280	17	263	
G	REGULAR-F6	162	29	1	28	4	24	
H	REGULAR-F6	1164	118	3	115	9	106	
J	REGULAR-F6	472	86	1	85	3	82	
J	REGULAR-F7	2048	198	5	193	29	164	
K	REGULAR-F7	2072	216	4	212	30	182	
K	REGULAR-misc	50	23		23			
K	REGULAR-RLN	297	297					
P	RLN "Persia 20"	228	9	1	8	0	8	
Kal. hill plots	Stripe rust seln	560	75		75	15	60	
STEMRUST	OBSERVATION	2006	0					
Regular, SF	M&P (8 sets)	936		0			24	
	2013 total	24552	2837	55	2485	292	1417	636

- Cultivar releases. Warhorse, Colter, and WB3768 (MTW08168) were released to Montana seed growers in 2013. Judee, Bearpaw, and Decade are increasing in production. Performance summaries are available at: http://plantsciences.montana.edu/FoundationSeed/quickfacts/. No additional winter wheat releases are proposed in 2014.
- Progress – Clearfield wheat. The MSU winter wheat CLEARFIELD program has transitioned to two-gene imazamox-tolerant germplasm (two genes conferring imidazolinone tolerance). The two homeologous genes work in an additive fashion and will allow lines to tolerate higher doses of Beyond without crop injury. We transferred the second herbicide tolerance gene from CDC Teal 11A spring wheat into winter wheat. In 2012, a 2-gene Yellowstone Clearfield selection, was released and licensed to Syngenta Seeds, Inc. and subsequently named ‘SY Clearstone 2CL’. Additional advanced breeding Clearfield lines are being tested.

SUMMARY:

Progress has been made in winter wheat cultivar development. Yields have been improved an average of 0.8 and 1.0 bu/acre/cycle over 12 breeding cycles (2002-2013) in MAES hollow and solid stem lines, respectively (Fig. 1). This rate of yield improvement is about 1% per year, similar to the overall rate of genetic gain reported for U.S. winter wheat breeding programs since 1959 (Crop Sci. 50:1882-1890). Yellowstone represents the highest yielding winter wheat line ever developed at MSU. Decade adds increased winter hardiness and reduced plant height at a similar yield level. Judee and Bearpaw solid-stem, semi-dwarf cultivars have now entered commercial production are expected to replace Genou, whose popularity has declined since the 2011 stem rust epidemic. Excellent progress in selection of lines with stripe rust resistance was made in 2011to 2013. 2013 releases Warhorse and Colter represent further gains in yield potential in rust-resistant backgrounds. Several promising experimental lines are emerging from the testing program and are being increased and considered for variety release.

Fig. 1. Estimated yield gain by MAES winter wheat program, 2002-2013.



~1+% gain/year

Priority breeding objectives will remain higher grain yield, resistance to wheat stem sawfly, imidazolinone herbicide tolerance, winter hardiness, and end-use quality. Development of yield-competitive, winter hardy, sawfly-resistant HRWW and HWWW cultivars is priority. The sawfly selection nurseries at Havre and Loma will be used as a selection site for phenotypic screening of sawfly resistance. Selection for winter hardiness and sawfly resistance will also be conducted at Research Center sites including Williston, Havre, Conrad, and Moccasin. End-use quality protocols have expanded to evaluate noodle-making characteristics. Proprietary research such as development of herbicide-resistant varieties will be conducted for benefit of Montana wheat producers.

FUNDING SUMMARY:

The Clearfield cultivar development program is supported by a grant in aid from BASF ($20,000 FY2014). The general winter wheat breeding program is supported by project generated research fees and royalties (FY2014 ~$27,000 & ~$10,000, respectively).

MWBC FY2013 Grant Submission Plans:

I will submit one proposal, Winter Wheat Breeding. We likely will ask for slightly higher financial support due to increasing salaries and expenses we are incurring.

FY2014 Montana Wheat and Barley Compliance Midyear Report

Title: Trapping click beetles with pheromone traps (Coleoptera: Elateridae); Grant#W4604

Principal Investigator: Dr. Gadi V.P. Reddy

Objectives:

1. Screen European based pheromone lures (Hungary) in the Golden Triangle areas using Yatlor Funnel trap (Italy) which is specifically designed for catching click beetles.

2. Develop the appropriate pheromone traps suitable for use under Montana weather conditions.

3. Isolate the chemicals, investigate the active components, and identify them from the pheromones of the predominant species found in the Golden Triangle.

4. Develop laboratory rearing technique for the wireworms/click beetles based on the pheromone trap catches.

The pheromone lures was obtained from Dr. Tóth Miklós, MTA lev. tagja - corr. member of HAS tud. tan. - Scientific advisor, Plant Protection Institute, MTA ATK, Budapest, Pf 102, Hungary, H-1525, and was stored in the laboratory until use.

The Yatlor Funnel traps with the European based lures were installed in the growers' field in Kalispell, Ledger, Conrad, Rock city and Valier in May 2013. Traps with different lures and control (without lures) were tested independently (12 pheromone lures × 3 replications × 4 sites) at the above mentioned locations. The experiment was carried out from May to August 2013. The trap catches were recorded every two weeks. The trapped adults were brought to the laboratory to be reared.

Results:

The Yatlor traps baited with European based lures (Figure 1) installed at Kalispell, Ledger, Conrad, Rock city and Valier collected different species of wireworms. None of the tested lures collected significantly high number of adults (Figures 2). The trap with the lures of *Agriotes sputator* appeared to be more effective than other lures. However, no major difference was found.

A laboratory rearing of wireworms is being maintained at the Western Triangle Agricultural Research Center in Conrad. These adults will be used for the identification of pheromone compounds for the wireworm species in Montana.

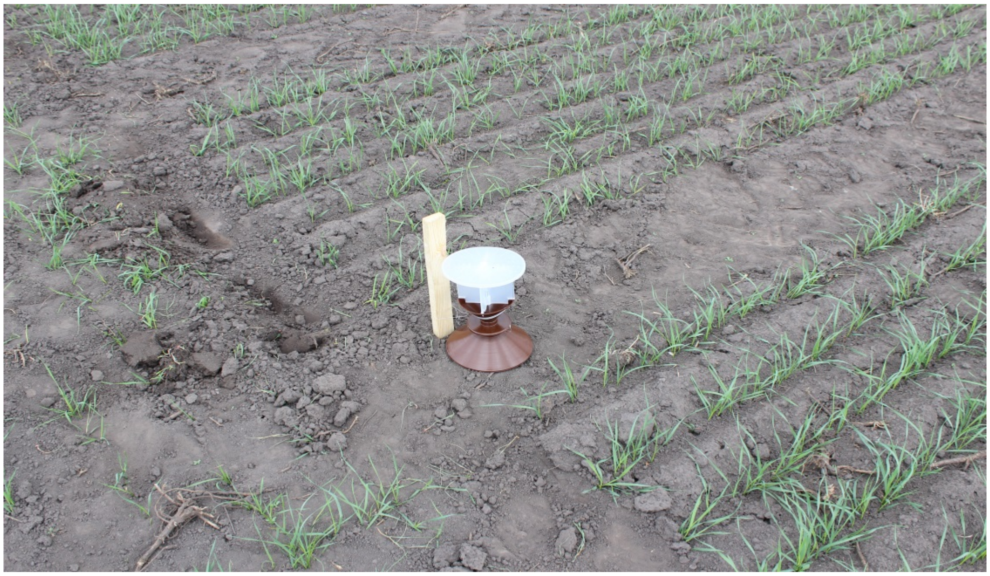


Figure 1: Yatlor Funnel trap designed specifically for pheromone trapping of click beetles (Photo credit: L. Furlan, Italy; *Inform. Fitopatol*. 10: 49–54, 2004).

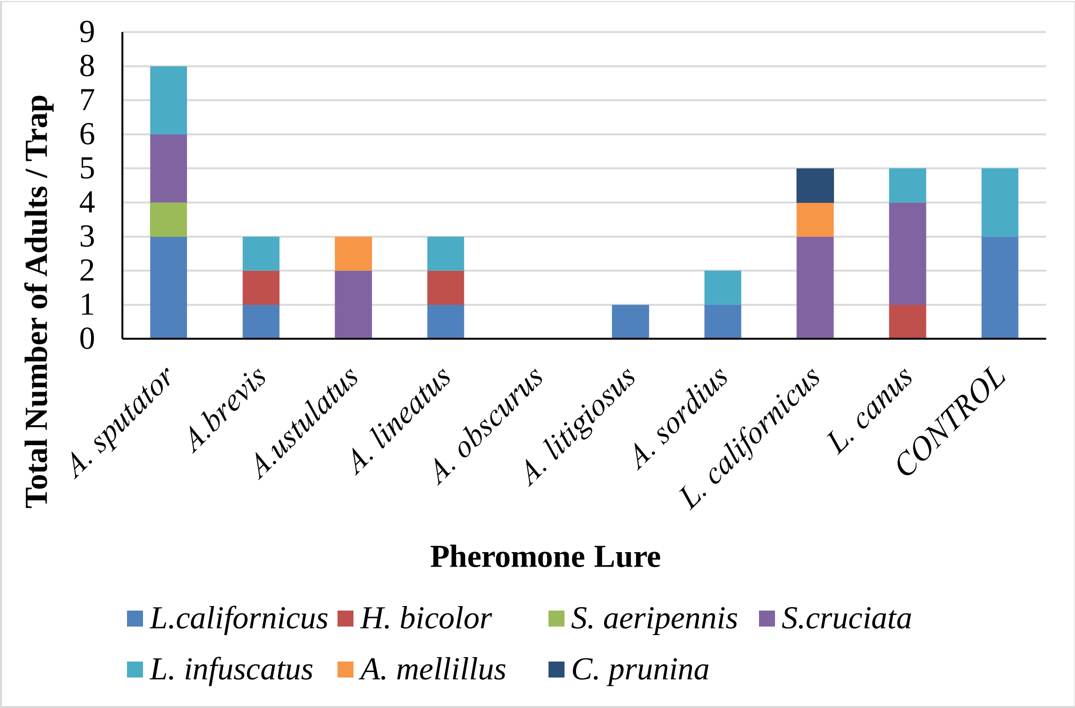


Figure 2: Total number of adults caught in Yatlor traps baited with European-based lures.

Summary:

1. Screen European based pheromone lures (Hungary) in the Golden Triangle areas using Yatlor Funnel trap (Italy) which is specifically designed for catching click beetles.

None of European-based pheromone lures were highly effective in catching the wireworms species recorded in Montana, although lures with *A. sputator* tended to be more effective than others. According to the recent survey, *Limonius californicus* and *Hypnoidus bicolor*, are the two common wireworm species damaging the spring wheat in the Golden Triangle areas of Montana. However, *L. californicus* is the predominant species found in Montana.

2. Develop the appropriate pheromone traps suitable for use under Montana weather conditions.

The same experiment will be repeated again for summer 2014 with more lure types. Once we know the effective lure, several types will be evaluated for this summer with the available grant.

3. Isolate the chemicals, investigate the active components, and identify them from the pheromones of the predominant species found in the Western Triangle.

Dr. Tóth Miklós will be sending his Postdoctoral Research Associate Dr. Jozsef Vuts to Conrad in May to help us with isolation and identification of pheromone compounds from the wireworm species. Meanwhile, we have obtained all the necessary supplies for identification of the compounds.

4. Develop laboratory rearing technique for the wireworms/click beetles based on the pheromone trap catches.

We have already developed a laboratory wireworm rearing method in incubators. Since they have very long lifecycles (2-7 years), it is taking time. Anyway, we will be developing mass rearing will be developed in order to conduct some laboratory experiments.

Funding Summary (Indicate other funds supporting this project to date. MWBC grant expenditures will be provided to MWBC by OSP.)

The entire costs for this work have been charged to the project funded by Montana Wheat and Barley Committee.

MWBC FY2015 Grant Submission Plans:

Since the isolation, identification and field evaluation of click beetle pheromones require substantial time and input, the proposal will be submitted to continuing the work.

Also the project on the effectiveness of the entomopathogenic fungi and nematodes will be submitted for possible consideration and funding.

FY2014 Montana Wheat and Barley Compliance Midyear Report

Title (4W4618):

Obtaining a Diesel Pickup for the survey work at the Triangle Areas of Montana

Principle Investigators:

Gadi V.P. Reddy (PI), Superintendent, Western Triangle Ag Research Center, Conrad
Olga Walsh (Co-PI), Assistant Professor of Soil Nutrient Management, WTARC, Conrad

Objectives:

The objective is to a purchase Diesel Pick Up to help the Entomology/Insect Ecology, Soil Nutrient Management and Entomology and Varietal Trials programs in the Golden Triangle Area of Montana.

Results:

At this moment we are waiting for the Spring Vehicle Call to place an order for this new Diesel pickup. Currently at WTARC pickups are either set up to tow or transport personnel, thus two pickups could be replaced with one pickup set up for both towing trailers and transporting people.

Summary:

Diesel would provide much more fuel efficiency and decrease the number of stops needed while traveling to off station plots allowing for more time at plots. Diesel motors last substantially longer than gasoline powered motors, which can decrease the total cost of ownership.

Funding Summary:

Expenditure information for grant index 4W4618 is to be provided by Montana State University. Office of the Sponsored Programs. There no other grant support for this project.

MWBC FY2015 Grant Submission Plans:

This equipment grant is for a onetime purchase, so it will not be resubmitted in FY2015.

FY2014 Montana Wheat and Barley Compliance Midyear Report

TITLE: (Grant 4W4630) Impact of Adding ESN to Urea as the Nitrogen Source for Irrigated Spring Wheat Production in Montana

PRINCIPLE INVESTIGATOR: Kent A McVay

OBJECTIVES: Evaluate ESN in combination with Urea as a nitrogen fertilizer source for irrigated spring wheat production in Montana

RESULTS: Due to extremely dry conditions prior to the availability of irrigation water in early May, early growth of spring wheat was inconsistent and stressed. By late May significant rain was received which helped the spring wheat recover. A hail storm occurred on July 27, which caused an estimated field loss of 10 - 20%.

The analysis of variance indicated a significant response to applied nitrogen for grain yield and protein, but only protein responded to nitrogen source (Table 1). A significant interaction of nitrogen rate by source was seen for grain yield (Table 1).

Spring wheat did respond positively to applied nitrogen with check yields of only 36 bu/acre and yields plateauing by approximately 200 lbs/acre of applied fertilizer N (Table 2). There were no significant differences in grain yield due to fertilizer source, but grain protein was enhanced by the highest level of ESN (Table 2). Although the protein response to ESN was not linear as the trend in intermediate levels of ESN was reversed.

The significant interaction of nitrogen rate by source is expected for a product that is advertised to improve nitrogen use efficiency. At lower N rates of 50 and 100 lbs N/acre the mixes that had greater amounts of ESN yielded higher than those mixes where urea was the main component. But the plateau of the N response curve showed no apparent differences between N sources.

This is the second year ESN has been evaluated at SARC for spring wheat production. In 2012 a similar response in grain yield to N rate was seen, but no significant response to source occurred, with no significant interaction of rate by source (Table 3). Grain protein was also increased with higher N rates, but was actually decreased by greater amounts of ESN included in the fertilizer mix (Table 4). In 2012 there were no significant interactions for either grain yield or grain protein of spring wheat. Grain yields in 2012 were much better than those in 2013 with top yields of 112 bu/acre.

FUNDING SUMMARY: Grant expenditures will be provided to MWBC by OSP

MWBC FY2015 GRANT SUBMISSION PLANS: Results from the two years of evaluation of ESN do not warrant any further investigation of ESN in southcentral Montana.

Table 1. Analysis of variance summary for spring wheat response, Huntley, MT 2013.

	GRAIN YIELD	PROTEIN
REP	***	***
NITROGEN (N) RATE	***	***
UREA/ESN MIX	NS	***
N X MIX	**	NS

Significance levels are indicated as * 10%, ** 5%, and *** 1% using F statistic. NS is non-significant.

Table 2. Spring wheat grain yield and protein contents resulting from fertilizer N rate and source applications, Huntley, MT. 2013.

	GRAIN YIELD	PROTEIN
NITROGEN RATE	Bu/acre	%
0	36.0	12.8
50	45.5	12.8
100	52.7	13.1
150	59.2	13.9
200	66.2	14.5
250	69.1	15.1
300	67.2	15.5
LSD(.05)*	3.05	0.31
UREA/ESN MIX		
0/100	60.8	14.4
33/67	60.1	14.4
67/33	58.7	13.9
100/0	60.4	13.9
LSD(.05)	NS	0.26

*LSD values in each column are used to compare treatment means within the main variable using Fisher's protected LSD. Check values (0 N rate) are shown for comparison only and are not part of the ANOVA test. A separate ANOVA test (data not shown) was used to verify that there was a significant response to applied N for grain yield, and protein. Soil tests in fall 2012 indicated 80 lbs/acre nitrate in a 0-48" profile. NS indicates non-significant.

Table 3. Analysis of variance summary for spring wheat response, Huntley, MT 2012.

	GRAIN YIELD	PROTEIN
REP	**	**
NITROGEN (N) RATE	***	***
UREA/ESN MIX	NS	**
N X MIX	NS	NS

Significance levels are indicated as * 10%, ** 5%, and *** 1% using F statistic. NS is non-significant.

Table 4. Spring wheat grain yield and protein contents resulting from fertilizer N rate and source applications, Huntley, MT. 2012.

	GRAIN YIELD	PROTEIN
NITROGEN RATE	Bu/acre	%
0	88.1	10.5
40	99.3	11.1
80	104.8	11.6
120	107.9	12.1
160	112.3	12.6
200	110.6	13.4
240	112.0	13.7
LSD(.05)*	2.92	0.35
UREA/ESN MIX		
0/100	106.9	12.2
33/67	108.5	12.4
67/33	107.5	12.4
100/0	108.3	12.7
LSD(.05)	NS	0.28

*LSD values in each column are used to compare treatment means within the main variable using Fisher’s protected LSD. Check values (0 N rate) are shown for comparison only and are not part of the ANOVA test. A separate ANOVA test (data not shown) was used to verify that there was a significant response to applied N for grain yield, and protein. Soil tests in fall of 2011 indicated 138 lbs/acre available nitrate in a 0-48” profile. NS indicates non-significant.

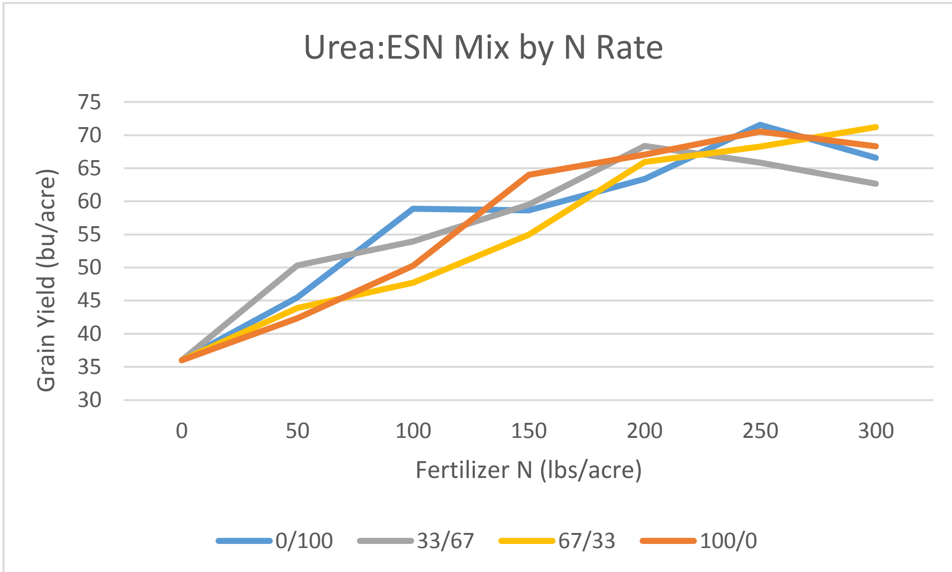


Figure 1. Interaction of nitrogen source by rate for irrigated spring wheat grain yield, Huntley 2013.

FY2014 Montana Wheat and Barley Compliance Midyear Report

1. **TITLE**: A Field Survey for Occurrence of Herbicide-Resistant Kochia in Northern Montana (Grant # 4W4623)

2. **PRINCIPAL INVESTIGATOR**: Prashant Jha, Weed Scientist, Montana State University, Department of Research Centers, Southern Agricultural Research Center, Huntley, MT

3. **OBJECTIVES**:
    1. Determine the distribution and frequency of glyphosate-, dicamba-, and sulfonylurea (ALS inhibitor)-resistant kochia in wheat-fallow systems of northern Montana.
    2. Develop and deliver education materials on herbicide resistance management and alternative herbicide programs for kochia management in wheat-fallow systems of Montana.

4. **RESULTS**:

Objective 1: Distribution and frequency of glyphosate-, dicamba-, and sulfonylurea (ALS inhibitor)-resistant kochia in wheat-fallow systems of northern Montana.

Survey Development: A random survey was conducted in October-November of 2013 to determine the distribution and frequency of herbicide-resistant [glyphosate (Roundup)-, dicamba-, and sulfonylurea (Ally Extra)] kochia in northern Montana Grain Belt (**Figure 1**). The seven Counties in Montana that were covered in the survey include Hill, Liberty, Glacier, Toole, Furgus, Judith Basin, and Choteau.

Kochia populations were sampled in fallow fields, field edges/ fence lines, and roadsides, although majority of populations were from chem-fallow or post-harvest wheat fields. Approximately 10 mature kochia plants were randomly collected at each sampling site. Collected samples from each sampling site were combined into a single sample (population). ***A total of 137 populations (22 populations from Hill, 18 from Liberty, 27 from Toole,14 from Glacier, 8 from Furgus, and 48 from***

Choteau County) were included in the survey. GPS coordinates (way points shown as Wpt# in Figure 1) were recorded at each sampling site.
Seeds for each field were put separately in labeled un-sealed paper bags to prevent fungal growth. Seeds were air-dried and stored at room temperature until screening for resistance.

Herbicide Resistance Screening: Greenhouse experiments were initiated during fall of 2013, and the resistance screening project is currently in-progress at the Southern Agricultural Research Center, Huntley, MT. Experiments were conducted to determine if kochia populations collected from the survey sites were resistant or susceptible to glyphosate (Roundup), dicamba (Banvel), and/or sulfonylurea (SU) (Ally Extra) herbicides using discriminate doses for the herbicides (Roundup @ 22 oz/a; Ally-Extra @ 0.5 oz/a, Dicamba @ 8 oz/a). The discriminate dose for a given herbicide was the minimum dose needed to obtain at least 90% control of the susceptible kochia population. A known susceptible population of kochia (used in our previous experiments) with no prior exposure to any of these herbicides were used as a reference. Additionally, known dicamba-resistant, SU-resistant, and glyphosate (Roundup)-resistant biotypes were used for comparison.

Three separate set of experiments were conducted for screening dicamba, Ally Extra, and glyphosate resistance. Seeds from a selected survey sample were planted on the surface of commercial potting mix in flat trays placed in the greenhouse. *Each tray comprised of 48 kochia seedlings, with three replicated trays for each herbicide treatment*. *Kochia plants were treated with the discriminating dose of the herbicide at the 3- to 4-inch height*. Applications were made inside a stationary spray chamber calibrated to deliver 10 GPA of the spray mixture. Appropriate adjuvants were used as defined by the herbicide label. *At 21 DAA, plant response to herbicide application was visually scored as susceptible: dead or nearly dead, or resistant: some injury but new growth, or no injury.* Assessments were made relative to known herbicide-treated and untreated susceptible and resistant populations. Based on the discriminating dose screening, the resistant populations will be further screened to determine the level of resistance compared to the known susceptible biotype (not included in this project).

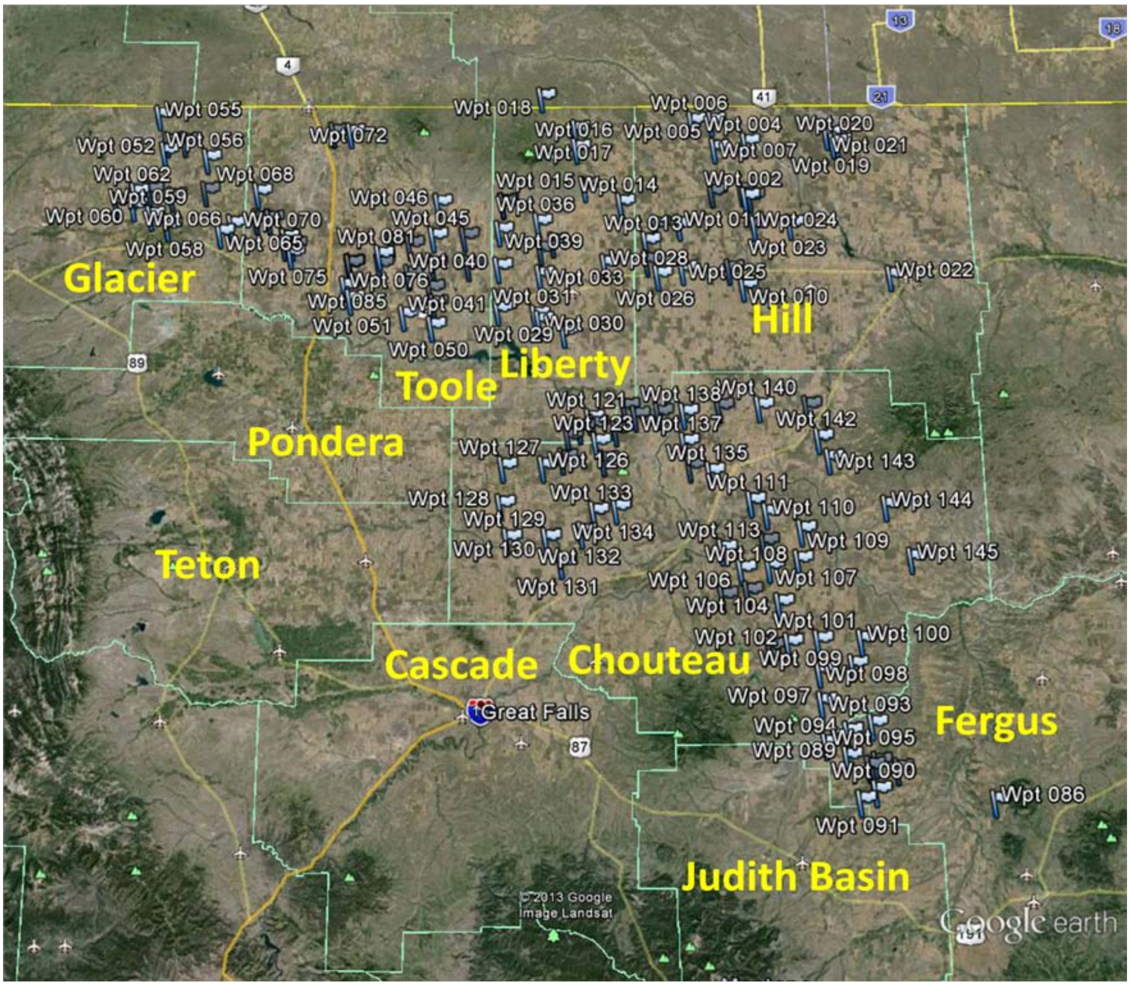


Figure 1. Survey of herbicide (glyphosate, SU, and dicamba)-resistant kochia in northern Montana conducted fall of 2013. A total of 137 populations were collected. Wpt # indicates the way point (GPS coordinates) for each sampling site.

Survey Results:

<u>Out of 137 populations collected, we are currently screening 90 populations in the greenhouse at SARC (November 20, 2013-January 14, 2014).</u>

Glyphosate (Roundup)-Resistant Kochia

For the glyphosate resistance screening, presently, we have data for 37 survey sites (Table 1). Out of those 37 sites tested, glyphosate-resistant kochia was identified in 23 sites (62% of the sites tested). Out of 19 survey sites from Hill County, 9 sites were identified with GR kochia infestation (47% of the survey sites tested). Occurrence of glyphosate-resistant kochia in Hill County was first reported in 2012. The frequency of resistance in Hill County confirmed populations varied from 1 to 96% (Table 1), with a low frequency of resistance (1 to 2%) being observed in populations collected from field borders. Except two in-field sites with resistance frequency below 30%, majority of the populations collected from fallow fields in Hill County had high frequency of glyphosate-resistance ranging from 84 to 96%.

Out of the 14 sites tested in Liberty County, kochia resistant to glyphosate was identified in10 sites (71% of the survey sites tested) (Table 1). Frequency of glyphosate resistance in those 10 confirmed populations varied from 1 to 95%, with two populations that were collected from fallow fields had 80 and 95% of the plants being resistant. We have reported occurrence of high level of glyphosate resistance (up to 10-fold) in Chester populations from Liberty County in 2012. Majority of the survey populations from the field borders had low resistance frequencies (1 to 4%). There was one population from roadside in Liberty County that was also tested positive for glyphosate resistance (resistance frequency of 1%).

All the four populations from the Toole County included in the current survey report were identified resistant to glyphosate. All those field-collected populations had high frequency of glyphosate resistance, which varied from 72 to 100% (meaning 72 to 100% of the plants in those populations were glyphosate-resistant). *This is the first reported occurrence of glyphosate resistant kochia in Toole County, Montana*. It is noteworthy that glyphosate resistance has evolved at an alarming rate in kochia populations from chem-fallow fields. Often resistance is realized in a field when at least 30% of the weed population is not controlled by a recommended field rate of an herbicide, which would otherwise provide >90% control of that population. Even though glyphosate resistance frequencies were low (1 to 5%) in a few survey samples, it is expected to increase over time with increase in selection pressure from repeated applications of glyphosate alone in pre-seeding cereals, chem-fallow, or post-harvest wheat stubble.

Dicamba (Banvel)-Resistant Kochia

Out of the 13 survey populations tested so far (as of January 14) with dicamba at the discriminating dose (8 oz/a), 10 populations were identified to be resistant to dicamba. Majority of those populations tested were from Hill and Toole Counties. Liberty county kochia populations have been sprayed recently and are being investigated. Seven of the glyphosate-resistant populations from Hill and Toole

Counties were also resistant to dicamba, with dicamba-resistance frequency of 2 to 15% in those populations. *This suggests the evolution of glyphosate and dicamba multiple herbicide-resistant kochia, which would make control efforts even more challenging in wheat-fallow systems of Montana*. Although we do not have results from the Choteau County populations yet (plants being grown in the greenhouse), occurrence of dicamba-resistant populations (in cereals) in Montana have been first reported in 1995 from this County. Although frequency of dicamba resistance in confirmed populations is low, it may increase with selection pressure over time.

Sulfonylurea (SU)-Resistant Kochia

Kochia resistant to sulfonylurea (SU) herbicides is believed to be widespread in Montana cereal production systems. We expected high frequency of resistance to SU herbicide (Ally Extra) in almost all survey populations tested from wheat-fallow fields. For the 4 populations tested so far, frequency of resistance to Ally Extra varied from 96 to 100%, with only one population showing a resistance frequency of <30%. The results from all the 37 populations will be presented (February, 2014) during the MWBC proposal report meeting. It is apparent that all populations (in-field or field borders) that are resistant to glyphosate and/or dicamba will be resistant to the SU herbicide. *This further suggests the occurrence of kochia populations with stacked multiple-resistance to glyphosate, dicamba, and SU herbicides in Montana cereal-based production systems*.

Based on the survey results obtained so far (November 20-January 14, 2014), glyphosate-resistant kochia has established in Hill, Liberty, and Toole Counties of Montana, where wheat-fallow is the major rotation. *The populations collected from the survey sites at Judith Basin, Glacier, Furgus, and Choteau Counties is currently under investigation*. The frequency of resistance will vary depending on the time when glyphosate-resistant individuals were selected or introduced (via pollen or tumbling mechanism of seed dispersal) in a given population and the intensity of selection pressure from glyphosate over time. Furthermore, the occurrence of multiple herbicide-resistant kochia populations observed in this survey is a concern for Montana growers, since those are the three major chemistries used prior to seeding, in-crop, or in chem-fallow for effective control of kochia.

Objective 2: Develop and deliver education materials on herbicide resistance management and alternative herbicide programs for kochia management in wheat-fallow systems of Montana

The weed science team at SARC, Huntley, has been proactive on developing research and education efforts for prevention and management of glyphosate-resistant kochia in Montana cropping systems, with main focus on wheat-fallow systems. Based on our research on alternative herbicides programs, dicamba is effective in controlling glyphosate-resistant kochia. Additionally, alternative POST herbicides including Huskie (at least 13 oz/a), Starane NXT, Huskie plus Starane Ultra will be effective in controlling those multiple-resistant kochia populations in cereals. Sharpen (1-2 oz/a) + 2,4-D, Distinct (2-3 oz/a) + 2,4-D, Aim plus 2,4-D are effective products for glyphosate-resistant kochia control in chem-fallow in conjunction with glyphosate (effective on other grassy and broadleaf weeds at recommended rates and application timing). Spot-treatment with Gramoxone alone or with 2,4-D will control glyphosate-resistant kochia in fallow fields during late summer (prior to winter wheat planting). Avoid drift from paraquat. We found paraquat + linuron to be more effective than paraquat alone on uncontrolled resistant kochia plants.

Over the duration of this project, growers across the state have been educated on the occurrence of glyphosate(Roundup)-resistant kochia in Montana farm fields in a timely manner. Several grower meetings and presentations were conducted across northern Montana. Recently, ***we published an extension research bulletin: "Glyphosate-resistant kochia in Montana- herbicide recommendations and best management practices for Montana growers"***. This extension publication (*Research Bulletin No. 4602*) can be obtained from MSU Extension office or your County extension office. Otherwise, contact me at 406-348-3400, pjha@montana.edu. The research has also been published in an international journal article (Weed Technology 2014; available online and currently in press).

5. SUMMARY:

The herbicide-resistance field survey will lead to: 1) a current distribution map of herbicide-resistant kochia in northern Montana grain belt (Golden Triangle region), 2) monitor the movement of resistance and prevent non-infested areas, 3) develop and implement appropriate resistance management programs, and 4) assess the impact of current alternative control programs. This survey shows that *glyphosate-resistant kochia has established in high frequencies (72 to 100% of a population being resistant to glyphosate) along with SU resistance in Hill, Liberty, and Toole Counties of Montana, where chem-fallow and winter wheat is the major rotation*. Additionally, *dicamba resistant populations have been identified in Hill and Toole County glyphosate-resistant populations*. Survey results for Judith Basin, Glacier, Furgus, and Choteau County kochia populations are pending. *A relatively rapid movement of resistant populations through wind or pollen mediated dispersal is expected.* ***This is the first report of evolution of multiple herbicide-resistant kochia populations in Montana cereal production, which will continue to be a challenge for growers, if proactive/reactive management programs are not implemented at the whole-farm level***. Growers should adopt best management practices and alternative herbicides programs (outlined in the extension bulletin) to manage or prevent further spread of these resistant weed populations in their farm fields. A complete survey result along with a survey map for occurrence of herbicide-resistant kochia in Montana will be included in the final report presented to the MWBC grants committee. Results presented in Table 1 (Page 8).

6. **FUNDING SUMMARY**: This is a new project, which was initiated in fall of 2013 and was funded through MWBC grants.

Table 1. Percentage of plants in a population resistant (R) to Roundup, dicamba, or Ally Extra (metsulfuron, thifensulfuron, and tribenuron), and the habitat and Montana county where populations were located.

Site	GPS Way-Point	Habitat	County	Roundup-R	Ally Extra-R	Dicamba-R
1	WPT-001	F	Hill	25	X	
2	WPT-002	F	Hill	96	X	
3	WPT-003	F	Hill	93	X	15
4	WPT-004	FE	Hill	84	X	
5	WPT-005	F	Hill	18	X	4
6	WPT-006	F	Hill	0	x	
7	WPT-009	F	Hill	95		6
8	WPT-010	F	Hill	0		15
9	WPT-011	F	Hill	0	98	6
10	WPT-013	FE	Hill	1	x	
11	WPT-015	FE	Liberty	0		
12	WPT-017	F	Liberty	1		
13	WPT-018	FE	Liberty	0	x	
14	WPT-019	F	Hill	0	x	
15	WPT-020	F	Hill	0	x	
16	WPT-021	FE	Hill	0		
17	WPT-022	FE	Hill	0	27	2
18	WPT-023	FE	Hill	1	96	15
19	WPT-024	FE	Hill	2	x	
20	WPT-025	F	Hill	0	x	
21	WPT-026	R	Hill	0	x	
22	WPT-027	FE	Hill	0		
23	WPT-028	FE	Liberty	4		
24	WPT-029	F	Liberty	1	x	
25	WPT-030	FE	Liberty	0	x	
26	WPT-032	FE	Liberty	0	X	
27	WPT-033	R	Liberty	1	X	
28	WPT-034	F	Liberty	2	X	
29	WPT-036	FE	Liberty	2	X	
30	WPT-039	FE	Liberty	2		
31	WPT-040	FE	Liberty	1		
32	WPT-049	F	Toole	72	100	4
33	WPT-070	F	Toole	87	x	8
34	WPT-072	F	Toole	100	x	2
35	WPT-082	F	Toole	78	x	0
36	2012	F	Liberty	98	95	0
37	2012	F	Liberty	85	98	0

"X" in Ally Extra column indicates that populations are currently being investigated and show evidence of resistance to Ally Extra. Based on visual assessments at 14 days after application, frequency of resistance to Ally Extra would likely vary from 85 to 100% in majority of the survey populations collected. The blanks indicate that the populations are still under investigation & will be included in final report.

7. FY2015 GRANT SUBMISSION PLANS:

1. Grant proposal will be submitted to further screen the level of resistance and molecular mechanisms of glyphosate, ALS (sulfonylurea), and dicamba resistance in confirmed kochia populations collected in this survey (2-yr project).

2. To design effective management strategies for growers, we propose to conduct a study on evaluating the ecological fitness of glyphosate (Roundup)-resistant kochia populations from Montana compared to a known susceptible kochia population (1-yr project). This will help in predicting the further spread of Roundup-resistant kochia in Montana cereal production systems (1-yr project).

3. We propose to continue evaluating some of those alternative herbicide options (outlined in the research bulletin No. 4602) for use in wheat-fallow system to control Roundup-resistant and multiple-resistant kochia. We plan to test the tolerance of winter wheat varieties (plant-back study) to preemergence soil residual fall or early spring products (effective on kochia), for developing specific recommendations based on Montana soil and environmental conditions (1-yr project).

4. We will submit another grant proposal to MWBC in FY2015 aimed at risk-assessment of gene flow or spread of multiple herbicide-resistant kochia in Montana cereal production, using genetic-diversity-based modeling approach (2-yr project).

FY2014 Montana Wheat and Barley Compliance Midyear Report

TITLE: Light-Activated Sensor Controlled (LASC) Sprayer Technology for Reduced Herbicide Use in No-Till Fallow (Grant # W4627)

PRINCIPAL INVESTIGATOR: Prashant Jha (PI), Weed Scientist, Montana State University, Department of Research Centers, Southern Agricultural Research Center, Huntley, MT

OBJECTIVES:

1. To compare weed control efficacy between LASC (Weed Seeker) and conventional broadcast sprayer in no-till fallow.
2. To determine the herbicide cost savings using LASC (Weed Seeker) sprayer vs. conventional broadcast sprayer in no-till fallow.

RESULTS:

The effectiveness of LASC (Weed Seeker) sprayer compared with broadcast sprayer for different herbicide programs used in chem-fallow (postharvest wheat) were determined using percent control (for kochia and prickly lettuce) and weed biomass reduction assessments. Furthermore, reduction in herbicide usage and cost savings per acre using Weed seeker spray technology was estimated for the herbicide programs in the study.

Percent Control of Kochia and Prickly Lettuce: The interaction of herbicide treatment by spray method (Weed Seeker vs broadcast) was not significant ($P > 0.05$) on kochia and prickly lettuce control 14 and 28 days after application (DAA) (Tables 1 & 2), suggesting that *weed control efficacy did not differ between LASC and broadcast application method*. Additionally, kochia and prickly lettuce control was consistent with Weed Seeker and broadcast spray for all herbicides (applied postharvest in no-till wheat stubble) tested. Gramoxone (48 fl oz/acre), gramoxone (32 fl oz/acre) + linex (16 fl oz/acre), and sharpen (1.5 fl oz/acre) + 2, 4-D (16 fl oz/acre) provided greater control

(92 to 100%) of kochia and prickly lettuce compared with all other herbicide programs 14 and 28 DAA. Roundup @ 64 fl oz/acre was more effective in controlling kochia (97%) and prickly lettuce (91 to 93%) compared with roundup at lower rates (22 and 32 fl oz/acre) applied postharvest in wheat stubble. Kochia control with huskie (15 fl oz/acre) (85 to 96%) did not differ from roundup (32 oz/a) alone or roundup (22 fl oz/acre) + clarity (8 fl oz/acre) + 2, 4-D (16 fl oz/acre) (85 to 88%) 28 DAA. However, huskie was more effective (96 to 98%) compared with roundup + clarity + 2, 4-D (80 to 85%) on prickly lettuce control 28 DAA. Control of kochia and prickly lettuce was least with clarity (8 fl oz/acre) + 2, 4-D (16 fl oz/acre) (47 to 52%), followed by aim (2 fl oz/acre) + clarity (8 fl oz/acre) (63 to 72%), and distinct (2 oz/acre) + 2, 4-D (16 fl oz/acre) (68 to 77%).

Weed Biomass Reduction: No significant interaction was observed between herbicide treatment and spray method (LASC vs. broadcast) for weed biomass (% of nontreated check) 28 DAA (Table 1). For each herbicide treatment, shoot dry weight response of kochia treated with LASC and broadcast spray did not differ, and was consistent with percent control ratings. Gramoxone, gramoxone + linex, and sharpen + 2, 4-D treatments had lower kochia dry weights (20 to 25% of nontreated) compared with huskie (28 to 32% of nontreated) and roundup + clarity + 2,4-D (25 to 27% of nontreated). Among the three roundup rates used, roundup @ 64 fl oz/acre was most effective in reducing the kochia dry weight (20% of nontreated), followed by roundup @ 32 fl oz/acre (25% of nontreated) and round-up @ 22 fl oz/acre (31 to 35% of nontreated). Consistent with poor control, kochia treated with clarity + 2, 4-D, aim + clarity, and distinct + 2, 4-D had the greatest shoot dry weights, which averaged 58% of the nontreated check.

Herbicide and Cost Savings per Acre: The amount of herbicide saved for each treatment using LASC sprayer and their respective cost savings per acre are presented in Table 3. *LASC sprayer reduced the herbicide (plus adjuvant) usage for all treatments by 45 to 67% of the amounts used with a conventional broadcast sprayer*. *The herbicide savings were mainly due to savings in the spray volume using LASC sprayer vs.*

broadcast application. Consistently, ***use of LASC sprayer reduced herbicide costs per acre by 45 to 62% compared with the broadcast application for the herbicide programs tested in this study***. For gramoxone, gramoxone + linex, and sharpen + 2, 4-D (which had the best treatments), LASC sprayer reduced the herbicide costs by 54 to 62% per acre, which would make these products more affordable to use in chem-fallow or post-harvest wheat stubble in Montana. Using LASC sprayer, tank-mixing of roundup with clarity + 2, 4-D had higher weed control efficacy and cost savings of 58% compared with 55 or 54% cost savings with roundup alone @ 22 or 32 fl oz/acre, respectively. ***This research suggests that with LASC (Weed Seeker) spot-spray technology, it is economically feasible to use high rates of an herbicide or herbicide tank-mixtures.***

RELEVANCE TO MONTANA GROWERS:

Herbicides are the foremost weed management tool used in Montana wheat-fallow systems. However, increase in herbicide use and sole-reliance on a single herbicide mode of action (for example, roundup) has led to the evolution of herbicide-resistant weeds like kochia. For effective control of herbicide-resistant weeds, often herbicides with multiple modes of action are recommended, which in turn increases the cost of weed control. However, results from this research suggest that LASC Weed Seeker sprayer can be used to apply higher rates of an herbicide (for example, roundup @ 64 fl oz/acre) or mixture of herbicides (round up + clarity + 2, 4-D, gramoxone + linex, or sharpen + 2, 4-D) with considerably lower herbicide costs. This implies that LASC technology can be utilized by growers to not only reduce the cost of weed control in chem-fallow, but also limit the spread of roundup-resistant weeds like kochia. Additionally, spot application with a LASC sprayer could potentially reduce weed control uncertainties due to delayed applications or problems associated with windy, hot or dry conditions, which is common in Montana. ***Therefore, LASC technology has the potential to provide Montana growers greater flexibility and consistency in their weed control operations in no-till fallow systems, with economic and environmental sustainability (less pesticide use per acre) at the whole farm-level***.

Table 1. Comparison of LASC (Weed Seeker)[a] and broadcast spray for kochia control in no-till fallow.

Herbicide(s)[b]	Rate(s) (fl oz/acre)	LASC Spray[c] 14 DAA	LASC Spray[c] 28 DAA	LASC Spray[c] Shoot dry weight (% of nontreated)	Broadcast Spray[c] 14 DAA	Broadcast Spray[c] 28 DAA	Broadcast Spray[c] Shoot dry weight (% of nontreated)
		-----% Control-----			-------% Control----		
Roundup Powermax™	22	18f	82d	31c	23f	85d	35c
Roundup Powermax™	32	67c	87cd	25ef	62c	90cd	25ef
Roundup Powermax™	64	87b	98a	20g	87b	98a	20g
Roundup Powermax™ + Clarity + 2,4-D LV 4	22 + 8 + 16	62c	85cd	27de	58c	88cd	25de
Clarity + 2,4-D LV 4	8 + 16	30e	47f	59a	33e	50f	61a
Huskie	15	80b	85bc	28cd	88b	96bc	32cd
Aim + Clarity	2 + 8	50d	63e	53b	48d	72e	50b
Gramoxone Inteon	48	93a	95a	21fg	98a	100a	21fg
Gramoxone Inteon + Linex	32 + 16	97a	99a	25efg	98a	99a	22efg
Sharpen + 2,4-D LV 4	1.5 + 16	93a	93ab	21g	94a	98ab	20g
Distinct + 2,4-D LV 4	2 oz wt +	63c	70e	57a	62c	68e	62a

[a]Abbreviations: LASC, Light activated sensor controlled.
[b]Roundup treatments included AMS (2% v/v), and other herbicides included NIS (0.25% v/v) or MSO (1% v/v) as per the label.
[c]Means followed by similar letters are not significantly different based on Fisher's Protected LSD test at $P < 0.05$.

Table 2. Comparison of LASC (Weed Seeker)[a] and broadcast spray for prickly lettuce control in no-till fallow.

Herbicide(s)[b]	Rate(s) (fl oz/acre)	LASC Spray[c] 14 DAA	LASC Spray[c] 28 DAA	Broadcast Spray[c] 14 DAA	Broadcast Spray[c] 28 DAA
		---------% Control-------		---------% Control--------	
Roundup Powermax™	22	17e	67e	20e	73e
Roundup Powermax™	32	38d	73d	38d	82d
Roundup Powermax™	64	73b	93b	73b	91b
Roundup Powermax™ + Clarity + 2,4-D LV 4	22 + 8 + 16	52c	80c	52c	85c
Clarity + 2,4-D LV 4	8 + 16	23e	50f	28e	52f
Huskie	15	90a	96a	93a	98a
Aim + Clarity	2 + 8	63b	72e	67b	72e
Gramoxone Inteon	48	93a	98a	95a	98a
Gramoxone Inteon + Linex	32 + 16	98a	100a	93a	99a
Sharpen + 2,4-D LV 4	1.5 + 16	99a	100a	99a	100a
Distinct + 2,4-D LV 4	2 oz wt + 16	55c	77d	55c	77d

[a]Abbreviations: LASC, Light activated sensor controlled.
[b]Roundup treatments included AMS (2% v/v), and other herbicides included NIS (0.25% v/v) or MSO (1% v/v) as per the label.
[c]Means followed by similar letters are not significantly different based on Fisher's Protected LSD test at $P < 0.05$.

Table 3. Herbicide cost savings with LASC (Weed Seeker) technology in no-till fallow.

Herbicide(s)*	Rate (fl oz/acre)	Cost ($/acre)**	LASC Herbicide savings (fl oz/acre)	LASC Cost Savings ($/acre)**	% cost saved/acre**
Roundup	22	4.29	12	2.35	55
Roundup	32	5.69	17	3.05	54
Roundup	64	10.21	29	4.62	45
Roundup Powermax™ + Clarity	22 + 8 + 16	14.84	12 + 4 + 9	8.54	58
Clarity + 2,4-D LV 4	8 + 16	11.74	5 + 10	7.28	62
Huskie	15	14.88	8	7.85	53
Aim + Clarity	2 + 8	25.04	1 + 4	12.65	51
Gramoxone Inteon	48	15.60	26	8.46	54
Gramoxone Inteon + Linex	32 + 16	16.03	17 + 9	8.71	54
Sharpen + 2,4-D LV 4	1.5 + 16	16.24	1 + 9	10.03	62
Distinct + 2,4-D LV 4	2 oz wt +	11	1 oz wt + 9	5.86	53

*Roundup treatments included AMS (2% v/v), and other herbicides included NIS (0.25% v/v) or MSO (1% v/v) as per the label.

**Adjuvant costs included for all treatments.

SUMMARY: *LASC technology operates on differential red and near infrared light absorption by a green plant relative to bare ground or residue cover to detect a plant and activate a solenoid switch above a spray nozzle for a set period of time. Each nozzle can operate independent of each other*. A field study was conducted at Huntley, MT, in 2013, in a chem-fallow (post-harvest wheat) field to evaluate the efficacy of POST herbicide treatments applied with a light-activated sensor-controlled (LASC) sprayer (Weed Seeker®) vs. a broadcast application. LASC applications for all herbicide treatments had weed control similar to broadcast application. Kochia control with Roundup @ 32 fl oz/acre, gramoxone alone, gramoxone + linex, or sharpen + 2, 4-D, was ≥ 87% with LASC or broadcast sprayer 28 DAA. LASC sprayer reduced the herbicide usage by 45 to 67% for all treatments. Overall, LASC spray system saved 45 to 62% of the herbicide cost per acre compared with broadcast spray application. This research suggests that LASC Weed Seeker sprayer can be used to apply higher rates of an herbicide or tank-mixtures with cost savings.

Figure 1. ATV-mounted sprayer fitted with LASC (Weed Seeker). 5 weed seeker units and a controller. Each unit fitted with 6702 nozzles with 12” spacing (5’ boom). Height adjustments of 18 to 30”. Equipment cost: 5 Weed Seeker units plus 1 controller: $8000. Photo by Prashant Jha, MSU-Southern Ag. Research Center, Huntley, MT, 2013.

FUNDING SUMMARY: This is a new project, which was initiated in 2013 and was funded through MWBC grants.

MWBC FY2015 GRANT SUBMISSION PLANS:

1. This project on testing the efficacy and economics of using Weed Seeker Precision Weed Control Technology will be continued in 2014. The aim of this preliminary study conducted in 2013 was to get first-hand information on the effectiveness and precision of herbicide application and herbicide cost savings using LASC sprayer compared with a standard broadcast sprayer. Further research is necessary to validate the efficacy of LASC technology on a larger scale (larger plots) with diversified herbicide programs for weed management in chem-fallow. <u>Additional research will be focused on evaluating the weed control efficacy of LASC sprayer at varying speeds (3 vs. 5 and 10 mph) and weed heights to simulate grower-field application and detect the sensitivity of the weed seeker unit for spraying small-sized grassy and broadleaf weeds in chem-fallow</u>.

2. Grant proposal will be submitted to further screen the molecular mechanisms of glyphosate, ALS (sulfonylurea), and auxinic resistance in kochia populations that were surveyed last year from wheat-fallow fields in northern Montana (2-yr project).

3. Based on our previous research supported by Montana growers and MWBC, we discovered the first occurrence of Roundup-resistant kochia in Montana in 2012. To design effective management strategies for growers, we propose to conduct a study on evaluating the ecological fitness of Roundup-resistant Kochia populations from Montana compared to known susceptible kochia populations (1-yr project).

4. The weed science team at MSU-SARC, Huntley, have conducted several grower meetings last year in coordination with MSU extension agents to deliver the much needed information on evolution and management of Roundup-resistant kochia in northern Montana. An extension article (Research Bulletin No. 4602) has been published on best management practices and herbicide recommendations for

Roundup-resistant kochia management, which should be available now through MSU Extension. We propose to continue evaluating some of those alternative herbicide options for use in wheat-fallow system to control Roundup-and multiple herbicide-resistant kochia. We plan to test the tolerance of winter wheat varieties (plant-back) to some of those preemergence residual fall or early spring products (effective on kochia), for developing specific recommendations based on Montana soil and environment conditions (1-yr project).

5. We will submit another grant proposal to MWBC in FY2015 aimed at risk-assessment of gene flow or spread of multiple herbicide-resistant kochia in Montana cereal production, using genetic-diversity-based modeling approach (2-yr project).

The aim of all these research is to develop proactive/reactive management strategies and producer-based information to prevent/reduce occurrence of herbicide-resistant weed populations in Montana cereal production system.

FY2014 Montana Wheat and Barley Compliance Midyear Report

Title (Grant Number): A Strategic Investment in the Southern Agricultural Research Center for Small Grains Research in South Central Montana (4W4626).

Principal Investigator: Kenneth D. Kephart

Objectives: Acquisition of a notill grain drill. No-till crop rotation studies conducted by SARC personnel (and supported by MWBC) have utilized a John Deere 752 no-till drill on extended loan from an area farmer. That drill was permanently repossessed in January 2013, leaving SARC without the capability to continue the no-till related aspects of this research. Since 2002, no state funds have been appropriated by the Montana Legislature to the MAES for investment in capital equipment at the agricultural research centers.

Results: Competitive bids for a 15' notill drill were requested from several manufacturers. Successful (low) bid was obtained from Straw Track Manufacturing of Emerald Park, Saskatchewan for a SeedMaster Model 15-11 ¼" SXG-15 drill. Drill was ordered on 25 June 2013.

Summary: Delivery of the SeedMaster drill occurred in late September of 2013 and placed in SARC's capital equipment inventory. The drill has been successfully used to establish notill winter wheat plots in the aforementioned rotation studies, and for the production of 8 acres of bulk winter wheat at SARC. The SARC faculty and staff is most appreciative of MWBC's assisting with the purchase of this equipment.

Funding Summary: (Indicate other funds supporting this project to date. MWBC grant expenditures will be provided to MWBC by OSP.)

Source	Amount
MSU College of Ag Equipment Grant	$27,000
SARC Sales and Services Montana	$2,110
Wheat & Barley Committee	$15,000
Total Expenditure	$44,110

MWBC FY2015 Grant Submission Plans: No requests for equipment acquisitions at SARC are planned for FY2015.

FY 2014 MONTANA WHEAT AND BARLEY COMMITTEE COMPLIANCE MIDYEAR REPORT

I. Title: Improved Quality of Montana Hard Red and Hard White Wheat (4W4613)

II. Principal Investigator: Deanna Nash

Project Personnel: Luther Talbert, Phil Bruckner, Mike Giroux, Jack Martin, Research Center Personnel

III. Objectives:

1. Evaluate end-use quality of hard red and hard white wheat lines developed by MSU spring and winter wheat breeding programs.

2. Showcase Montana's newest varietal releases for visiting Trade Teams while they tour the Cereal Quality Lab (CQL) testing facilities.

3. Participate in the milling and baking contest for the Central Montana Fair.

4. Promote Montana wheat quality by conducting tours and hands-on demonstrations.

5. Participate in research projects designed to determine ways to improve end-use quality parameters of new wheat varieties by cooperating with Montana Agricultural Experiment Station (MAES) researchers, the general public and industry.

IV. Results:

1. <u>End-use Quality Evaluation of Wheat Lines Developed by MSU.</u>

The CQL provides the MSU wheat breeding programs reliable data in the most efficient way to assure varieties developed at Montana State have the highest possible end-use quality. A primary objective for the wheat breeding programs is to develop new varieties with excellent characteristics important to making bread and other end-use products. To meet this objective, several analytical tests were performed by the CQL during all stages of the breeding programs. First, protein analysis was conducted on several thousand early generation lines. Of these lines only subsets selected for high protein content were advanced to the next round of selection. We have completed these analyses for the 2013 crop. Seed of selected lines is increased and evaluated more thoroughly in later generations. Reducing the number of lines with early generation testing allows us to perform more extensive milling and baking quality tests as each line advances. For the 2013 crop year, we will process approximately 2800 SDS sedimentation tests on lines that are in the intermediate stages of the breeding process. This test correlates well with loaf volume and is an indicator of protein quality. We also have the Single Kernel Characterization System (SKCS) to evaluate early breeding lines for hardness, uniformity and other parameters that are significantly correlated with milling. Spring wheat SKCS evaluations are completed. Winter wheat SKCS evaluations have been started with an estimated completion date of March 15, 2014.

Due to an increase in the number of nurseries submitted this year we have approximately five additional weeks added to our routine schedule. The CQL has completed the annual testing for ash for 2013 spring wheat and has initiated ash analysis for 2013 winter wheat. The projected completion date is April 15, 2014. We have also started setting up the PPO testing on spring wheat and winter wheat nurseries. Expected completion date for all PPO analysis is April 10, 2014.

Our advanced yield trials contain highly selected lines which have performed well in regard to protein and SDS sedimentation. We are in the process of conducting full mill and bake analyses on approximately 1800 of these lines that have been grown across numerous locations in Montana. Data from the CQL along with agronomic data is used in making decisions regarding the recommendation for release. These meetings were conducted during the week of January 27, 2014. Each of the varieties up for release by the MSU breeding programs has been deemed acceptable in milling and baking quality in early and advanced testing.

At the date of this writing (January 10, 2014), we have completed all Advanced Spring Wheat nurseries and we are currently evaluating the Preliminary Spring Wheat nurseries. Analysis has started on the winter wheat nurseries for the 2013 crop year. Estimated completion date is June 1, 2014.

2. <u>Host visiting Trade teams.</u>

During the summer of 2013 we met with two trade teams from Japan and hosted numerous tours in the lab throughout the year. Montana's newest varietal releases are showcased to interested trade teams and tour groups.

3. <u>Participate in county fair milling and baking contests around Montana.</u>

The CQL participated in the milling and baking contests by milling and baking bread for the 2013 Central Montana Fair. We processed a total of 84 samples. The time investment in the fair was approximately 10 days of full time work for the CQL staff.

4. <u>Promote Montana Wheat by conducting tours and demonstrations.</u>

Throughout the year the CQL has hosted numerous tours in an effort to promote Montana wheat quality and explain our function at MSU. We have conducted several hands-on demonstrations to educate faculty, students and anyone who is interested in Montana wheat. We have participated in the <u>Follow the Gain</u> class, which is a crop production class, as well as the <u>Field Crop Production</u> class. We appreciate all interest in our facility and make a concerted effort to accommodate and welcome anyone who is interested in a tour

5. Participate in Research to Improve End-use Quality Parameters.

We participate in numerous research studies each year designed to test the influence of various genetic factors upon grain quality. Our job is to conduct the same quality analyses such as milling, bread baking and noodle making on different nurseries submitted to us by the Montana State University wheat breeder's, MSU researchers and MAES researchers. Some of the more important traits we aid in researching are noodle color, milling quality, starch quality characteristics, Polyphenol Oxidase (PPO) and Imidazolinone (IMI) tolerance.

Noodle color change is the single most important parameter researchers look at when analyzing noodles prepared from Montana wheat varieties.

Milling quality and milling yield research involves participating in studies that utilize varieties varying only in grain hardness as measured by the SKCS.

Starch quality is an area of research that is a focus of numerous U.S. breeding programs because small changes in starch quality influence bread loaf volume as well as noodle and bread firmness.

Imidazolinone herbicides control a broad spectrum of grass and broadleaf weeds in imidazolinone-tolerant crops**.**

Polyphenol Oxidase is implicated in the undesirable darkening of cereal products.

V. Summary:

Beyond our work with the MSU breeding programs, the CQL continues to cooperate with MAES researchers and the general public for addressing end-use quality attributes of experimental material.

We actively participate in collaborations across the Pacific Northwest (PNW) in order to promote Montana wheat and to be contributing members in the society of wheat researchers.

VI. Funding Summary:

No other funding is supporting this project.

VII. MWBC FY2015 Grant Submission Plans:

We are committed to providing continued reliable and consistent data to the breeding programs for the improvement of Montana wheat. With this in mind, I anticipate our MWBC FY 2015 grant submission plan to be similar to 2014.

MONTANA PLANT SCIENCES CHAIR

At Montana State University

Grant Number XXXXX

Principal Investigator Lori Cox

INDUSTRY GOALS

- Improve yields and quality
- Increased margins
- Increased capacities to markets in demand
- Open new markets with innovative varieties
- Continue as world’s finest grain leader

OBJECTIVES

- Create the first chair in MSU's College of Agriculture, "Montana Plant Sciences Chair," to focus on research of temperature and water stress tolerance; diverse and enhanced pest resistance; and nutrient use efficiency.
- Measureable objectives established:
  - Total funding needed: $5 million by December 31, 2018
  - Initial benchmarks:
    - Raise $1 million by December 31, 2013
    - Raise $2 million by December 31, 2014
    - One-half of dollars raised shall be producer dollars; remaining one-half shall be from corporate and other organizational support

RESULTS

- A Terms of Fund has been written and signed by Montana State University, the MSU Alumni Foundation, and the Montana Wheat & Barley Committee.
- Montana State University created a match: MSU will match a minimum of $40,000 annually for every million raised, up to $80,000.
- The first donor was the Montana Grains Foundation at $40,000.
- Since October 1, 2013, the Montana Grains Foundation and the MSU Alumni Foundation have visited 19 counties and counting, logging more than 8,500 miles to spread the word about the chair.

RESULTS CONT.

- As of December 31, 2013, the fund has commitments of $2.1 million, a full year ahead of schedule.
- The search for a top candidate has begun in the form of a draft job description with contributing dialogue between the Montana Grains Foundation and the College of Agriculture.
- The top corporate donor to date is Northwest Farm Credit Services at $250,000.

SUMMARY

- As the purpose of the fund is to support the Montana Plant Sciences Chair, and the goal of $5 million would appear to be daunting, it is impressive if not remarkable that Montana producers have responded passionately and swiftly to the call for funding. Their response is due to several factors:
    1. An advisory council shall be established with Montana producer representation, which will create a supporting structure to strengthen communication and reporting between funders and other interested parties, and Montana State University.
    2. A direct reporting process on a semi-annual basis will be available to all publics and will focus on the chair's financials, research progress, future expectations and plans, and impacts and implications for farmers.
- Upcoming fund strategy includes further outreach for producer support, particularly in geographic areas not yet visited, and corporate and foundation support.

FUNDING SUMMARY

- The donor roll for the Montana Plant Sciences Chair has yet to be released but will be made public, for those with that allowance, upon the hire of the chair.
- Incoming gifts in this order, to date:
  - $250,000 and up: 2
  - $50,000 - $249,000: 4
  - $25,000 - $49,000: 19
  - $10,000 - $24,000: 14
  - Up to $10,000: 12

MWBC FY2015 GRANT SUBMISSION PLANS

- Montana State University, the MSU Alumni Foundation and the Montana Grains Foundation are humbled by the gracious past support of the Montana Wheat & Barley Committee.
- We are encouraged by the rapid funding progress made thus far, and look to the Montana Wheat & Barley Committee for further support it deems prudent as we move into the second phase of fundraising for the chair.

Title: Orange Wheat Blossom Midge (OWBM) Management (4W4102)

Principal Investigators: Bob Stougaard, Luther Talbert, Gadi Reddy and David Weaver

Project personnel: Brooke Bohannon, Dan Picard and Nancy Blake

Objective 1: Monitor midge populations in the Flathead and Triangle counties

Flathead

The midge life cycle was assessed at the Northwestern Agricultural Research Center, near Kalispell. Midge larvae were first observed on the soil surface on May 20, which is similar to the past three years. Soil surface sightings were May 28, May 27, and May 22 during 2010, 2011, and 2012 respectively. Although the calendar dates were similar among the three years, the accumulated growing degree days differed somewhat. The GDD requirements for soil surface sightings were 490, 363, 510, and 426 during 2010, 2011, 2012, and 2013, respectively. These results indicate that soil temperature is not the sole driving force affecting midge development. It seems probable that soil moisture also contributes to this behavior.

Adult emergence was monitored with the use of pheromone traps. These traps first captured adult males on June 18, which is 10 days earlier than the previous year. The first capture equates to 870 GDDs, which is less than the Canadian degree day model of 1300. This indicates that we may have a unique midge biotype with a lower temperature threshold. Overall midge numbers were low for this area. However, we did collect over 1000 adults over a two day period at the NWARC and at a field near Whitefish, MT.

Golden Triangle

We continued monitoring OWBM in the Golden Triangle area including Chouteau, Fergus, Glacier, Judith Basin, Liberty, Pondera, Teton, and Toole Counties. During 2012, only Pondera County had detectable OWBM populations, with one irrigated field having economically significant numbers. In 2013, over 12,000 acres in Pondera County were treated for this pest.

Midge adults were first detected in pheromone traps on June 29 in a field near Valier. Midge adults were also detected near Ledger and Conrad. It is noteworthy to report that OWBM were captured at the Western Triangle Agricultural Research Center (WTARC). Toole County also reported significant numbers east of Oilmont and south of Shelby. Chouteau, Glacier, and Liberty Counties recorded the presence of midge, but the numbers were low. Midge adults were not observed in Fergus, Judith Basin, or Teton Counties. Although not included in our monitoring program, a producer near Scobey in Daniels County reported economic damaged due to midge in a field of durum wheat.

Objective 2: Screen Sm1 experimental lines for resistance to the Orange Wheat Blossom Midge

Results

The Sm1 gene is the only known form of antibiotic resistance against the orange wheat blossom midge (OWBM). A backcross and selection program has been on-going to incorporate the Sm1 gene into locally adapted spring wheats.

A head row nursery was established at the Northwestern Agricultural Research Center near Kalispell during 2013 to evaluate 220 early generation lines for resistance to the OWBM. Secondary consideration was given to stripe rust resistance. The most promising lines were selected and retained for further evaluation.

In a separate nursery, sixteen advanced experimental lines were screened for resistance to the midge as well as for agronomic performance (Table 1). The cultivars included nine experimental lines (CAP) containing the Sm1 gene, three commercially available varieties, Solano, Hank and Reeder, and four experimental lines derived from crosses between Hank and Reeder (MQTL).

Stripe rust (SR) was evident throughout the nursery with an average infection rating of 26 percent (Table 1). CAP400-1 demonstrated the lowest infection at 4% while Hank was the most susceptible variety with an infection rating of 83 percent. Hank also was the most susceptible/attractive to the midge, having 27 larvae per spike.

Overall, midge pressure was low this year in comparison to previous years. The average number of OWBM was only about 4 per spike. However, this number is slightly biased since OWBM were generally not found on lines with the Sm1 gene. To be sure, the Sm1 gene was very efficacious, resulting in almost complete mortality of the midge larvae. However, the low insect pressure limited differentiation among entries for yield.

Yields ranged from a low of 59 bu/A for Hank to a high of 90 bu/A for CAP400-1. Overall, the nonresistant lines had an average yield of 73 bu/A, while lines with the Sm1 gene averaged 81 bu/A. Protein averaged 15% and ranged from a low of 13.5% for CAP34-1 to a high of 16.9 for CAP400-1. Test weights averaged 60.6 lb/bu, with the seven nonresistant lines averaging 59.7 lb/bu, while the resistant lines averaged 60.5. Falling numbers averaged 340 seconds for the nursery. CAP400-1 produced the highest falling number (408) while Hank had the lowest (272). Overall, grain yield and quality improved as a result of the Sm1 gene.

Table 1. Effect of genetic resistance on OWBM control – 2013

Treatment	SR %	HT in	OWBM no/spk	YLD bu/A	PRO %	TWT lb/bu	TKW g	FN sec
CAP 34-1	40.0	33.0	0.0	81.7	13.5	60.5	32.4	335.9
CAP 84-1	40.0	36.2	0.0	73.3	14.8	60.1	32.2	347.9
CAP 84-2	30.0	36.1	0.3	71.4	14.8	60.5	32.5	347.6
CAP 108-3	25.0	35.0	0.0	86.4	14.9	60.6	34.0	357.2
CAP 151-3	23.3	32.3	0.0	77.4	15.4	61.5	31.2	362.2
CAP 197-3	20.0	38.1	0.0	87.8	13.7	60.0	30.6	328.7
CAP 201-2	26.7	36.9	0.0	83.3	14.9	60.4	31.9	321.5
CAP 219-3	35.0	35.6	0.0	76.7	14.0	60.3	31.7	318.8
CAP 400-1	4.3	37.3	0.0	90.8	16.9	60.8	33.8	408.0
MQTL 1075	21.0	35.3	13.0	66.7	16.6	58.9	39.1	294.5
MQTL 1076	16.0	38.9	7.7	78.5	16.3	59.2	34.9	365.5
MQTL 3042	33.3	37.5	11.0	74.3	15.3	60.5	38.9	347.7
MQTL 3043	26.7	37.4	9.7	69.9	16.3	60.5	38.4	317.8
REEDER	11.7	39.0	7.0	79.2	15.7	61.1	37.4	347.8
HANK	83.3	33.6	27.0	59.1	14.7	57.7	39.1	272.4
SOLANO	5.0	31.6	18.3	83.0	16.5	60.1	38.8	310.8
Mean	26.2	35.8	3.8	82.7	15.0	60.6	35.2	340.9
CV	33.2	3.9	74.4	5.7	1.4	0.6	1.9	3.6
LSD	14.2	2.3	4.6	7.7	0.3	0.6	1.1	20.0
Pr>F	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

SR: stripe rust, HD: heading HT: height, LOD: lodging, OWBM: orange wheat blossom midge, YLD: Yield, PRO: protein, TWT: test weight, TKW: thousand kernel weight, FN: falling number

Objective 3: Evaluating the concept of insect refuges using wheat varietal blends

Results

The purpose of the interspersed refuge system is to delay the selection of virulent, Sm1 resistant midge populations. The refuge, or susceptible variety, is blended with the midge resistant variety at a ratio of 1:9. The combination is then planted together in an effort to maintain the genetic diversity of the midge population.

In this study, CAP 34-1 and CAP 400-1 contain the Sm1 gene for OWBM resistance, while Solano and Choteau are midge susceptible varieties. These four cultivars were planted alone and as blends (Table 2), where the CAP lines comprise 90% of the blended mixtures. This study was established at The Northwestern Ag Research Center near Kalispell (NWARC), and at a producer field near Valier (WTARC).

Despite modest midge pressures at both locations, differences were detected among varieties. The non-resistant varieties, Solano and Choteau, had significantly higher number of larvae compared to the Sm1 resistant CAP lines. The CAP lines, alone or blended, resulted in 86% to 100% midge mortality at Kalispell and 100% to 80% mortality at Conrad. Yield difference were not observed at WTARC, but were detected at NWARC. The blend of CAP 400-1 & Choteau resulted in a 19.1 bu/A increase over Choteau. These results demonstrate that the interspersed refuge can allow a low number of OWBM to reproduce without sacrificing grain yield.

Table 2. Evaluation of the interspersed refuge system for OWBM management.

	Yield (bu/A)		Protein (%)		OWBM (No./spike)	
Treatment	NWARC	WTARC	NWARC	WTARC	NWARC	WTARC
SOLANO	84.2	67.7	15.2	15.7	11.9	1.7
CHOTEAU	73.5	75.0	15.5	14.7	13.4	6.0
CAP 34	88.6	70.7	13.1	14.2	0.0	0.0
CAP 400	95.8	85.6	15.5	16.6	0.0	0.0
CAP 34 & SOLANO	90.0	70.3	13.4	14.5	0.0	0.0
CAP 34 & CHOTEAU	88.2	80.1	13.4	14.4	1.8	1.2
CAP 400 & SOLANO	91.5	83.2	15.6	16.5	0.0	0.0
CAP 400 & CHOTEAU	92.6	82.8	16.1	16.5	0.0	0.4
Mean	88.0	76.9	14.7	15.4	3.4	1.2
CV	5.6	12.4	4.4	1.5	94.8	71.3
LSD	8.7	16.7	1.1	0.4	5.6	1.5
Pr>F	0.0030	0.2297	0.0001	0.0001	0.0002	0.0001

Objective 4: Determining the interaction between Sm1 resistant varieties and insecticides.

Results

An experiment was conducted to evaluate the potential interaction between insecticide applications and host plant resistance to the OWBM. In the first study, sixteen spring wheat cultivars were screened for OWBM control (Table 3). Nine of the cultivars were experimental lines containing the Sm1 gene for resistance (CAP), four of the cultivars were experimental lines derived from crosses between Hank and Reeder (MQTL), and three entries were the commercial varieties Solano, Hank, and Reeder. The experiment was a split plot design where one set of sixteen cultivars were treated with Lorsban, and the second set was left untreated.

Stripe rust (SR) was evident throughout the nursery with an average infection rate of 26 percent. Solano and CAP400-1 demonstrated excellent resistance toward stripe rust. In contrast, Hank was very susceptible with an average infection rating of 65 percent. Hank also was the most susceptible to the orange wheat blossom midge, having 27 larvae per spike.

Overall midge pressure was low this year in comparison to previous years. The average number of OWBM was only about 4 per spike. Nevertheless, the Sm1 gene was very efficacious and lines with this trait performed better than lines without it.

While the Sm1 gene resulted in almost complete insect mortality, the effect of the insecticide treatment was still apparent. Grain yields increased when plots were treated with Lorsban, regardless of the cultivar. The average yield increase for Reeder, Hank, and Solano was 12.8 bu/A. Likewise, the average yield increase for the MQTL lines was 17 bu/A.

This illustrates that low midge populations can have a negative impact on yield. However, even the CAP lines benefited from the insecticide application. For example, untreated CAP400-1 was devoid of midge larvae and produced 90 bu/A, but the same germplasm produced 99 bu/A when treated with Lorsban. Average over all of the CAP lines, yields increased by 6.6 bu/A when treated with the insecticide. This indicates that the young larvae manage to cause significant damage to the wheat seed before the Sm1 gene can elicit its lethal effect.

While the previous study evaluated the interaction between antibiosis and insecticide applications, the second experiment evaluated the interaction between antixenosis and insecticide application (Tables 4 – 6).

The factorial treatment arrangement consisted of three insecticide treatments and eight spring wheat varieties that varied in attractiveness/susceptibility to the orange wheat blossom midge. The spring wheat varieties consisted of Brennan, Hank, Kuntz, McNeal, Reeder, Treasure, MT0802 and MT1073. The insecticide treatments included Lorsban, Warrior, and a non-treated control. The study was planted on May 6, and individual plots consisted of seven, 6-inch rows, 15 feet in length, with each variety-insecticide combination replicated 3 times in a split plot design. Warrior and Lorsban were applied on July 2 at 1.9 oz/A, and 1 pt/A, respectively. Treatments were applied with a backpack sprayer in 20 GPA of water. The fungicide Headline was applied at 9 oz/A on June 21 to control stripe rust.

Table 3. Effect of genetic resistance and insecticide application on OWBM control.

Treatment	SR %	HT in	OWBM no/spk	YLD bu/A	PRO %	TWT lb/bu	TKW g	FN sec
				Treated				
CAP 34-1	36.7	33.7	0.0	88.4	13.4	61.4	32.9	324.8
CAP 84-1	35.0	37.0	0.0	80.4	14.6	60.9	33.2	353.0
CAP 84-2	31.7	34.5	0.0	82.3	14.3	61.0	34.4	347.3
CAP 108-3	20.0	34.1	0.0	94.8	14.4	61.4	35.9	349.3
CAP 151-3	18.3	31.6	0.0	87.3	15.0	62.2	32.5	380.0
CAP 197-3	25.0	38.3	0.0	88.7	13.6	60.1	31.6	333.7
CAP 201-2	26.7	36.6	0.0	84.6	14.6	61.2	33.1	317.1
CAP 219-3	40.0	35.3	0.3	82.9	13.8	61.3	33.1	337.3
CAP 400-1	5.0	37.5	0.0	99.2	17.0	61.4	34.6	420.5
MQTL 1075	21.7	36.5	4.0	86.4	16.0	60.1	39.4	332.0
MQTL 1076	16.7	37.7	4.3	88.2	16.1	59.8	36.4	365.5
MQTL 3042	28.3	38.1	3.0	94.2	14.3	61.6	38.5	353.9
MQTL 3043	30.0	37.3	4.7	89.9	15.2	61.7	37.9	355.0
REEDER	7.3	39.3	0.3	87.0	15.0	61.6	36.7	368.9
HANK	48.3	33.6	5.7	75.7	13.4	58.9	39.4	272.8
SOLANO	7.3	31.0	4.0	97.1	15.9	61.3	39.7	311.7
				Nontreated				
CAP 34-1	40.0	33.0	0.0	81.7	13.5	60.5	32.4	335.9
CAP 84-1	40.0	36.2	0.0	73.3	14.8	60.1	32.2	347.9
CAP 84-2	30.0	36.1	0.3	71.4	14.8	60.5	32.5	347.6
CAP 108-3	25.0	35.0	0.0	86.4	14.9	60.6	34.0	357.2
CAP 151-3	23.3	32.3	0.0	77.4	15.4	61.5	31.2	362.2
CAP 197-3	20.0	38.1	0.0	87.8	13.7	60.0	30.6	328.7
CAP 201-2	26.7	36.9	0.0	83.3	14.9	60.4	31.9	321.5
CAP 219-3	35.0	35.6	0.0	76.7	14.0	60.3	31.7	318.8
CAP 400-1	4.3	37.3	0.0	90.8	16.9	60.8	33.8	408.0
MQTL 1075	21.0	35.3	13.0	66.7	16.6	58.9	39.1	294.5
MQTL 1076	16.0	38.9	7.7	78.5	16.3	59.2	34.9	365.5
MQTL 3042	33.3	37.5	11.0	74.3	15.3	60.5	38.9	347.7
MQTL 3043	26.7	37.4	9.7	69.9	16.3	60.5	38.4	317.8
REEDER	11.7	39.0	7.0	79.2	15.7	61.1	37.4	347.8
HANK	83.3	33.6	27.0	59.1	14.7	57.7	39.1	272.4
SOLANO	5.0	31.6	18.3	83.0	16.5	60.1	38.8	310.8
Mean	26.2	35.8	3.8	82.7	15.0	60.6	35.2	340.9
CV	33.2	3.9	74.4	5.7	1.4	0.6	1.9	3.6
LSD	14.2	2.3	4.6	7.7	0.3	0.6	1.1	20.0
Pr>F	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

SR: stripe rust, HT: height, OWBM: orange wheat blossom midge, YLD: Yield, PRO: protein, TWT: test weight, TKW: thousand kernel weight, FN: falling number

Table 4. Main effect of insecticide treatment on management of OWBM

Treatment	SR %	OWBM no/spk	YLD bu/A	PRO %	TWT lb/bu	TKW g	FN sec
Check	17.2	10.9	85.9	14.6	60.6	37.8	358.3
Lorsban	11.8	3.4	98.1	14.3	61.1	37.7	376.1
Warrior	21.8	1.7	98.0	14.2	61.3	38.3	363.3
Mean	16.9	5.3	94.0	14.3	61.0	38.0	365.9
LSD	3.7	2.6	7.1	0.8	0.4	1.3	32.3
Pr>F	0.0045	0.0012	0.0138	0.4833	0.0198	0.4499	0.3802

Table 5. Performance of spring wheat cultivars on management of OWBM

Cultivar	SR %	OWBM no/spk	YLD bu/A	PRO %	TWT lb/bu	TKW g	FN sec
Brennan	6.0	4.3	77.7	15.6	61.4	35.5	297.7
Hank	46.4	10.7	88.4	14.0	59.1	42.8	295.5
Kuntz	6.6	6.9	95.0	14.0	62.3	33.7	412.8
McNeal	25.6	6.9	84.5	14.9	60.7	36.9	483.8
Reeder	7.8	2.3	97.9	15.1	61.6	38.1	400.2
Treasure	22.7	0.9	109.5	11.0	59.8	36.1	303.8
MT0802	18.3	8.6	95.8	15.3	60.6	42.4	358.1
MT1073	2.2	1.9	103.4	14.6	62.5	38.2	375.0
Mean	16.9	5.3	94.0	14.3	61.0	38.0	365.9
LSD	9.1	2.9	7.3	0.4	0.5	1.8	20.0
Pr>F	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

SR: stripe rust, OWBM: orange wheat blossom midge, YLD: Yield, PRO: protein, TWT: test weight, TKW: thousand kernel weight,FN: falling number.

Midge numbers were modest and averaged only 5.3 larvae per spike, yet significant yield differences were observed for the main effect of insecticide treatments (Table 4). Averaged over the eight varieties, yields for the non-treated check were 86 bu/A, whereas the average yield for the Lorsban and Warrior applications was 98 bu/A. This increase of 12 bu/A is impressive, if not disconcerting, considering the low midge population present and illustrates just how damaging this pest can be.

Differences in OWBM levels also were detected among varieties (Table 5). MT0802 and Hank had the highest infestations while MT1073 and Treasure had the lowest numbers. Nonetheless, cultivar attractiveness did not impact insecticide efficacy (Table 6). In summary, low midge pressures did not affect insecticide performance, but did impact yields.

Table 6. The effects of insecticide and variety on the management of OWBM

Cultivar	SR %	OWBM no/spk	YLD bu/A	PRO %	TWT lb/bu	TKW g	FN sec
				Check			
Brennan	6.3	8.3	66.4	15.8	60.6	34.2	272.1
Hank	46.0	26.3	73.2	14.6	58.5	43.9	291.1
Kuntz	8.0	11.9	90.5	14.4	62.2	34.3	404.9
McNeal	25.0	9.5	75.5	15.2	60.1	36.5	491.3
Reeder	10.7	5.2	93.0	15.3	61.3	37.7	396.2
Treasure	20.0	1.1	104.6	11.0	59.8	36.0	308.6
MT0802	18.3	20.3	85.9	15.6	60.1	41.7	338.4
MT1073	3.3	4.5	98.3	14.6	62.0	38.2	363.7
				Warrior			
Brennan	4.0	2.0	87.8	15.6	61.7	36.8	291.1
Hank	71.7	3.6	95.3	13.7	59.2	42.2	286.2
Kuntz	7.3	3.5	92.4	13.9	62.6	34.1	421.6
McNeal	30.0	2.7	90.1	14.7	61.4	38.0	459.6
Reeder	8.3	0.1	104.5	15.1	61.9	38.4	403.2
Treasure	31.7	0.0	107.6	11.1	59.7	35.6	288.8
MT0802	20.0	1.2	102.3	15.0	61.1	43.0	379.6
MT1073	1.3	0.3	104.3	14.6	62.8	38.6	376.0
				Lorsban			
Brennan	7.7	2.6	78.9	15.4	61.8	35.4	329.7
Hank	21.7	2.3	96.6	13.8	59.5	42.3	309.2
Kuntz	4.3	5.2	102.2	13.6	62.2	32.7	412.0
McNeal	21.7	8.5	88.0	15.0	60.7	36.0	500.6
Reeder	4.3	1.6	96.4	15.1	61.5	38.2	401.3
Treasure	16.3	1.7	116.3	11.1	59.9	36.8	313.9
MT0802	16.7	4.2	99.2	15.3	60.7	42.5	356.4
MT1073	2.0	0.9	107.6	14.7	62.6	37.9	385.3
Mean	16.9	5.3	94.0	14.3	61.0	38.0	365.9
LSD	15.8	5.1	12.7	0.6	0.8	3.1	34.7
Pr>F	0.0119	0.0001	0.3175	0.5139	0.4408	0.8662	0.1355

SR: stripe rust, OWBM: orange wheat blossom midge, YLD: Yield, PRO: protein, TWT: test weight, TKW: thousand kernel weight,FN: falling number

Objective 5: Determine the interaction between Sm1 resistant varieties and plant growth regulators

Results

This study was conducted to compare the treatment effects of Cerone and Lorsban when applied to CAP 400-1, an experimental cultivar with resistance to the OWBM, and Solano, a non-resistant cultivar. The study was planted as a split-plot design with three replications. Cerone treatments were applied at a rate of 0.75 pt/A, at early boot, on June 26. Lorsban treatments were applied at a rate of 1 pt/A, at heading, on July 2.

The main effect of PGR and insecticide treatments had a significant effect on heading date, yield and thousand kernel weights (Table 7). Cerone applied alone or in combination with Lorsban, delayed heading by two days and resulted in lower thousand kernel weights. The combination of Cerone with Lorsban produced the highest yields.

Table 7. Main effect of PGR and insecticide inputs on Spring Wheat. 2013

Input	HD Julian	HT in	OWBM no/spk	YLD bu/A	PRO %	TWT lb/bu	TKW g	FN sec
Check	184	35.5	12.2	84.1	15.0	61.6	37.3	376.0
Cerone	186	35.8	8.4	83.6	15.2	61.5	36.4	367.3
Lorsban	184	37.3	5.7	92.6	14.1	62.3	37.9	361.3
Cerone & Lorsban	186	34.9	4.8	100.9	14.9	62.3	36.8	387.5
LSD	0.9	1.9	6.1	13.3	1.7	0.8	0.5	54.1
Pr>F	0.0019	0.0881	0.0895	0.0555	0.4898	0.0837	0.0009	0.6792

HD: heading, HT: height, OWBM: orange wheat blossom midge, YLD: yield, PRO: protein, TWT: test weight, TKW: thousand kernel weight, FN: falling number,

Significant differences were observed with the main effect of cultivar (Table 8). CAP 400-1 afforded complete control of OWBM, and resulted in higher test weights and falling number values than Solano. Solano had higher thousand kernel weights. Although Solano had significantly greater OWBM numbers, Solano and CAP 400-1 had similar yields when averaged over PGR and insecticide inputs. However, Interactions were observed for yield (Table 9).

Table 8. Main effect of variety on agronomic performance of spring wheat. 2013

Input	HD Julian	HT in	OWBM no/spk	YLD bu/A	PRO %	TWT lb/bu	TKW g	FN sec
CAP 400-1	185	34.9	0.0	89.8	14.8	62.4	34.6	413.7
Solano	185	36.8	15.5	90.8	14.8	61.5	39.6	332.4
LSD	1	2.2	4	4.2	0.6	0.4	0.4	27.3
Pr>F	0.7200	0.0799	0.0001	0.6260	0.9287	0.0011	0.0001	0.0001

HD: heading, HT: height, OWBM: orange wheat blossom midge, YLD: yield, PRO: protein, TWT: test weight, TKW: thousand kernel weight, FN: falling number, Overall, Cerone plus Lorsban afforded the greatest yield increase for both CAP 400-1 and Solano. However, Solano also benefitted from lorsban applied alone. These results indicate that there could be a synergistic effect to yield by applying lorsban plus cerone, regardless of the variety.

Table 9. Effect of PGR and insecticide on spring wheat agronomic performance. 2013

Input	HD Julian	HT in	OWBM no/spk	YLD bu/A	PRO %	TWT lb/bu	TKW g	FN sec
				CAP 400-1				
Check	184	35.1	0.0	83.0	15.0	62.1	34.5	429.7
Cerone	186	34.2	0.0	88.6	15.1	62.2	34.2	410.7
Lorsban	184	36.6	0.0	88.8	14.2	62.7	35.4	391.7
Cerone & Lorsban	186	33.7	0.0	99.0	15.0	62.6	34.4	422.7
				Solano				
Check	184	35.8	24.3	85.3	15.0	61.0	40.1	322.3
Cerone	186	37.4	16.8	78.7	15.2	60.8	38.5	324.0
Lorsban	184	38.1	11.4	96.4	14.1	62.0	40.4	331.0
Cerone & Lorsban	186	36.1	9.6	102.7	14.8	62.1	39.2	352.3
LSD	2.1	4.4	7.9	8.4	1.2	0.8	0.8	54.7
Pr>F	0.9860	0.8167	0.0618	0.0429	0.9799	0.3647	0.1474	0.5560

HD: heading, HT: height, OWBM: orange wheat blossom midge, YLD: yield, PRO: protein, TWT: test weight, TKW: thousand kernel weight, FN: falling number,

Objective 6: Evaluation of spring wheat cultivars for susceptibility to the OWBM

Results

Germplasm from the off-station spring wheat nursery was evaluated for susceptibility to the OWBM in order to determine if alternative resistance mechanisms might exist (Table 10). Midge densities were extremely low, averaging only 15 larvae per spike. The highest midge densities recorded were found on Hank (31), Jefferson (26.7) and Oneal (26.3). In contrast, the lowest larvae numbers were recorded for the CAP lines. Not surprisingly, the CAP lines afforded almost complete control of the larvae. In addition, Reeder and MT1172 both had low midge numbers, at 8.3 larvae per spike for both entries.

Yields generally declined as larvae numbers increase, but yield results were confounded by the effects of stripe rust, which averaged 36% for the nursery. Yields averaged 66 bu/A, ranging from a high of 94 bu/A for Volt to a low of 48 for AP604CL and Choteau. Several entries had falling number values less than 300, but this did not appear to be related to midge numbers.

Overall, the results of this nursery substantiate previous finding, where Hank is considered highly attractive/susceptible to the midge, and Reeder is unattractive. The most interesting observation is that MT1172 is similar to Reeder in attractiveness to midge egg-laying. This may provide another option in areas where Reeder is not well adapted.

Table 10. Agronomic performance of commercial spring wheat varieites.

Cultivar	HD Julian	HT in	SR %	OWBM no/spk	YLD bu/A	PRO %	TWT 13%	TKW 13%	FN sec
AP604CL	180	37.7	95.3	15.7	47.9	14.1	60.6	31.2	330.0
Brennan	181	30.2	34.7	17.0	74.4	15.6	60.7	35.4	248.2
BuckPronto	180	35.8	13.3	11.3	66.5	16.6	60.3	42.6	325.2
CAP 197-3	183	38.1	36.0	0.0	78.0	13.7	59.9	32.4	343.4
CAP 34-1	182	33.6	54.7	5.0	72.2	13.8	60.6	33.6	362.9
CAP 400-1	184	39.2	4.7	0.0	84.4	16.3	61.1	33.8	446.6
CAP219-3	181	36.3	44.0	0.0	73.7	14.1	60.3	32.7	354.2
Choteau	183	35.0	46.0	14.0	48.3	15.6	59.0	35.4	368.7
Corbin	181	35.5	28.3	21.3	60.8	15.7	60.7	42.5	344.7
Duclair	181	37.3	27.3	12.0	55.3	16.2	58.4	38.7	294.9
Fortuna	183	46.7	18.7	14.7	55.1	15.7	59.3	39.8	302.6
Hank	180	31.9	71.0	31.0	54.5	14.9	57.0	38.5	237.2
Jefferson	181	37.4	20.3	26.7	75.6	15.2	61.6	41.1	334.1
Kelby	180	30.8	39.0	18.3	54.6	16.0	59.7	33.2	203.0
McNeal	184	38.3	21.7	16.3	57.7	15.6	59.5	35.4	453.4
MT 1053	183	35.3	42.3	19.0	62.8	15.0	59.0	38.6	262.1
MT 1142	182	39.8	17.3	17.3	75.3	16.1	61.5	37.6	358.4
MT 1172	183	37.2	2.3	8.3	74.6	16.2	57.8	39.6	303.4
Oneal	184	36.3	64.3	26.3	44.0	15.2	57.8	31.6	388.5
Reeder	182	39.5	12.3	8.3	84.9	15.1	61.4	37.2	388.9
Solano	183	29.0	4.7	23.3	71.6	16.3	59.7	40.8	315.4
Vida	184	37.9	15.3	17.0	69.6	15.9	59.5	37.2	278.4
Volt	188	37.3	0.0	16.3	94.6	14.3	62.2	36.2	393.0
WB9879CLP	182	36.1	46.7	17.7	60.5	15.8	58.0	33.9	377.5
Mean	182	36.3	31.7	14.9	66.5	15.4	59.8	36.6	334.0
LSD	1.1	2.7	11.4	12.8	15.7	0.7	1.0	3.3	42.9

HD: heading, HT: height, SR: stripe rust, OWBM: orange wheat blossom midge, YLD: yield, PRO: protein, TWT: test weight, TKW: thousand kernel weight, FN: falling numbers.

Objective 7: Verify varietal preference behavior and trap performance using on-farm evaluations

Results

Previous studies conducted at NWARC have demonstrated that certain spring wheat varieties attract the adult egg-laying midge, while other varieties deter egg-laying. To test this apparent preference trend under a field scale basis, Reeder (non-attractive) and Solano (attractive), were planted at five on-farm locations in Flathead County. Field size ranged from 5 to 16 acres per variety. The locations selected had a previous history of substantial OWBM pressure.

Fields were seeded at 100 lb/A (Reeder) and 135 lb/A (Solano) to achieve a target population of 35 plants per square foot. Planting was delayed until approximately May 1, to insure that heading coincided with peak oviposition (Table 11). Reeder, a taller variety and therefore prone to lodging, was treated with Palisade, a plant growth regulator, at the 2 node stage to all fields except the Passmore site. The insecticide, Warrior II, was applied at each location when OWBM populations reached economic threshold levels.

Table 11. Material and Methods

Location	Seeding	Harvest	Palisade	Insecticide	OWBM #/ trap	OWBM Date
HCF	5/6	8/22	6/22	7/6	660	6/24-6/27
NWARC	5/9	9/12	6/21	7/9	1010	6/29-7/1
Passmore	5/1	8/25	–	7/5	161	6/27-7/1
Tutvedt	4/27	9/4	6/19	7/5	1115	7/2-7/4

Despite high OWBM numbers observed at all locations (Table 11), there were no significant differences in the number of larvae found per spike (Table 12). Significant differences were observed in plant height with Reeder being on average 5 inches taller than Solano.

Table 12. Agronomic data from the on-farm comparison of varietal preference to egg-laying by OWBM

	Plant Density #/sqft		Height inches		OWBM no/spike		Yield bu/A	
Location	Reeder	Solano	Reeder	Solano	Reeder	Solano	Reeder	Solano
HCF	25	26	28	27	4	7	42	41
NWARC R13	32	23	36	33	5	1	70	100
NWARC Y7	40	30	38	33	6	12	73	85
Passmore	26	28	38	31	1	3	69	88
Tutvedt	19	34	36	28	0	0	97	107
Mean	28	28	35	30	3	5	70	84
LSD	12.6		3.6		4.6		14.2	
Pr>F	0.9669		0.0200		0.4466		0.0524	

OWBM: orange wheat blossom midge

On average, Solano produced 14 bu/A more grain than Reeder. However, yields were confounded by hail damage at three of the five locations, with Reeder being more susceptible to hail damage. Grain quality was similar between the two varieties (Table 13).

Table 13. Agronomic data from the on-farm comparison of varietal preference to egg-laying by OWBM

	Protein %		FNa seconds		FNb seconds		TWT lb/bu	
Location	Reeder	Solano	Reeder	Solano	Reeder	Solano	Reeder	Solano
HCF	17.4	16.7	386	375	451	387	56	54
NWARC R13	14.8	15.3	385	355	353	391	59	60
NWARC Y7	15.7	15.4	345	334	425	356	59	60
Passmore	14.6	15.3	331	401	394	460	62	61
Tutvedt	14.9	14.2	369	354	417	367	60	60
Mean	15.5	15.4	363.2	364	408	392	59	59
CV	3.0		7.6		11.1		1.7	
LSD	0.8		49.1		78.3		1.8	
Pr>F	0.7530		0.9746		0.6052		0.6051	

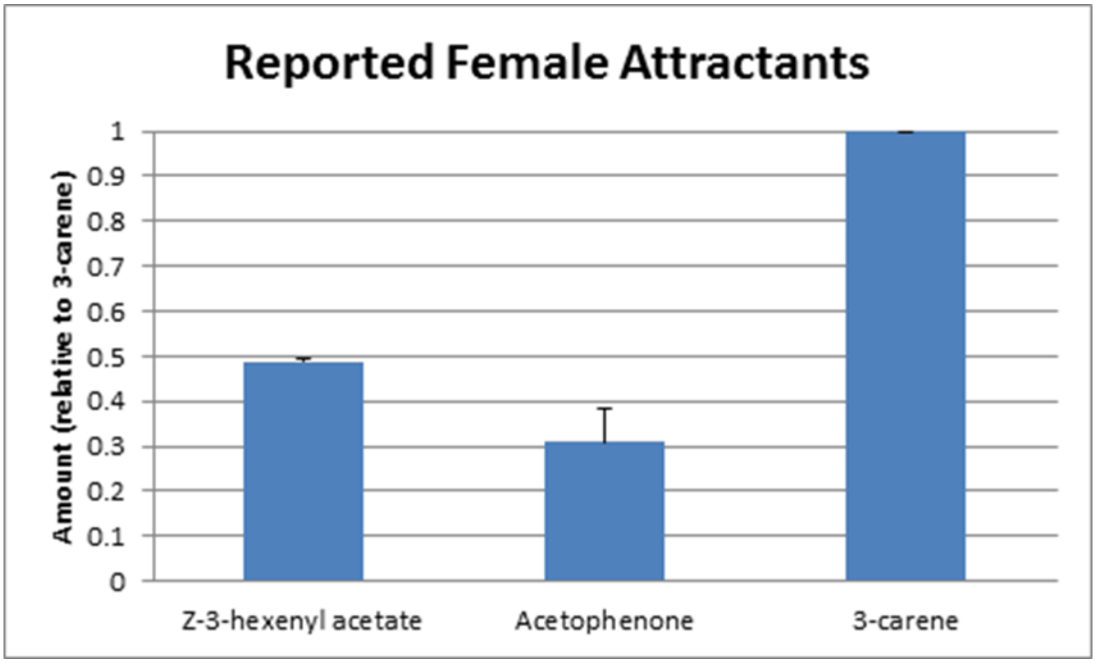
Fna: falling numbers tested at NWARC, FNb: falling numbers tested at the Nat'l Quality Inspection Lab, TWT: test weight

In small nursery plot situations, Reeder usually has far fewer midge larvae than Solano. This in turn translates to higher yields and better quality for Reeder. Either the application of an insecticide negated this advantage, or perhaps this ovipositioning dynamic does not hold when the varieties are grown on a large scale basis. Differential hail damage between varieties further complicates the results. It would be advantageous to repeat this exercise one more year. Overall, it seems beneficial to scale-up experiments in an attempt to substantiate preliminary findings.

Although attractiveness of midge to wheat varieties is of interest, we are also interested in attractiveness among midges. We conducted two sets of experiments with OWBM semiochemicals. The first was a simple comparison of pheromone lures from two suppliers. Given the importance of monitoring the spread of OWBM in the Triangle, we want to use the best one. This trial will be conducted again in the coming weeks because the initial comparison used lures that had been in the inventory for one supply for too long.

The second experiment was to test reported female OWBM attractants from a study conducted in England as lures for capturing females. In previous years, we collected volatiles from attractive and unattractive MT spring wheat varieties and found that these contradicted the published study. In 2013 we prepared lures in the compound ratios reported in the published paper. We targeted using approximately 100 wheat head equivalents of (*Z*)-3- hexenyl acetate, 3-carene and acetophenone in lures (Figure 1) and placed them in the same traps used for capturing male OWBM with pheromone. The lures did not catch a single female OWBM, which was not expected. The field location had a large OWBM infestation and we trapped during peak flight. An adjacent field baited with OWBM pheromone traps had average daily capture of male OWBM that were greater than 50. Therefore we can definitively conclude that these compounds are not suitable for lures for female OWBM in this MT population because MT spring wheat does not produce all of them and the females display no innate response to these.

Figure 1. Proportions of three reported female OWBM attractants.



Summary:

One of the most significant finding from this season is the fact that the orange wheat blossom midge has become well established in Pondera County, and to a lesser extent, can be found in other counties throughout the Golden Triangle. Further, reports indicate a resurgence of the midge in northeastern Montana as well.

Thanks to funding from the Montana Wheat and Barley Committee, our monitoring efforts have enabled us to alert affected growers, making them aware of the negative effects of this pest. This proactive strategy has helped to minimize the negative economic consequences of the midge. However, the insects' exact distribution is uncertain, and it may be established in other parts of Montana as well. It is for this reason that expanding our monitoring and education efforts throughout Montana would seem like a prudent response.

We are fortunate to have several management options available to combat this pest. One of the most economical and effective strategies is the use of resistant varieties. Efforts to incorporate the S*m*1 gene into Montana adapted varieties have progressed well. Several lines have been identified that have resistance to the midge, while also possessing excellent agronomic and quality attributes. In particular, CAP400-1 has resistance to the midge and stripe rust. In addition, we anticipated that midge might become established in areas where the wheat stem saw fly is also present. As such, we have several experimental lines that contain the Sm1 gene and also possess the solid stem trait. These efforts will take on a greater urgency now that we have confirmed that the midge has expanded into saw fly country.

Efforts to conserve this resistance trait are very important. Our preliminary results indicate that blending resistant and susceptible wheat varieties is a viable strategy to delay the development of resistant midge populations. The use of an interspersed refuge can allow a low number of midges to reproduce without sacrificing yield or quality.

While the resistant gene is highly effective, this season efforts reconfirmed that midge larvae negatively impact grain yield even in materials that carry the Sm1 gene. The gene does cause mortality, which in turn reduces future midge densities and yield loss. However, yield reductions still occur as a result of the lag phase between the initial feeding, and the production of the toxic compound(s). The end result being that we observed a significant economic benefit to using insecticides in conjunction with the resistant spring wheats. In short, both tactics may be needed to maximize profits, depending on midge numbers. Towards that end, it would seem that separate economic thresholds should be used for susceptible and resistant spring wheat varieties.

We evaluated the use of plant growth regulators in an effort to shorten this lag phase between initial feeding damage and the production of the toxin. Low midge densities prevented a robust assessment of this strategy. However, preliminary results indicate a possible synergistic effect to applying a plant growth regulator plus an insecticide.

We continue to screen germplasm for new forms of plant resistance. Previous efforts have demonstrated that certain varieties seem to deter egg-laying (Reeder) while other varieties seem to encourage it (Solano). Five on-farm comparisons between Reeder and Solano were established to see if this differential egg-laying behavior transferred to large scale settings. There were no differences between varieties for OWBM numbers, but this may have been due to the application of an insecticide treatment. Future comparisons should include non-treated areas as well.

Funding Summary:

Budget information to be provided by OSP. No other support for this project.

MWBC FY2011 Grant Submission Plans: Resubmittal is planned

Title: **Spring Wheat Breeding and Genetics (4W4601)**

Principal Investigator: **Luther Talbert**

Objectives:

1) Develop spring wheat varieties for Montana producers.

2) Coordinate the variety testing program.

3) Conduct genetic studies for wheat improvement.

Results

The primary responsibility of the spring wheat breeding and genetics project is to develop improved spring wheat varieties for producers in Montana. Primary objectives include high yield potential, wheat stem sawfly resistance, and excellent bread-making properties. This is a long-term process, which commences with a cross involving wheat lines with complementary characteristics. On our program, four generations of inbreeding are conducted after the initial cross to generate materials for field testing. The first look at new lines is in unreplicated plots grown in Bozeman, where less than 5% of lines are retained for more thorough testing in subsequent years. Field analysis becomes more rigorous as lines are selected through generations, culminating in a few dozen lines tested in our Advanced Yield Trial grown at several sites in Montana. Data from this trial is used to identify potential new varieties for release to Montana growers. Trial data from the spring wheat program is tabulated in our annual report.

Two new varieties underwent seed increase and purification in 2013 and are under consideration for potential release. These include ‘CAP400’ and MT1172. CAP400 is an experimental line which combines genes from several parents that confer desirable traits in northwest Montana. The genes are *Sm1* for resistance to the orange wheat blossom midge (OWBM), HGPC for high grain protein content, and Yr36 for stripe rust resistance. Data from the Northwestern Agricultural Research Center has shown superior performance of CAP400 for yield, grain protein, OWBM resistance and stripe rust resistance. The second line increased in 2013 was MT1172, which is a Clearfield variety with two genes for resistance to imidazolinone herbicides. MT1172 is a backcross-derived line closely related to Vida. Properties are similar to Vida, including very high yield potential and modest grain protein levels. MT1172 will be complement to WB9879CLP, which is a 2-gene Clearfield cultivar similar to Choteau. WB9879CLP was developed by MSU and licensed to Westbred for commercialization.

Pending the decision by the release committee, CAP400 and MT1172 will join several other MSU-developed spring wheat varieties in Montana agriculture. These include Vida and

Choteau, which occupied over one million acres in Montana in 2013. The solid-stemmed variety Duclair is a more recent release, and will see significant acreage in 2014.

Yield trials conducted in Bozeman in 2013 were completed satisfactorily, including our Advanced Yield Trial, Preliminary Yield Trial, Single Row Yield Trial, F_5 head row nursery, F_4 head row nursery and the F1 nursery. Most other locations obtained satisfactory nurseries in 2013, with the exception being loss to hail in Sidney for the Advanced and Preliminary Yield Trials. Data from the Advanced Yield Trial is being assembled for publication of the annual variety performance bulletin.

Our crossing block in 2013 has concentrated on introducing useful diversity into the breeding program. Our current new varieties have a high percentage of genes from the varieties Choteau and Reeder. Choteau has been used as a parent due to its solid stem characteristics, while Reeder has been used primarily due to its high yield potential. In that genetic diversity is necessary to make progress from crossing and selection, we have obtained the best experimental lines from 12 breeding programs in North America. These lines have been tested for agronomic traits in Bozeman and Huntley, as well as additional sites in the US and Canada. This project has been facilitated by our participation in the USDA-funded TCAP program. We selected the best lines from diverse programs to use as parents in our 2013 crossing block, and will repeat this process with additional lines in 2014. The goal of the crosses is to insure continued productivity from the spring wheat breeding program by complementing our current gene pool with the best genes from other breeding programs.

Several other breeding nurseries were grown in 2013. Two large nurseries were established in cooperation with Dr. Weaver to identify new sources of resistance to the wheat stem sawfly. Hail destroyed the nursery planted in Amsterdam, but we obtained very nice results from a Loma nursery. These nurseries are a significant time and resource commitment for the project, in that we need to travel from Bozeman for planting, weed control, note-taking, and harvest. However, they have been extremely valuable to help us identify and exploit new genes for sawfly resistance. This screening project in sawfly sites will grow in 2014 as we received a USDA grant to conduct this screening on a larger scale.

We also grew screening nurseries to select OWBM resistant lines in cooperation with Dr. Bob Stougaard at Creston. Resistant types from this nursery will be tested more thoroughly in 2014. A current goal is to develop a solid-stemmed line with resistance to the OWBM to help combat the insect as it moves eastward into the major wheat growing regions of Montana. Finally, we grew a nursery in Bozeman where we inoculated our most advanced 700 lines with stem rust. Susceptible types were identified and discarded from the program.

Several field-based genetic studies were completed, primarily as graduate student thesis projects. These trials included analysis of genes identified in cooperation with Drs. Sherman and Martin for high tiller number, solid stems, stay-green leaves, and super-strong gluten properties. Many of these studies have depended on the identification of molecular markers for the genes of interest, and subsequent development of appropriate genetic materials. The use of the markers is finding its way into the mainstream breeding program, as markers were used to aid the development of MT1172 (Clearfield) and CAP400 (OWBM-resistant), which are the two lines we will propose for release this year. However, for traits such as grain yield potential, there is still no substitute for multiple field–testing sites. Fortunately, the excellence of the MAES Research Center faculty and staff insures that the breeding programs will be able to continue the necessary field trials.

Summary

The year 2013 was very successful for the breeding programs. Colleagues and the weather both cooperated so that most of our nurseries were grown to good effect. Two new lines will likely be proposed for release in 2014. These include a line resistant to the OWBM and a new Clearfield line. New crosses with diverse material will insure a full breeding pipeline as we seek new varieties for Montana agriculture. Primary goals will remain wheat stem sawfly resistance, heat and drought tolerance, and excellent end-use quality.

Funding Summary

The MAES provides support for about a 0.4 FTE research associate position, reduced from 0.5 FTE in 2013. Funding from the MWBC has been sufficient in the past to allow the spring wheat project to have two technical support staff for our breeding trials in Bozeman and at sites throughout Montana. Funding from the USDA has been necessary for the past year supplement the MAES and MWBC funds to fully fund two positions. Other funding from USDA is primarily being used to support graduate student research related to wheat breeding and genetics. A new grant from USDA, entitled "New Genes for Resistance to the Wheat Sawfly from Geographically Targeted Landrace Accessions of Wheat", with Drs. Weaver and Sherman will involve large scale screening in sawfly sites and genetic analysis of resistance genes.

MWBC

I plan to submit a proposal for 'Spring Wheat Breeding and Genetics' in 2014. I will request funding of $120,000 in order to resume full funding for two support staff from MAES and MWBC support.

Project Review Report, Montana Wheat and Barley Committee

1. Project Title:
Foliar fungicide in dryland winter wheat (4w4615)

2. Time Period:
July 1, 2013 - June 30, 2014

3. Project Personnel:
Dr. Mary Burrows, Assistant Professor and P.I., PSPP; Matt Moffet, Research Associate, PSPP, Montana State University.

4. Cooperators:
Peggy Lamb, Northern Ag Research Center; John Miller, Western Triangle Ag Research Center; David Wichman, Central Ag Research Center

5. Objectives

1. Evaluate fungicides in winter wheat for disease suppression and yield benefits in the absence of disease in demonstration trials throughout the state of Montana.

2. Disseminate the results of these studies to growers in Montana and throughout the Great Plains region.

6. Results:

Objective 1. Evaluate fungicides in winter wheat in on-farm demonstration trials.

The purpose of these experiments was to determine if fungicide applications at different rates and timing in the absence of disease or presence of natural disease (targeting stripe rust) were different at the herbicide application timing (Feekes 3-4) and flag (Feekes 8-9).

Methods: Plots (8x25') were established at on-farm locations in Judith Basin County, Choteau County, and Teton County as well as at the Northern Ag Research Station (NARC) in Havre, MT; the Western Triangle Ag Research Station (WTARC); the Central Ag Research Station (CARC); and the Lutz Research Farm at MSU in Gallatin County. Experiments were designed as a randomized complete block with four replications. Winter wheat variety and planting date were at the discretion of the landowner/farm manager and are shown in Table 1 below. Tillering treatments (on-station and on-farm) were applied on 13 May 2013 for Gallatin and Teton, 14 May 2013 for WTARC and NARC and Choteau, and 17 May 2013 CARC and Judith Basin with a CO_2-charged hand-held spray boom with four nozzles spaced 1 ft apart calibrated to deliver 20 gal/A at 30 psi with 8002VS nozzles. All on-farm and station locations were dryland and chemical fallow with varying tillage practices (Table 1). Plots were scouted by research station and research lab personnel for disease and phytotoxicity. No significant levels of phytotoxicity occurred at any location, but there were significant amounts of disease at the WTARC and Teton County locations. Hail at the Judith Basin location and a large fertilizer gradient in the field at the Choteau County location made the data from these locations unusable. The Teton location was harvested later than optimal.

Table 1. Agronomic variables for fungicide trial locations.

	2013						
	Choteau	Teton	Judith Basin	CARC	WTARC	NARC	Gallatin (Lutz)
Variety:	Bearpaw	Decade	Rampart	Genou	Genou	Genou	Yellowstone
Production type:	Chem-fallow, no-till	Chem-fallow, no-till	Chem-fallow, till	Chem-fallow, till	Chem-fallow, till	Chem-fallow, till	Chem-fallow, till
Planting date:	NA	9/11/12	NA	10/2/12	9/26/12	10/2/12	10/1/12
Fertilizer type, rate:	NA	urea 46-0-0 150 lbs/a incoroporated by till (July 11, 2012) prior to seeding and 14-26-0-10 @ 110lbs/a at seeding (9-11-12)	March topdressed with 130lbs/a of 46-0-0.	50lbs/a of 20-20-20-10 with seed. March topdressed with 130lbs/a of 46-0-0.	100 lbs of 11-52-0 at seeding. 51lbs of 46-0-0 and 40 lbs of 0-0-60 topdressed in fall. Then 210 lbs 46-0-0 was topdressed 4/7/13.	16.13 lb 0-0-62 per acre, 38.46 lbs 11-52-0 per acre, 208.19 lbs 46-0-0 per acre	No starter fert. 150 lbs. of 46-0-0 was top dressed in March.
Herbicide type, rate:	NA	9-15-12 Olympus Flex @ 2.6oz/a and on May6th 2013 Osprey at 4.75oz/a	NA	Bronate @ 2pts/a on 5-15-13	Huskie @ 11oz/a and Axial XL @ 16.4oz/a on 5-13-13	None	On June 6th 16 oz. Goldsky, 8 oz. 2-4D LV6, 1.5 lbs AMS per acre and 32 oz. of R-11 per 100 gallons @ 10gpa.
Seeding rate:	NA	65 to 67lbs/a	NA	60 lbs/ac	18 seeds/ft	23 seeds/ft	65 lbs/ac
Row spacing:	12"	12"	10"	12"	12"	12"	12"
Harvest date:	8/26/2013	9/12/2013	NA	8/22/2013	8/12/2013	8/13/2013	8/6/2013
Latitude	48DEG 3'32.68"N	47DEG 50'31.18"N	47DEG 6'41.65"N	47DEG 3'49.89"N	48DEG 18'25.20N	48DEG 29'35.66"N	45DEG 48'53.58"N
Longitude	110DEG 29'38.36"W	111DEG 41'5.74"W	109DEG 54'18.61"W	109DEG 57'59.78"W	111DEG 55'24.73"W	109DEG 47'53.53"W	111DEG 2'44.93W
Elevation	3040' (926.6m)	3692' (1125.3m)	4142' (1262.5m)	4263' (1299.4m)	3714' (1132.0m)	2705' (824.5m)	4647' (1416.4m)

At the time of tillering fungicide applications diseases were not present in the plots. The timing of the tillering and flag leaf applications did vary by location (Table 2). Diseases were noted by cooperators at low levels approximately one week after the flag applications. Disease occurrence was verified by research personnel and recorded (Table 3).

Table 2. Fungicide timing at trial locations.

Location	Timing of application	Date of application
MSU-Lutz Farm	F2+-F3	5/13/2013
	F9-9+	6/10/2013
NARC	F4	5/14/2013
	F10.1-2	6/12/2013
WTARC	F3	5/14/2013
	F9-9+	6/12/2013
CARC	F3	5/17/2013
	F9+	6/17/2013
Teton	F3+-4	5/13/2013
	F9	6/12/2013
Choteau	F3	5/14/2013
	F9	6/11/2013
Judith Basin	F3	5/17/2013
	F9+	6/17/2013

Table 3. Disease onset observations in fungicide trials

Location	Disease	Date rated	Relative incidence
MSU-Lutz Farm	Stripe rust	7/1/2013	Very Low (~1.0 to 5.0%)
NARC	Stripe rust	6/28/2013	Very-Very Low (<0.1%)
WTARC	Stripe rust	6/21/2013	Very High (~40 to 60%)
	Mildew	6/21/2013	Very-Very High
CARC	Stripe rust	7/2/2013	Medium/sporadic (~15 to 25%)
Teton	Stripe rust	6/21/2013	Very-Very High (>60%)
	Mildew	6/21/2013	Very-Very High (>60%)
Choteau	None		
Judith Basin	Stripe rust	6/17/2013	Very Low (~1.0 to 5.0%)
	Tan spot	6/17/2013	Very Low (~1.0 to 5.0%)

*Very –very Low defined as only finding several plants all season while scouting untreated areas of the field outside the experimental treatments, very-low as a dozen plants, medium as hundreds of plants, high is thousands, very high is a large percentage of plants, and very-very high is nearly every single plant in the field.

Results:
Summary tables are provided below for all measured variables. The ARC station locations were planted to Genou to target stripe rust. The only statistically significant differences were test weights and plant height at NARC (height data not shown), protein and disease levels at Teton, and disease ratings at WTARC.

Data is not presented for the Choteau and Judith Basin locations. The Choteau county location was treated and harvested, but upon analysis of the data it was discovered that there was a large fertilizer gradient running perpendicular to the direction of the treatments/replications, making analysis impossible and affecting all of the harvest variables. The Judith Basin location received heavy hail and harvest data was not collected.

Yield: There were no significant differences in grain yield due to fungicide application at any location (see Table 4 below). Average yield of all locations was 68.8 Bu/A with a large variation in yield between locations. There were no differences in yield due to fungicide application at any location.

Table 4. Yield (Bu/A) at all locations.

No.	Treatment	Rate	Timing	n	Yield (bu/A)	stderr	Yield (bu/A)	stderr	Yield (bu/A)	stderr	Yield (bu/A)	stderr	n	Yield (bu/A)	stderr
					NARC		WTARC		CARC		TETON			GALLATIN	
1	Control	N/A	N/A	4	94.1	2.8	94.6	1.9	43.0	1.8	67.0	8.1	4	29.7	2.6
2	Priaxor	2 oz (half)	Tillering	4	99.7	3.5	107.3	5.7	43.1	2.4	63.1	2.6	4	31.2	1.6
3	Priaxor	4 oz (full)	Tillering	4	99.4	1.3	104.9	7.7	39.0	1.3	64.9	5.9	4	32.4	1.8
4	Priaxor	4 oz (full)	Flag	4	100.5	1.0	106.1	12.8	46.6	1.3	72.6	6.0	4	30.4	2.0
5	Quilt Xcel	5.25 oz (half)	Tillering	4	99.9	3.3	96.6	5.4	39.6	1.2	74.4	4.9	3	32.6	6.5
6	Quilt Xcel	10.5 oz (full)	Tillering	4	97.3	3.1	100.5	3.0	45.3	0.5	75.2	5.8	4	31.9	2.4
7	Quilt Xcel	10.5 oz (full)	Flag	4	96.9	1.4	96.5	7.2	41.8	0.5	79.1	9.4	4	30.5	2.4
8	Tilt	2 oz (half)	Tillering	4	96.8	1.3	101.5	4.4	43.4	3.6	61.9	14.2	4	30.9	2.6
9	Tilt	4 oz (full)	Tillering	4	97.6	3.0	94.7	3.1	41.4	1.1	81.3	5.0	4	31.5	3.0
10	Tilt	4 oz (full)	Flag	4	99.9	3.7	101.8	13.2	41.2	2.7	91.1	9.8	4	29.6	2.0
11	Twinline	7 oz (full)	Flag	4	101.7	4.7	104.1	10.1	41.9	3.0	67.8	4.0	4	29.0	3.8
12	Stratego 250EC	4 oz (full)	Tillering	4	90.4	1.9	106.9	9.8	41.3	1.8	68.4	5.2	4	28.6	2.1
13	Stratego YLD	4 oz (full)	Flag	4	95.0	2.4	97.5	6.4	40.4	2.0	68.3	7.1	4	31.0	0.3
14	Prosaro	6.5 oz (full)	Flag	4	97.2	1.6	96.2	3.0	44.7	2.6	77.4	4.6	4	29.7	2.0
15	Headline	6 oz (full)	Tillering	4	98.5	1.9	103.3	9.3	41.4	1.8	76.4	2.9	4	32.4	2.8
16	Headline	6 oz (full)	Flag	4	100.4	3.7	99.4	6.7	39.6	2.4	68.9	3.2	4	32.6	2.6
			Mean		97.8		100.7		42.1		72.4			31.0	
			p-value rep		0.0164		0.0026		0.4334		0.0365			<0.0001	
			p-value trt		0.2585		0.9640		0.4796		0.1825			0.9665	
			CV		5.2		13.4		9.9		17.8			13.2	
			R sq		0.4		0.3		0.3		0.4			0.5	
			LSD trt		7.2		19.2		6.2		18.3			5.9	

<u>Seed Moisture:</u> Data from none of the sites showed significant differences in seed moisture. Comparisons were made after seed went thru a short term storage of a couple weeks (labeled “after harvest”) and a long term storage of over a month where all samples were at the same storage location (labeled “after storage”). Significant differences in seed moisture due to fungicide treatment were not detectable either the short term or longer term storage (Table 5).

Table 5. Seed moisture data for all locations.

No.	Treatment	Rate	Timing	n	Moisture (% after storage)	stderr	Moisture (% after harvest)	stderr	Moisture (% after storage)	stderr	Moisture (% after harvest)	stderr	Moisture (% after storage)	stderr	Moisture (% after harvest)	stderr	Moisture (% after storage)	stderr	Moisture (% after storage)	stderr
					NARC				WTARC				TETON				CARC		GALLATIN	
1	Control	N/A	N/A	4	12.0	0.04	12.0	0.13	10.6	0.1	12.3	0.04	8.8	0.06	10.6	0.12	8.4	0.07	9.7	0.04
2	Priaxor	2 oz (half)	Tillering	4	12.0	0.03	12.0	0.13	10.5	0.0	12.5	0.10	8.8	0.20	10.4	0.12	8.5	0.15	9.9	0.09
3	Priaxor	4 oz (full)	Tillering	4	12.0	0.04	12.0	0.12	10.5	0.1	12.3	0.04	8.7	0.05	10.5	0.17	8.6	0.07	9.7	0.10
4	Priaxor	4 oz (full)	Flag	4	12.1	0.02	12.2	0.17	10.4	0.1	12.4	0.07	8.9	0.07	10.6	0.15	8.6	0.06	9.8	0.05
5	Quilt Xcel	5.25 oz (half)	Tillering	4	12.1	0.02	12.2	0.02	10.7	0.0	12.3	0.16	8.8	0.10	10.5	0.11	8.6	0.10	9.9	0.10
6	Quilt Xcel	10.5 oz (full)	Tillering	4	12.1	0.06	12.1	0.06	10.7	0.1	12.5	0.05	8.8	0.04	10.4	0.20	8.5	0.09	10.0	0.09
7	Quilt Xcel	10.5 oz (full)	Flag	4	12.0	0.04	12.1	0.11	10.6	0.1	12.4	0.13	8.8	0.09	10.5	0.14	8.5	0.06	9.9	0.09
8	Tilt	2 oz (half)	Tillering	4	12.0	0.07	12.2	0.10	10.6	0.1	12.6	0.09	8.8	0.04	10.5	0.14	8.5	0.09	9.8	0.10
9	Tilt	4 oz (full)	Tillering	4	12.0	0.05	12.1	0.07	10.7	0.0	12.2	0.09	8.8	0.09	10.5	0.20	8.4	0.15	9.8	0.09
10	Tilt	4 oz (full)	Flag	4	12.2	0.06	12.2	0.10	10.5	0.1	12.4	0.13	8.6	0.08	10.2	0.21	8.4	0.11	9.8	0.04
11	Twinline	7 oz (full)	Flag	4	12.2	0.10	12.3	0.09	10.4	0.1	12.5	0.19	8.8	0.07	10.6	0.09	8.4	0.10	9.9	0.06
12	Stratego 250EC	4 oz (full)	Tillering	4	12.1	0.05	12.0	0.12	10.5	0.1	12.3	0.17	8.7	0.10	10.4	0.12	8.6	0.09	9.9	0.08
13	Stratego YLD	4 oz (full)	Flag	4	12.1	0.04	12.1	0.16	10.7	0.0	12.5	0.09	8.8	0.09	10.4	0.03	8.5	0.10	9.8	0.06
14	Prosaro	6.5 oz (full)	Flag	4	12.0	0.06	12.1	0.07	10.6	0.1	12.4	0.13	8.8	0.07	10.5	0.16	8.6	0.10	9.9	0.10
15	Headline	6 oz (full)	Tillering	4	11.9	0.05	12.0	0.09	10.5	0.1	12.4	0.13	8.9	0.09	10.6	0.16	8.7	0.05	9.8	0.09
16	Headline	6 oz (full)	Flag	4	12.0	0.07	12.2	0.11	10.6	0.1	12.4	0.09	8.6	0.15	10.6	0.13	8.3	0.07	9.7	0.10
			Mean		12.0		12.1		10.5		12.4		8.8		10.5		8.5		9.8	
			p-value rep		0.0088		0.0004		0.1495		0.8571		0.0834		0.6925		0.6465		0.1535	
			p-value trt		0.0904		0.4414		0.2679		0.8905		0.6143		0.9451		0.3732		0.4824	
			CV		0.8		1.5		1.6		1.9		2.1		2.9		2.2		1.6	
			R sq		0.5		0.5		0.4		0.2		0.3		0.2		0.3		0.3	
			LSD trt		0.1		0.3		0.2		0.3		0.3		0.4		0.3		0.2	

Test weight: There was a significant difference in test weight due to fungicide treatments at NARC where stratego 250 EC applied at tillering reduced test weight compared to the control. The average test weight from all locations was 57.3 lbs/Bu. There were low test weights at Teton and Gallatin locations lowering the average under 60 lbs/bu (Table 6).

Table 6. Test weight data for all locations.

No.	Treatment	Rate	Timing	n	Test Weight	lsd	stderr	Test Weight	stderr	Test Weight	stderr	Test Weight	stderr	Test Weight	stderr
					NARC			WTARC		CARC		TETON		GALLATIN	
1	Control	N/A	N/A	4	60.5	abcde	0.3	61.9	0.5	60.6	0.1	52.2	0.6	51.0	1.3
2	Priaxor	2 oz (half)	Tillering	4	60.0	ef	0.4	61.9	0.7	60.1	0.3	52.1	1.1	50.1	1.3
3	Priaxor	4 oz (full)	Tillering	4	60.1	ef	0.3	62.1	0.6	59.7	0.5	51.5	0.5	52.7	0.7
4	Priaxor	4 oz (full)	Flag	4	60.9	abc	0.1	61.4	0.9	61.2	0.3	53.4	1.2	52.3	0.7
5	Quilt Xcel	5.25 oz (half)	Tillering	4	60.4	bcde	0.1	61.7	0.5	59.5	0.7	53.0	0.7	54.0	1.2
6	Quilt Xcel	10.5 oz (full)	Tillering	4	60.2	def	0.2	60.8	0.2	60.2	0.1	53.2	1.5	52.2	1.6
7	Quilt Xcel	10.5 oz (full)	Flag	4	60.4	bcde	0.3	62.3	0.7	59.9	0.3	53.7	1.1	51.6	0.7
8	Tilt	2 oz (half)	Tillering	4	60.6	abcde	0.1	61.7	0.5	59.8	0.7	52.0	0.8	52.0	1.7
9	Tilt	4 oz (full)	Tillering	4	60.5	abcde	0.2	61.9	0.4	60.3	0.6	52.7	1.1	51.6	1.4
10	Tilt	4 oz (full)	Flag	4	60.9	abcd	0.1	61.8	0.9	59.4	0.5	53.3	1.1	51.8	0.9
11	Twinline	7 oz (full)	Flag	4	61.1	ab	0.2	61.0	0.9	59.8	0.7	52.6	1.4	49.5	1.8
12	Stratego 250EC	4 oz (full)	Tillering	4	59.6	f	0.2	62.1	0.5	60.6	0.6	51.0	0.9	52.1	1.7
13	Stratego YLD	4 oz (full)	Flag	4	60.4	bcde	0.3	61.4	0.7	60.4	0.5	53.2	0.3	51.2	0.8
14	Prosaro	6.5 oz (full)	Flag	4	60.3	cdef	0.4	61.7	0.6	60.7	0.4	53.2	0.9	52.2	0.5
15	Headline	6 oz (full)	Tillering	4	60.3	cde	0.3	61.5	1.2	60.3	0.5	53.1	1.2	52.1	0.8
16	Headline	6 oz (full)	Flag	4	61.1	a	0.1	62.3	0.2	60.5	0.8	52.9	1.0	49.6	1.0
			Mean		60.5			61.7		60.2		52.7		51.7	
			p-value rep		0.4912			0.0176		0.2912		<.0001		<0.0001	
			p-value trt		0.0045			0.9552		0.7085		0.2990		0.1442	
			CV		0.8			2.1		1.7		2.5		3.8	
			R sq		0.5			0.3		0.3		0.6		0.6	
			LSD trt		0.7			1.8		1.5		1.9		2.8	

Seed protein: There were no significant differences in seed protein due to fungicide treatments at most locations. At the Teton location, Twinline at Flag resulted in a 1% higher protein level than the control for unknown reasons. This location was harvested late which may have influenced the results. The average seed protein from all locations was 13.6% (Table 7).

Table 7. Seed protein data for all locations.

No.	Treatment	Rate	Timing	n	Protein	stderr	Protein	stderr	Protein	stderr	Protein	lsd	stderr	Protein	stderr
					NARC		WTARC		CARC		TETON			GALLATIN	
1	Control	N/A	N/A	4	12.7	0.1	12.3	0.1	12.8	0.3	13.9	bcde	0.3	16.0	0.4
2	Priaxor	2 oz (half)	Tillering	4	12.7	0.3	12.1	0.2	13.5	0.1	13.9	bcde	0.5	16.2	0.4
3	Priaxor	4 oz (full)	Tillering	4	12.6	0.2	12.2	0.2	13.5	0.3	14.4	abc	0.2	15.3	0.2
4	Priaxor	4 oz (full)	Flag	4	12.8	0.1	12.6	0.2	12.7	0.2	14.4	abc	0.3	15.2	0.4
5	Quilt Xcel	5.25 oz (half)	Tillering	4	12.6	0.1	12.5	0.2	13.4	0.3	14.1	abcd	0.3	15.3	0.3
6	Quilt Xcel	10.5 oz (full)	Tillering	4	12.4	0.2	12.3	0.2	13.4	0.1	13.3	de	0.7	15.6	0.5
7	Quilt Xcel	10.5 oz (full)	Flag	4	13.1	0.3	12.2	0.1	13.4	0.3	14.5	abc	0.2	16.3	0.3
8	Tilt	2 oz (half)	Tillering	4	12.7	0.3	12.2	0.2	13.7	0.4	14.5	abc	0.4	15.6	0.4
9	Tilt	4 oz (full)	Tillering	4	12.6	0.2	12.4	0.2	13.1	0.3	13.7	cde	0.7	15.9	0.3
10	Tilt	4 oz (full)	Flag	4	12.8	0.2	12.1	0.1	13.6	0.4	14.2	abcd	0.4	15.8	0.2
11	Twinline	7 oz (full)	Flag	4	12.4	0.1	12.4	0.3	13.7	0.4	14.9	a	0.5	16.4	0.5
12	Stratego 250EC	4 oz (full)	Tillering	4	12.7	0.3	12.0	0.3	12.5	0.7	14.6	abc	0.3	16.1	0.5
13	Stratego YLD	4 oz (full)	Flag	4	13.0	0.2	12.3	0.1	13.5	0.4	14.4	abc	0.1	16.0	0.3
14	Prosaro	6.5 oz (full)	Flag	4	12.9	0.3	12.5	0.1	12.7	0.5	14.7	abc	0.3	15.9	0.1
15	Headline	6 oz (full)	Tillering	4	12.6	0.3	12.3	0.2	12.7	0.5	13.1	e	0.8	15.5	0.3
16	Headline	6 oz (full)	Flag	4	12.9	0.1	12.1	0.1	12.8	0.6	14.7	ab	0.4	16.4	0.3
			Mean		12.7		12.3		13.2		14.2			15.8	
			p-value rep		0.0182		0.1716		0.8534		<.0001			0.7773	
			p-value trt		0.5228		0.7221		0.3798		0.0125			0.1850	
			CV		3.1		3.2		5.8		4.6			4.7	
			R sq		0.4		0.3		0.3		0.6			0.3	
			LSD trt		0.6		0.6		1.1		0.9			1.1	

Severity and incidence of stripe rust: Stripe rust occurred at two locations, Teton and WTARC. Severity differed between locations with Teton averaging 5.2% across the plots and WTARC averaging 0.6%. Both locations showed significant reductions in stripe rust severity (% of flag leaf area covered by stripe rust pustules) due to flag timing fungicide treatments (p-value <0.0001, Table 8). Stripe rust incidence (number of plants affected) also differed between the locations with Teton averaging 55.9% across the plots and WTARC averaging 10.6%.

Table 8. Stripe rust disease at WTARC and Teton.

Stripe Rust Disease					Severity						Incidence					
No.	Treatment	Rate	Timing	n	Disease (% flag leaf area)	LSD	stderr	Disease (% flag leaf area)	LSD	stderr	% Incidence	LSD	stderr	% Incidence	LSD	stderr
					TETON			WTARC			TETON			WTARC		
1	Control	N/A	N/A	100	14.4	a	1.4	0.1	a	0.0	96.0	a	2.0	8.0	ab	2.7
2	Priaxor	2 oz (half)	Tillering	100	5.8	bcde	0.7	0.3	a	0.0	77.0	abc	4.2	24.0	ab	4.3
3	Priaxor	4 oz (full)	Tillering	100	4.0	de	0.6	1.8	a	0.5	52.0	cde	5.0	30.0	ab	4.6
4	Priaxor	4 oz (full)	Flag	100	3.4	de	0.7	0.1	a	0.0	34.0	efg	4.8	13.0	ab	3.4
5	Quilt Xcel	5.25 oz (half)	Tillering	100	7.8	abcd	0.7	0.2	a	0.1	91.0	a	2.9	9.0	ab	2.9
6	Quilt Xcel	10.5 oz (full)	Tillering	100	4.5	cde	0.6	0.1	a	0.1	68.0	abcd	4.7	2.0	ab	1.4
7	Quilt Xcel	10.5 oz (full)	Flag	100	0.4	e	0.2	0.0	a	0.0	8.0	g	2.7	0.0	b	0.0
8	Tilt	2 oz (half)	Tillering	100	12.3	ab	1.7	2.8	a	0.7	83.0	ab	3.8	27.0	ab	4.5
9	Tilt	4 oz (full)	Tillering	100	7.7	abcd	0.9	0.0	a	0.0	80.0	abc	4.0	0.0	b	0.0
10	Tilt	4 oz (full)	Flag	100	0.4	e	0.1	0.0	a	0.0	17.0	fg	3.8	0.0	b	0.0
11	Twinline	7 oz (full)	Flag	100	4.1	cde	0.6	0.0	a	0.0	59.0	bcde	4.9	0.0	b	0.0
12	Stratego 250EC	4 oz (full)	Tillering	100	10.9	abc	1.2	2.0	a	0.5	85.0	ab	3.6	33.0	a	4.7
13	Stratego YLD	4 oz (full)	Flag	100	1.9	de	0.6	0.0	a	0.0	41.0	def	4.9	0.0	b	0.0
14	Prosaro	6.5 oz (full)	Flag	100	0.1	e	0.0	0.0	a	0.0	6.0	g	2.4	2.0	ab	1.4
15	Headline	6 oz (full)	Tillering	100	4.2	cde	0.5	2.2	a	0.7	82.0	abc	3.9	22.0	ab	4.2
16	Headline	6 oz (full)	Flag	100	0.6	e	0.2	0.0	a	0.0	15.0	fg	3.6	0.0	b	0.0
			Mean		5.2			0.6			55.9			10.6		
					log transformed for analysis											
			p-value rep		<.0001			<.0001			<.0001			<.0001		
			p-value trt		<.0001			<.0001			<.0001			<.0001		
			CV		74.1			218.8			62.5			195.3		
			R sq		0.6			0.6			0.5			0.6		
			LSD trt		6.9			2.8			30.4			31.4		

Severity and incidence of 'mildew': Mildew was scored on a scale of % leaf surface area covered by mildew, with 100% being the most severe and 0% being absent. Mildew severity was very close between the locations with Teton averaging 7.6% across the plots and WTARC averaging 6.1%. Both locations showed significant differences in the mildew severity due to some of the treatments (p-value <0.0001). Mildew incidence also was very close between the locations with Teton averaging 58.2% across the plots and WTARC averaging 51.5%. Both locations showed significant differences in the mildew incidence due to some of the treatments (p-value < 0.0001) (Table 9).

Table 9. Powdery mildew incidence and severity at WTARC and Teton.

'Mildew' Disease					Severity						Incidence					
No.	Treatment	Rate	Timing	n	Disease (% flag leaf area)	LSD	stderr	Disease (% flag leaf area)	LSD	stderr	% Incidence	LSD	stderr	% Incidence	LSD	stderr
					TETON			WTARC			TETON			WTARC		
1	Control	N/A	N/A	100	6.8	cd	1.4	4.9	abcd	0.4	65.0	bcdef	4.8	73.0	abc	4.5
2	Priaxor	2 oz (half)	Tillering	100	13.3	b	2.1	10.9	ab	1.6	75.0	abcd	4.4	75.0	abc	4.4
3	Priaxor	4 oz (full)	Tillering	100	4.1	def	0.8	25.3	a	3.5	50.0	defgh	5.0	81.0	ab	3.9
4	Priaxor	4 oz (full)	Flag	100	3.3	ef	0.5	3.0	bcde	0.5	47.0	efgh	5.0	37.0	cdef	4.9
5	Quilt Xcel	5.25 oz (half)	Tillering	100	8.6	c	1.6	6.2	abcd	1.0	67.0	bcdef	4.7	65.0	abcd	4.8
6	Quilt Xcel	10.5 oz (full)	Tillering	100	11.5	b	1.9	6.2	abcd	1.3	78.0	abc	4.2	62.0	abcd	4.9
7	Quilt Xcel	10.5 oz (full)	Flag	100	1.2	h	0.3	0.9	e	0.5	31.0	gh	4.6	8.0	f	2.7
8	Tilt	2 oz (half)	Tillering	100	7.2	c	1.4	7.9	ab	1.7	71.0	abcde	4.6	82.0	ab	3.9
9	Tilt	4 oz (full)	Tillering	100	20.4	a	2.5	3.7	bcd	0.5	87.0	ab	3.4	70.0	abc	4.6
10	Tilt	4 oz (full)	Flag	100	4.1	fgh	1.3	2.1	bcde	0.2	41.0	fgh	4.9	47.0	bcde	5.0
11	Twinline	7 oz (full)	Flag	100	3.5	efg	0.8	2.0	de	0.8	45.0	efgh	5.0	22.0	ef	4.2
12	Stratego 250EC	4 oz (full)	Tillering	100	7.5	c	1.6	11.1	ab	2.0	63.0	bcdef	4.9	91.0	a	2.9
13	Stratego YLD	4 oz (full)	Flag	100	1.4	h	0.3	0.3	e	0.1	31.0	gh	4.6	10.0	ef	3.0
14	Prosaro	6.5 oz (full)	Flag	100	1.9	gh	0.4	1.4	cde	0.2	29.0	h	4.6	31.0	def	4.6
15	Headline	6 oz (full)	Tillering	100	23.0	a	2.6	11.2	abc	1.9	95.0	a	2.2	63.0	abcd	4.9
16	Headline	6 oz (full)	Flag	100	4.5	cde	0.7	0.2	e	0.1	56.0	cdefg	5.0	7.0	f	2.6
			Mean		7.6			6.1			58.2			51.5		
								log transformed for analysis								
			p-value rep		<.0001			<.0001			<.0001			<.0001		
			p-value trt		<.0001			<.0001			<.0001			<.0001		
			CV		90.3			68.8			73.4			66.1		
			R sq		0.2			0.6			0.3			0.6		
			LSD trt		4.0			3.6			26.8			38.3		

Objective 2. Disseminate results of MWBC-sponsored research (2013)

Professional publications (journals and posters):

Miller, Z., F. Menalled, M. Moffet, D. Ito, M. **Burrows.** 2014. Impacts of crop variety and time of inoculation on the susceptibility and tolerance of winter wheat to Wheat streak mosaic virus. Plant Dis. (submitted)

Moffet, M, **M. Burrows,** P. Bruckner, J. Berg. 2013. Evaluation of fungicides for control of stem rust in Montana, 2012. Plant Disease Management Reports. 7:CF035.

Burrows, M. Z.J. Miller, N. Ranabhat, D. Delaney-Falcon, and F. Menalled. 2014. Estimating Impacts of Grassy Weed Species on Risk of Cereal Viruses. WSSA-CWSS Joint Metting, Vancouver, Canada.

Burrows, M., Z. Miller, F. Menalled. 2013. Estimating susceptibility to Wheat streak mosaic virus infection in non-crop grasses. American Phytopathological Society Meeting, Austin, TX. August 10-14.

Miller, Z., M. Burrows, F. Menalled. 2013. Effects of nitrogen fertilization on risks and impacts of wheat streak mosaic disease. American Phytopathological Society Meeting, Austin, TX. August 10-14.

Ranabhat, N., D. Delaney-Falcon, F. Menalled, M. Burrows and Z. Miller. 2013. Effects of inoculation method on host plant susceptibility to WSMV infection. NCB-ESA. Rapid City, SD. June 16-19. Poster DR-41.

Pol, C., Z. Miller and M. Burrows. 2013. Chemical and biological control of the wheat curl mite (Aceria tosichella). NCB-ESA. Rapid City, SD. June 16-19. Poster DR-42.

AgAlerts:

21 May, 2013. We got some rain! Should I spray a fungicide on wheat? 338 downloads.
18 June, 2013. Potential stripe rust in Hill county. 450 downloads.
19 June, 2013. Stripe rust confirmed in Flathead and Hill counties on spring and winter wheat. 450 downloads
24 June, 2013. Stripe rust considered widespread in the triangle. 450 downloads.
2 July, 2013. Observations on wheat and pulse crops in the triangle. 587 downloads.
24 September, 2013. Disease risk this fall in winter wheat. 270 downloads.

Media:
8 appearances on Montana Ag Live, 10,000 viewers/appearance
9 January, KQTV in Billings; diseases of barley and pulse crops
25 January, KSEN radio in the triangle; diseases of wheat and pulses forecast

Presentations: (of 29 presentations to 2319 participants in 2013 by Burrows)

Invited speaker, Innovation in research and extension in Wheat IPM. Northcentral Region Entomological Society of America meeting. Rapid City, SD.

Extension presentations on wheat:

Date	Title	#	Event	Location
23-Jan-13	Disease update	20	Broadwater Co training	Townsend, MT
7-Jun-13	Montana Farm Bureau Tour of Clinic	60	Montana Farm Bureau	Bozeman, MT
12-Jun-13	Plant Disease	15	Sheridan Co Extension field day	Medicine Lake, MT
12-Jun-13	Plant Disease	5	Sheridan Co Extension field day	Plentywood, MT
13-Jun-13	Plant Disease	10	Philips Co Extension field day	Malta, MT
14-Jun-13	Plant Disease	20	Toole Co Extension field day	Sunburst, MT
14-Jun-13	Plant Disease	12	Pondera Co Extension field day	Conrad, MT
26-Jun-13	Plant Disease	250	NARC field day	Havre, MT
9-Jul-13	Plant Disease	150	CARC field day	Mocassin, MT
10-Jul-13	Plant Disease	150	WTARC field day	Conrad, MT
5-Aug-13	Advanced Plant Disease Diagnosis for field crops	16	Workshop Aug 5-6	Bozeman, MT
7-Aug-13	Cereal disease update	50	CCA Training	Huntley, MT
17-Dec-13	Fungicide resistance in	260	NPGA	Great Falls, MT

pulse crops

7. Summary:

Fungicides are frequently used on dryland winter wheat in Montana as a preventative measure and prophylactic protection against disease. In 2013, we obtained useful data from five of seven winter wheat fungicide trials located throughout Montana. A variety of common fungicides were applied at tillering and flag, at half and full rates. Stripe rust and powdery mildew were present at the WTARC and Teton Co. locations after the flag stage of growth. Yields varied from 31 to 101 bu/A depending on location. There was no positive yield response due to fungicide application at any location. This is consistent with previous results. Although there were minor differences in protein, test weight, and seed moisture at each location, there was no pattern attributable to fungicide application. The results of this research will continue to feed into extension efforts and planning of future trials.

8. Funding summary:

This research was partially supported by gifts from chemical companies.

9. FY2015 Grant submission plans: I'd like to maintain trials on research stations, but move to an on-farm research platform on fungicide application to dryland winter wheat with large replicated strip plots put out by a few producers.

Contract between the Agricultural Experiment Station or MSU Extension Service and the Montana Wheat and Barley Committee

Organization: Department of Plant Sciences and Plant Pathology
Title: Molecular Breeding Pipeline for Wheat (4W4612)
Time Period: July1, 2013 – June 30, 2014
Principle Investigator: Jamie D. Sherman
Associate Research Professor
Department of Plant Sciences
Cooperators: Luther Talbert, David Weaver, Bob Stougaard

Mission:

Traditionally, breeders have made selections by observing plant performance (phenotype) in the field. With the advent of molecular genetics, a complementary way of making plant selections, termed marker assisted selection (MAS), has been developed. Markers used in MAS are pieces of DNA associated with a trait of interest and serve as indicators for the presence of a specific gene. MAS has several advantages over traditional phenotyping, and has become an integral part of wheat breeding programs throughout the world.

Funding from MWBC has helped establish and support the molecular breeding pipeline for wheat at MSU. The pipeline currently has materials in all five stages of development. The final step of either release or continued use of lines in breeding is a measure of success.

Objectives:

- Maintain all 5 segments of the molecular breeding pipeline for wheat
    1. Mine for markers by making new marker/trait associations
    2. Confirm newly found marker/trait associations
    3. Utilize useful markers in breeding
    4. Test materials created through molecular breeding to ensure suitability
    5. Release lines for public use or use in further breeding
- Convert to a new more efficient marker system

Results:

Funding was received to support all segments of the molecular breeding pipeline for Montana. The segments are detailed below:

1. **Mine for markers by making new marker/trait associations**

In the past several years, we have been successful associating markers with a number of traits including wheat stem sawfly resistance, OWBM resistance, productive tiller number, extended grain fill, yield components, and quality traits. The populations we have used thus far have been from crosses between hard red spring parents. However, we believe traits of importance to Montana wheat may be in other populations. Because wheat breeding is often class specific, gene pools for different classes have become isolated. In other words, there are likely to be positive genes in winter, spring, red, white, bread and durum wheats that could be used to improve the other classes. Over the last several years we have created three mapping populations – a winter by spring cross (Yellowstone by Choteau), a red by white spring cross (Vida by MTHW0202) and a durum by bread cross (Mountrail by Choteau), which we will mine for new genes. It is important to note that the creation of all these populations was facilitated by markers, some of which we helped create. The durum/bread wheat map and the spring/winter maps are almost complete. The Vida/0202 population was field tested in summer 2013 and map construction has begun.

Marker Data Points Generated to Create New Maps

Traits	Population	Rationale	Number of data points
Yield	Choteau X Spring Yellowstone	To determine if different genes contribute to high yield in spring and winter	2300
Grain fill duration	Vida X MTHW0202	Dissect grain fill duration for drought tolerance and yield stability	1400
Total			3700

2. Confirm newly found marker/trait associations

We have created a number of lines over the last several years to confirm marker/trait associations that we have identified. For example, a mining for markers experiment identified a marker that associated with increased tillering. We used markers to create sister lines for that trait and those lines are currently being tested in several environments to determine under what conditions high tillering increases yield. Other sister lines in testing during 2013 include: large seed/seeds per head, yield, solid stem, and sawfly resistance.

As we identify new marker/trait associations, we continue to create new populations for confirming markers. Thus far this year, more than 2,400 data points have been run in the creation of new populations to confirm markers associated with sawfly resistance, yield and grainfill duration.

3. Utilize useful markers in breeding

Our goal is to be aware of emerging problems for Montana and be prepared to address them. The breeders, through interactions with stakeholders, identify breeding targets and help direct our focus. Interactions with national groups such as the USDA Wheat CAP and the USDA TCAP help us be aware of emerging problems and the availability of markers to address those problems. Through continued interactions we will target important traits and implement MAS for Montana. In the past, we have implemented markers others have identified as well as those we have created.

Sawfly is spreading into areas where there is also orange wheat blossom midge and stripe rust. Using markers we will create lines resistant to all 3 pests. In 2013 we began a project to develop lines bearing resistance to both pests. We have completed three crosses. We will complete the crossing in 2014 with the goal of field testing in 2015.

Spring wheat tends to be high protein which provides an economic benefit to growers. However, high yield often acts counter to high protein. For example, Vida a high yielding spring wheat line has lower protein than many other spring wheat lines. The higher yield and lower protein maybe related to the staygreen trait. In a previous project funded by USDA, we used MAS to place a high protein gene in several Montana lines. Unfortunately, this gene while increasing protein reduced yield due to early maturity. We have moved the high protein gene into staygreen lines like Vida using MAS. We will determine if the early senescence, lower yield of the high protein gene can be compensated for with staygreen. If successful then the process will create a higher protein line with yield characteristics of Vida. We completed backcrosses in 2013 and have increased the lines for initial testing in 2014.

Thus far this year, we have continued to develop lines using marker-assisted selection for high protein, orange wheat blossom midge resistance, wheat stem sawfly resistance, height, vernalization and photoperiod response.

Marker assisted selection data points in 2013

Trait type	**Trait**	**Rationale**	**Number of data points**
Quality	High Protein	Increase protein and determine if possible to have high protein stay-green line	400
Biotic resistance	Wheat Stem Sawfly	Create sawfly resistant lines	1600
	Midge	Combine midge and sawfly resistance	400
Agronomic	Photoperiod	Determine which photoperiod gene combinations are best for Montana	400
	Vernalization	Winter/spring habit conversion	300
	Height	Determine genotype of lines	400
Total			3500

4. **Test materials created through molecular breeding to ensure suitability**

Once lines have been created an important step is to field and quality test the lines, not only to ensure the required trait is present, but also to ensure acceptable performance of the lines overall.

Hard White lines have been created using markers to convert high performing hard red lines.

MT 1255	HANK*6/CLEARWHITE
MT 1273	VIDA*6/CLEARWHITE
MT 1276	VIDA*6/CLEARWHITE

The above lines were selected for white color alleles. Preliminary data indicate these white lines have equal yield and quality to the red parents from which they were derived. They will be tested another year in the advanced yield trial.

Strong gluten lines have been created in hopes of filling a market niche.
A hard white super-strong variety would be very unique and desirable for domestic and international bakers potentially improving whole wheat bread quality. We recently were able

to identify the gene causing the super-strong characteristic, and identified a breeder-friendly marker for the gene. We have backcrossed strong gluten into the White Vida and White Choteau as well as several other white lines using marker assisted selection. In 2013, the first field trial of these lines was completed. In winter of 2014 initial quality tests will be completed. Next year a large scale trial at several locations is planned.

5. **Release lines for public use or use in further breeding**

SY Tyra is a line created using marker assisted backcrossing of the solid stem gene into an Agripro line and it is currently in production.

CAP 34-1	CHOTEAU*3/CAP19
CAP197-3	MT0515*2//CAP19/MT0515
CAP219-3	MT0515*2//CAP19/MT0515
CAP400-1	(MCNEAL*5/GLUPRO)*2//CAP19/CHOTEAU

The CAP lines listed to the left were all selected with the marker for Sm1(Orange Wheat Blossum Midge resistance). Also, CAP 400 has as a parent a line that was created with marker assisted selection for high grain protein and stripe rust resistance and has been proposed for release this year.

MT 1172	MT0245/IMI8209-1//MT0245
MT 1173	MT0245/IMI8209-1//MT0245
WB9879CL	CHOTEAU*3/CHOTEAU/IMI8134

The lines to the left were selected for imi-resistance (Clearfield) using markers. WB9879CLP is currently in production. We proposed MT1172 for release this year.

Convert to a new more efficient marker system

To remain competitive, it is important that we stay on the cutting edge of molecular genetics, which has been facilitated by our participation in the USDA funded Triticeae Coordinated Agricultural Project (TCAP). In the past we have been limited to applying about 500 markers to any given population. Markers newly designed by TCAP have the potential of providing tens of thousands of markers. Unfortunately, these new markers systems have not been easily accessible to breeding programs for marker assisted selection. However, in 2013, with the acquisition of two new pieces of equipment (thanks to Phil Bruckner and Dean Jeff Jacobson), we are now able to utilize these new markers systems. We have already generated about 4,000 data points with this new system. We have used it to add markers to our maps and make marker assisted selections.

Summary

For Montana wheat breeding programs to remain competitive, we must continue to discover and implement markers that will facilitate wheat improvement for traits specific to Montana. The MAS lab at MSU has produced over 13,000 data points in 2013. These data points have facilitated breeding and been used to search for new trait marker associations. We will continue to assist the breeding programs with marker analysis using existing markers and continue to develop new markers for other traits critical for improving wheat for Montana farmers. The current funding has continued to empower us in the conversion of the basic research of genetic mapping to the practical application of marker assisted breeding, addressing problems specific to Montana.

Funding Summary

My salary in the past has been funded through grant money obtained from various sources. This year the Dean provided salary support for me to teach Genetics. Currently, half of my funding is through a competitive grant from the USDA-NIFA as the education lead for the grant for five years. The MWBC support is critical to fund myself and other personnel to keep marker work going. Currently, two undergraduate students are supported. We spend about $2000 per month on expendable supplies and so are on track to completely utilize funds by the end of the fiscal year. The direct support supplied by the MWBC for applied marker assisted selection to address Montana-specific problems is unique, necessary and important.

MWBC FY2014 Grant Submission Plans

I plan to resubmit to MWBC for FY2014. A primary value of my research has been to increase the effective sizes of the wheat breeding programs by allowing genes from different classes to be more accessible. It is important to note that we are on the cutting edge of wheat genomics as indicated by our ability to participate in the national TCAP project. Continued support will allow us to build on the momentum gained over the past few years and allow me to leverage other funding to ensure that Montana remains competitive with other breeding programs. By combining state and federal funding we have been able to establish MAS in Montana wheat breeding to bring immediate and long-term benefits in the form of improved varieties.

FY2014 Montana Wheat and Barley Compliance Midyear Report

Determining the Potential of Wheat Stem WSS Endosymbiotic Microbiota for Exploitation in Developing Unique Management Strategies

PI Carl J. Yeoman
Co-PI David Weaver

Background:
The endosymbiotic microbes of a number of insects including fruit flies, mosquitos, and wasps have been shown to be capable of causing sterility and affecting the sex ratios of insect larvae[1]. Additionally, the various metabolic contributions of endogenous microbes are known to be critical to the nutritive, physiological, immunological and developmental health of all animals[2]. To date, the microbes that colonize wheat stem WSS (WSS) have not been explored, nor have their metabolic and phenotypic contributions. We proposed to comprehensively evaluate the microbiomes of WSS with the express purpose of determining microbes and their metabolisms that could be exploited to manage, reduce or eliminate this pest.

Key Terms:

Metagenomics A DNA sequencing-based survey of microbial genes present in WSS microbiota

Microbiota The microbes (e.g. bacteria and archaea) that colonize the WSS.

Microbiome The genetically encoded capabilities of the microbiota.

Objectives:

1) Determine the composition of microbial populations that reside within WSS at various developmental stages and haplotypes.
2) Explore metagenomically, the metabolic capabilities of the resident microbiota
3) Identify microbes and their metabolisms that may be supporting WSS health or reproductive performance

Results to date:

Student recruitment We have recruited graduate student, Laura Brutscher to the project. Laura is a Molecular Biosciences fellow who is currently pursuing a Ph.D. in microbiology working on honeybee gastrointestinal microbial ecosystems under co-supervision from PI Carl J. Yeoman and Dr. Michelle Flenniken (Dept. Plant Sciences and Plant Pathology). As bees are also insects of the order Hymenoptera, this study of the WSS microbiome will enrich her Ph.D. program.

Sample collection Samples were collected over the 2013 growing season by Co-PI Dr. David Weaver with mid-season haplodiploid larval and from early-adult male representatives of highland grass-, (Flesher pass, Lincoln, MT) and lowland wheat- (Three Forks, MT) inhabiting populations. These populations represent two major haplotype clades determined by Dr. Weaver and colleagues to reside in Montana.

Optimization of DNA extraction protocols Metagenomic interrogation of the WSS microbiome depends on the ability to extract sufficient high quality DNA for sequencing. Two DNA extraction protocols, Mo-Bio and "Norma's protocol", were tested for their efficacy at obtaining sufficient and high quality DNA for metagenomic processing. The Mo-Bio protocol uses a Power-Soil kit (Mo-Bio, Carlsbad, CA) following the manufacturers protocol except for the addition of a 2 minute bead beating step. The Mo-Bio protocol has traditionally been used in PI Yeoman's lab for extracting DNA from a variety of host-associated microbial ecosystems. Norma's protocol is a protocol developed by Norma Irish (personal communication) from the Weaver lab and is described in appendix 1. Additionally, we tested for improved yields when pooling 5 WSS larva or adults as opposed to extracting from individuals. The results are summarized below in Table 1.

Table 1. DNA Extraction Comparisons

Sample (Protocol)	**Total DNA (µg)**	**DNA purity ($A_{260/280}$)****
Adult (Norma's)	3.28 +/- 1.05	1.75 +/- 0.10
Adult (Mo-Bio)	0.64 +/- 0.14	1.88 +/- 0.03
Adult batch (Mo-Bio)*	2.1	1.85
Larvae (Mo-Bio)	0.53 +/- 0.23	1.79 +/- 0.08
Larvae batch (Mo-Bio)*	20.4	1.88

*** Batches were not replicated **DNA purity is assessed by the ratio of spectrophotometric absorbance at wavelengths A_{260}/A_{280}. Pure DNA should have a ratio of ~1.8 with decreases reflecting protein contamination and increases reflecting RNA or Phenol contamination**

As a further test of DNA quality, we used polymerase chain reaction (PCR) to amplify a universal microbial gene marker from the DNAs obtained by each protocol (Fig. 1).

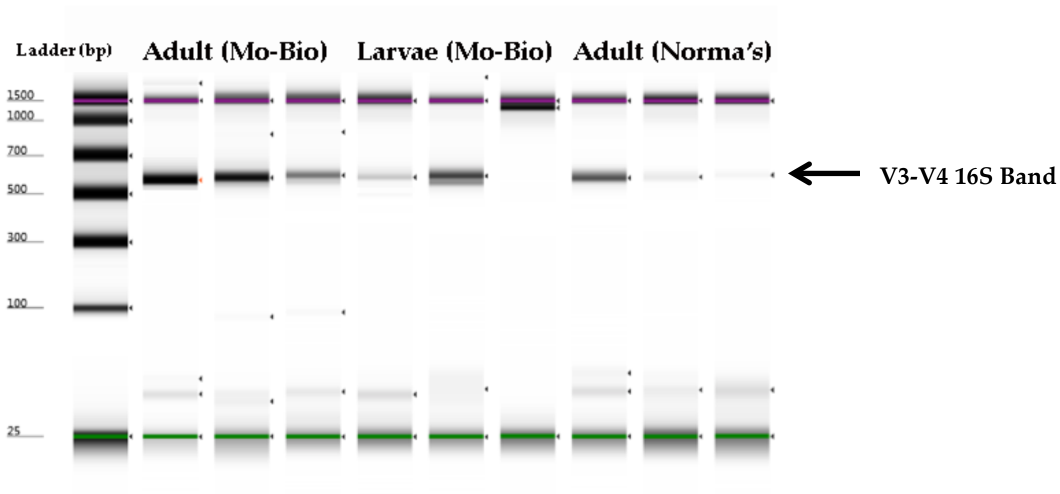


Figure 1 – Polymerase Chain Reaction Amplification of V3-V4 region of 16S rRNA gene from samples.

Despite higher concentrations of DNA being produced by Norma's protocol, less microbial DNA could be amplified. These observations may be explained by either increased host (WSS) DNA in the extract, or the DNA being more degraded using Norma's protocol. Based on these observations, we determined that Norma's protocol provided a greater amount of DNA, however the DNA was not of sufficient quality of metagenomic analyses. We therefore elected to use the Mo-Bio protocol and determined that sufficient DNA could be extracted using this method from individual sawflies such that we would not be required to pool samples.

Determination of Microbiota Composition and Variation Among WSS As the WSS microbiota and microbiome have not previously been investigated we elected to provide additional analyses, beyond those proposed, and sequence the 16S rRNA gene complements from the above DNA extractions and amplifications to determine the composition of WSS microbiota This information adds depth to our understanding of the WSS commensal microbial ecosystem and will empower our metagenomic analyses by allowing us to: a) estimate the total numbers of microbes present in the WSS microbiota so we can then optimize sequencing depth to ensure metagenomic data is sufficiently informative; b) examine variation in microbiota among individual WSS, so we can ascertain how representative our 12 total metagenomes will be; and c) ensure that individuals selected for metagenomic sequencing are representative of most WSS and are not outliers.

Our analyses identified 8 unique bacterial genera resident within the WSS (Fig. 2). The most common and abundant being *Spiroplasma,* which represented between 73 – 100% of the total microbiota detected in individual sawflies. All other observed microbial genera are of the family Pasteurellaceae. Basic descriptions of the identified microbial genera are provided in table 2.

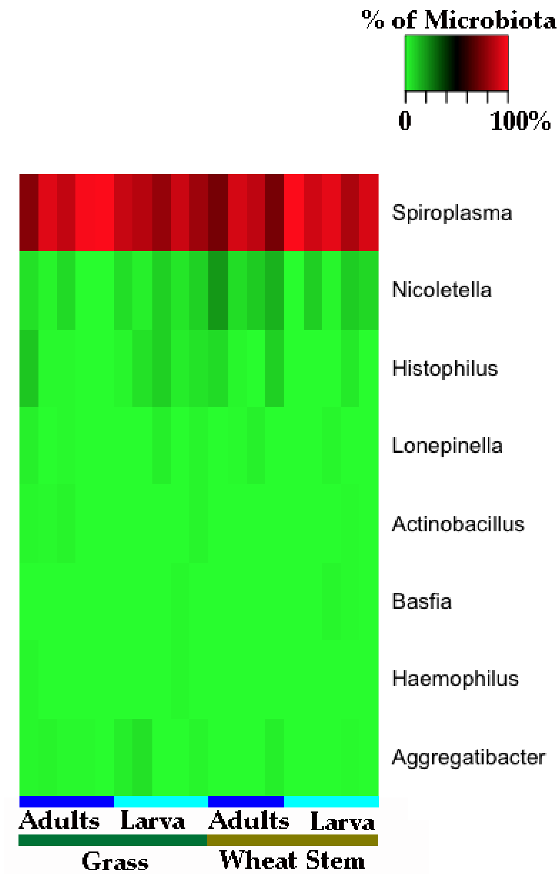


Figure 2. **Heatmap of WSS Microbiota.** Figure shows the eight microbial genera found to be associated with wheat- and grass-inhabiting WSS. Their relative abundances within individual sawflies is represented by shade of color as defined in the key. More abundant microbes tend toward lighter shades of red and less abundant toward lighter shades of green.

Although our approach of partial sequencing of 16S rRNA genes does not provide sufficient resolution to look at species level diversity, we can approximate species diversity by clustering sequences into operational taxonomic units (OTUs) that approximate species-level units (95% sequence identity). This allows us to estimate species richness (how many different species are present) and diversity (richness and evenness – is there one species that dominates or are they more evenly distributed). These pieces of information are important in helping us optimize the level of sequencing that will be required to obtain sufficiently detailed information about the WSS microbiome. Using this approach we detected 30-50 different OTUs in either grass or wheat-stem late stage larvae and adult WSS (Table 3). Chao1 estimates of total OTU diversity indicate that as many as 113 – 198 microbial species may be present associated with the WSS (Table 3). Diversity estimates indicate low levels of diversity consistent with other observations.

Table 2. Microbial Descriptions

Microbe	Description
Spiroplasma spp.	Small helical bacteria from the Spiroplasmataceae family. These bacteria lack a cell wall and are aflagellate but motile via corkscrew like motion. Most members are inhabitants of insect gut or hemolymph[3], or the phloem of plants[4]. Some *Spiroplasma spp.* have been shown to cause diseases in plants (incl. Citrus Stubborn disease and Corn Stunt disease) [5]. In these cases the bacteria are transmitted between plants by insect vectors, wherein they multiply[5]. Some strains are also known to impact sex ratios in other insect vectors (i.e. *S. poulsonii* kills male progeny of infected *Drosophilla* flies[5].
Nicoletella spp.	Gram-negative non-motile bacterium of the family Pasteurellaceae. Little is known about this genera with only one known species that was isolated from the airways of horses with respiratory disease[6].
Histophilus spp.	Gram-negative non-motile bacterium of the family Pasteurellaceae. Only two species of this genus are described (*H. ovis* and *H. somni*). *H. somni* is a commensal organism of cattle upper respiratory tracts that can be an opportunistic pathogen and cause a variety of diseases (incl. thrombotic meningoencephalitis, and respiratory disease) in immunocompromised cattle[7].
Lonepinella spp.	Gram-negative non-motile bacterium of the family Pasteurellaceae. This genus currently has only one described species (*L. koalarum*), which was isolated from the feces of a Koala and had the unusual ability to degrade tannin-protein complexes[8].
Actinobacillus spp.	Gram-negative non-motile bacterium of the family Pasteurellaceae that is commonly found in the respiratory tracts of mammals (incl. humans), birds, and reptiles[9].
Basfia spp.	Gram-negative non-motile bacteria of the family Pasteurellaceae that are found in cow rumen[10].
Haemophilus spp.	Gram-negative non-motile bacteria of the family Pasteurellaceae. Many species are described and includes commensal and opportunistic pathogens. These bacteria all have heme (iron) requirements[11].
Aggregatibacter spp.	Gram-negative non-motile bacteria of the family Pasteurellaceae. There are three species currently described (*A. actinomycetemcomitans, A. aphrophilus,* and *A. segnis*)[12]. These bacteria include commensal and highly virulent members and are most commonly found in the oral cavity occasionally associated with periodontitis[13].

OTU data for individual WSS were compared using Bray-Curtis dissimilarity[14], a common metric for assessing the compositional similarity between ecological samples. Relationships were then plotted on a non-metric multi-dimensional scaling ordination (Fig 3). Overall the plots showed that few differences existed between individual sawfly. This indicates that our metagenomic effort will be broadly representative of sawfly microbiomes. We did note, however, that three sawfly were modest outliers (adult 6, and adult 9 from the wheat inhabiting WSS and adult 9 from the grass inhabiting WSS). These samples are therefore being excluded from further analyses (i.e. metagenomics). The samples selected for metagenomics will be: grass-inhabiting WSS adults 6, 7, and 8; grass-inhabiting WSS larva 7, 8, and 10; wheat-inhabiting adults 7, 8, and 10; and wheat-inhabiting larva 6, 8, and 10. These individuals exhibit the least between individual differences within their respective groups (location and developmental status).

Table 3. Microbiota Profile Overview of WSS

Sample Group	N	16S rRNA Sequences Obtained	Coverage estimate	Observed OTUs*	Predicted species (Chao1)	Diversity (Shannon's index)
Grass (Larvae)	5	5844 +/- 3128	46 +/- 13 %	42 +/- 10	198 +/- 182	3.0 +/- 0.9
Grass (Adult)	5	4096 +/- 1175	70 +/- 22 %	49.2 +/- 24	127 +/- 74	3.5 +/- 0.2
Wheat stem (Larvae)	5	3910 +/- 2944	40 +/- 29 %	35.2 +/- 25	113 +/- 68	2.9 +/- 0.8
Wheat stem (Adult)	4	2117 +/- 1448	51 +/- 16 %	29.8 +/- 14	114 +/- 94	2.8 +/- 0.5

*** Operational taxonomic units (Sequences clustered at 95% identity)**

Estimating Required Sequencing Depth.

We used an adapted approach described by Ni et al. (2013)[15] to estimate the amount of sequencing required to achieve 20x coverage of species-level OTUs with greater than 1% abundance. 55% of OTUs in the targeted WSS were found to be above 1% abundance. We used this number to adjust Chao1 estimates of total diversity to estimate total diversity of OTUs >1% (109, 70, 62, and 63 OTUs, respectively). The expected genome sizes of *Spiroplasma spp.* are ~ 1.2 Mb[16], while members of the *Pasteurellaceae* have genomes ~ 2 - 2.4Mb[17, 18] (we averaged these to 2.2Mb). Among samples, an average of 88.5% of taxonomic abundance was attributed to *Spiroplasma*. We therefore used the following equation to estimate the amount of sequencing required:

$$\textbf{Sequencing} = 20_{\text{(coverage)}} \times \left(1.2\text{Mb}_{\text{(Spiroplasma genome size)}} \times \frac{88.5}{100}\right) + \left(2.2\text{Mb}_{\text{(Pasteurellaceae genome size)}} \times \frac{11.5}{100}\right) \times \text{OTUs} > 1\%$$

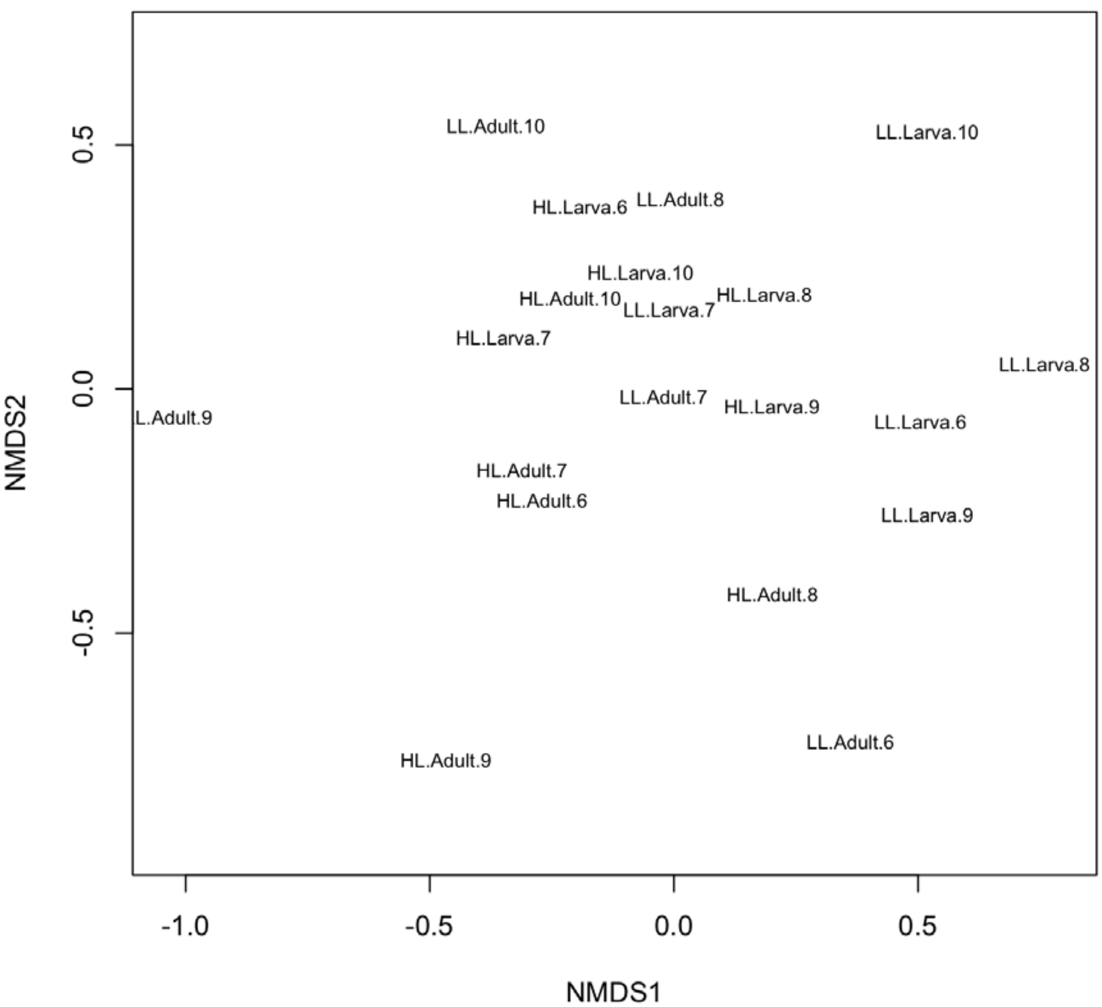


Figure 3 Nonmetric Multidimensional Scaling Ordination Showing Relationships in Microbiota Between Individual WSS. The relationship between microbiota of individual WSS from grass- (HL) and wheat- (LL) inhabiting populations were compared by Bray-Curtis dissimilarity and examined using an nMDS ordination (those with more similar microbiota are closer to each other, those with less similar microbiota are further away from each other.

This equation gave us estimates of 2.9, 1.8, 1.6, and 1.7 Gb of required sequence per grass-inhabiting adult, larvae, and wheat-inhabiting adult and larvae metagenome, respectively. Currently we are achieving on average 7.95 Gb of sequence per run, meaning we can achieve these levels of coverage by pooling 2-3 metagenomes onto each sequencing run.

Summary

We have collected samples, optimized DNA extraction procedures and undertaken sequencing of the V3-V4 region of 16S rRNA genes present in 19

WSS samples. These samples represent two developmental stages (mid-season larvae and early-season adults) and two geographically separate groups that have previously been found by Co-PI Weaver to represent distinct haplotypes (highland grass-inhabiting WSS, and lowland wheat-inhabiting WSS). Using this information we have determined the microbiota that colonize WSS and developed estimates of total species-level OTU diversity. We have also used these findings to select the most representative samples for each of the WSS groups for metagenomic sequencing. Metagenomics will inform us of the metabolic interactions taking place between the WSS and its microbiota, including any potentially critical interactions that may impact WSS health, nutrition, or reproductive performance. We hope to identify these interactions that could then be used as targets for novel and effective biocontrol strategies.

Funding Summary

No additional funding for this project has been sought or received. Although we expect the project to potentially yield important information that could be used to develop unique and effective biocontrol strategies, the project is early in the exploratory stage and we therefore believe it would be premature to seek additional funding.

MWBC FY2015 Grant Submission Plans

We would like this project to continue moving forward toward development of a unique, microbially-based biocontrol method in 2015. However, we are addressing the basic questions posed in the current proposal at this time. Thus we do not know if there will be a need for further research in this area as yet.

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Appendix 1 **Norma's DNA Extraction Protocol**

i. In a sterile petri dish, use a syringe plunger to smash individual sawflies in 100 ul T.E. buffer (pH 8). Once the fly seems thoroughly homoginized, rinsed the plunger with 100 ul T.E. Pipette out the liquid and push the other remains into a 1.5 ml tube with a pipette tip.
ii. Add 5 ul of 20mg/ml of the proteinase K solution to each tube.
iii. Add 10 ul of 20% SDS to each tube.
iv. Incubate samples at room temp for 2 hours.
v. Allow the required amount of phenol:chloroform:isoamyl alcohol to reach room temp.
vi. Add 200 ul of phenol:chloroform:isoamyl alcohol to each tube and incubate each tube horizontally at room temp on a orbital shaker.
vii. Centrifuge tubes at 10,000 g for ten minutes.
viii. Pipette supernatant into new tube.
ix. Add 2X volume 95% EtOH.
x. Add 1:10 volume 7.5M Ammonium Acetate
xi. Incubate in -20 freezer for 10 minutes.
xii. Centrifuge at 10,000 g for 15 minutes.
xiii. Drain EtOH without disturbing pellet.
xiv. Add 100 microliters 70% EtOH to wash pellet.
    1. Repeat
xv. Air-dry pellets in tubes.
xvi. Resuspend pellet in 50ul 10mM Tris-HCl.

FY2013 Montana Wheat and Barley Midterm Compliance Report

Title : Identifying and Developing Improved Barley Varieties for Montana (4W4605)

Principal Investigator: Dr. Thomas Blake

Objectives:

The MAES barley improvement program strives to develop new barley varieties that offer barley producers improved profitability. We utilize the most advanced field, analytical and genetics technologies to develop varieties that meet the needs of each of barley's feed, malt, food and hay markets.

Results:

Haxby continues to dominate Montana's feed barley acres, Haybet, Hays and Levina dominate the hay barley market and Hockett has established itself as the most drought tolerant malt barley in the region. In 2006 we expanded our germplasm base to include several potential sources of improved drought stress tolerance from Asia, and one of these lines (MT103022) performed extraordinarily well in both 2012 and 2013 Montana Intrastate Barley Trials. In the coming months I will propose release of several new hulless varieties, some to replace Prowashonupana, and other low fiber hulless barley lines to support Montana's swine and poultry industries. We have several new hay barley lines that await one more year of forage yield trials prior to release and have new low grain protein malt barley lines entering AMBA's pilot scale trials this spring.

Summary:

FY 2013 was another challenging year for the MAES barley improvement program. PhD student Duke Pauli and I have kept the barley breeding program running for the past two seasons, and I plan to continue the project through the 2014 field season. Duke Pauli is funded by our USDA Wheat-Barley CAP grant. MWBC funds support our talented cadre of undergraduate workers who help in the field, and largely manage the seed processing operations required by the breeding project. These undergraduates worked amazingly well last summer and are now completing the process of cleaning and processing our grain samples. I am now completing the first draft of the barley project's annual report.

MWBC Grant Submission Plans:

The MAES barley improvement project needs recapitalization. I retired Dec. 31, and will keep the project running through the 2014 field season. Unfortunately, a technician working for a plant pathology project borrowed our old Wintersteiger combine and blew its engine. Our seed room equipment is archaic and worn, and I still drive the John Deere 1010 that I inherited from Bob Eslick. It's a great little tractor, but its likely to need replacement in the near future. I plan to submit two proposals, one to continue our barley breeding program (a $60,000 request) and one to support the purchast of a new combine and a new deawner. I will explain this on February 20. Since I am retired, I will leave the hiring of a new field technician to my replacement. Association analysis funded by the CAP projects has provided us with remarkable insight into the genes controlling variation for both grain quality and agronomic performance. I believe that barley breeding is now in position to be able to predict field and malthouse performance by genotype analysis. If this view is correct, then we will spend far less time and effort evaluating unworthy lines. There are alternative approaches to the pedigree breeding approach currently used by the MAES wheat and barley projects that could dramatically speed genetic gain. I hope my successor will have the freedom to explore new, more efficient breeding approaches that will enable Montana barley producers to cope with their changing business and physical environments.

MONTANA STATE UNIVERSITY
College of AGRICULTURE
MONTANA AGRICULTURAL EXPERIMENT STATION
EXTENSION

To: S. Fraser
From: Tony Hartshorn | Montana State University
Re: FY2014 Montana Wheat and Barley Compliance Midyear Report
Date: 15 January 2014

- Title (Grant Number): Rapid assessment of soil carbon turnover times associated with alternative cropping strategies for dryland wheat: A $60,000 proposal to upgrade an existing gas analyzer (W4606).

- Principal Investigator: Anthony S. Hartshorn

- Objectives: Upgrade an existing departmental field infrared gas analyzer that can be connected to long-term chambers, suitable for replicated and unattended measurements of soil carbon dioxide. This equipment upgrade will allow Montana producers to better understand the rates at which soil organic matter is broken down and converted to carbon dioxide. Soil organic matter management provides opportunities to improve soil water-holding capacity, which could buffer producers from effects of drought, and crop nutrient availability, which could also buffer producers from fertilizer price shocks.

- Results: None to date.

- Summary: Initial summer 2013 measurements were planned as part of the Greenhouse Gas Rotation Study (GGRS) at Post Farm, 3 miles west of the Bozeman campus. However, funds were not made available to enable summer measurements. (On 18 September, I was notified grant funds could be disbursed; on 19 September, I obtained a template for a sole source justification from our Director of Procurement Services to initiate the purchase process; on 20 September, I made the decision to put the purchase on hold until closer to the time when I would be able to deploy the equipment as part of the GGRS in Spring 2014. Equipment purchases are expected by the time of the February 2014 MWBC Meeting.

- Funding Summary (Indicate other funds supporting this project to date.) Original instrument acquisition (~$50K) was supported through faculty hire/startup funds from the MSU Vice President for Research, the College of Agriculture, and the Department of Land Resources & Environmental Sciences.

- MWBC FY2015 Grant Submission Plans. The PI will apply for FY2015 MWBC funding to partially support a graduate student to develop best practices for the rapid **deployment** of this instrument, for quality assurance and quality control (**QA/QC**) procedures for both calibration as well as data (using R programming language to minimize potential for transcription or data manipulation errors), and for effective **dissemination** of results (patterned after both formal and less formal outreach approaches, including peer-reviewed manuscripts and audience-appropriate music videos, respectively, each with appropriate assessment instruments to quantify effectiveness).

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FY2014 MONTANA WHEAT AND BARLEY COMPLIANCE MIDYEAR REPORT

TITLE: Expanded Implementation of Wheat Stem Sawfly IPM (4W4599)

PRINCIPAL INVESTIGATOR**:** David Weaver, with Luther Talbert, Phil Bruckner and Gadi Reddy

Objectives:

1. Isolate wheat stem sawfly (WSS) antibiosis resistance mechanism(s) from oat
2. Screen landraces from world accessions of spring wheat from WSS resistance
3. Screen winter wheat varieties to explore promising lines with new host plant resistance
4. Aid in development of genetic markers for new host plant resistance in spring wheat
5. Screen barley varieties for potential resistance to wheat stem sawfly
6. Explore interactions between spring wheat line developed for orange wheat blossom midge (OWBM) resistance - Sm1 gene and WSS
7. Verify varietal preference behavior and trap performance using on-farm evaluation
8. Conduct large area sampling to develop trap crop economics to further adoption
9. Evaluate permanent border traps and cover crops for WSS management
10. Field and laboratory bioassays of entomopathogenic fungi and nematodes
11. Complete pheromone trap evaluation and optimization of trapping technique using the 9-acetyloxynonanal lure

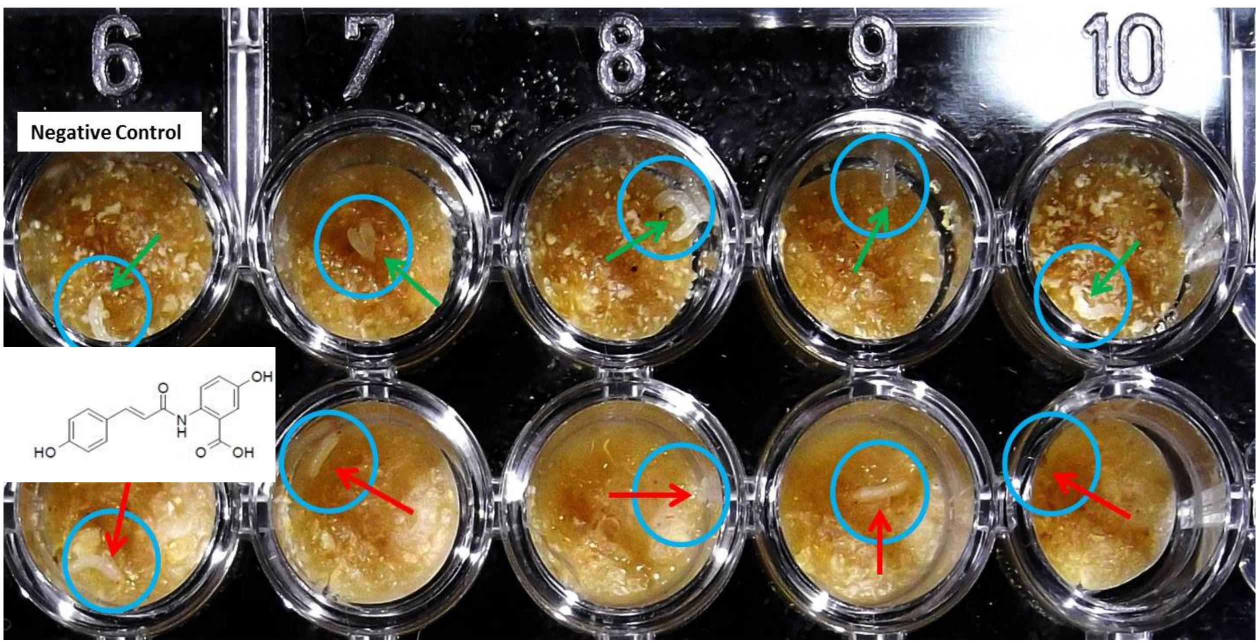
Results:

Objective 1. This ongoing research has been conducted only in the laboratory and one Research Associate is dedicated exclusively to this objective. The project has been developing via screening the bioactivity of compounds. As previously reported, we have refocused our efforts beyond determining the activity of compounds known to cause insect mortality that were innately present in the plant in both oat and solid stem wheat. So we have ruled out constituitive defense based on compounds present in the plant.

Next we identified that mortality in oats was likely triggered as a response to being infested by wheat stem sawfly, more specifically no later than when the larvae would hatch from the egg. However, the actual moment of induction must be earlier because some eggs never develop and the embryos die due to the response of the plant.

Now, we are focusing on unique induced compounds in oats that can be triggered by spraying the plants with commercial inducer “Actigard”, so it is not necessary to go through the additional steps of growing the oat in the greenhouse and infesting with sawflies. We use Actigard treatments at the Zadok’s stage in stem elongation that matches when wheat stem sawflies lay their eggs in oat stem in the field. We are currently focusing on unique induced chemistry in oats that includes phenolics, avenathramides, avenacins, plus avenocosides and their derivatives. To do this effectively, we need to effectively extract and concentrate materials for bioassay. These compounds are not commercially available and are far from abundant in our extracted stem tissue. Thus, we have switched to using 96 well trays that require minimal amounts of our diet and further adapted this to reduce the amount of material that needs to be used in each well.

This second step is critical and involves a using a small amount of extract mixed with cooling liquid diet and layered on the top of pure diet. The larvae must consume this, because transfer an active newly hatched larva into the well and score mortality at 72 hours. In the photo below, there are live sawflies in control buffer treated diet (green arrows) and dead ones from a treatment that had toxicity. The structure of a known avenanthramide is posted on the bottom right.



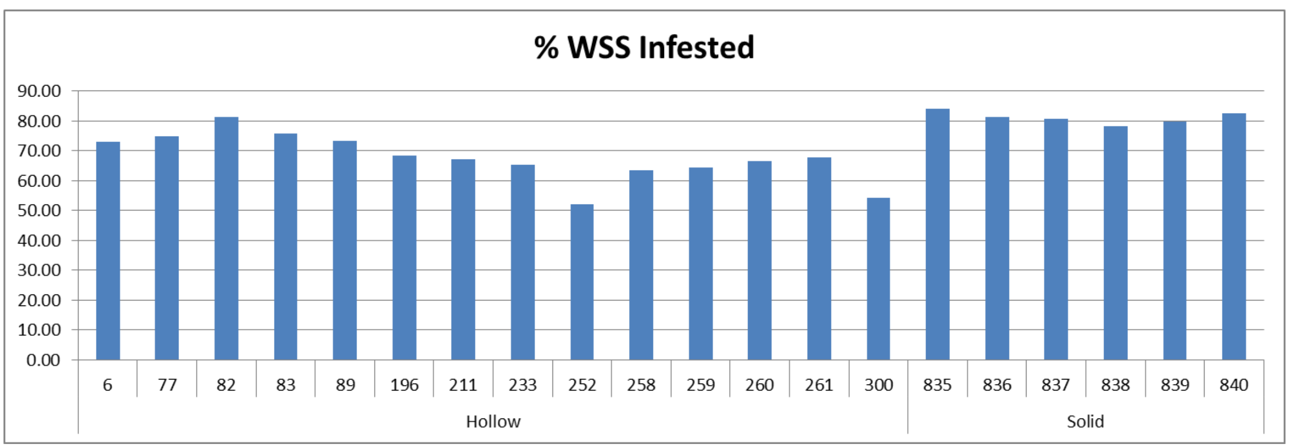
The dead sawflies are opaque and there is no frass (insect excrement) in the wells, while healthy sawflies are translucent and produce frass.

The next step was to alter the extraction protocol from: one that required several grams of dried oat powder from pooled stems that had to be processed in large ultracentrifuge and rotary evaporation equipment and used large amounts of solvent. This procedure required several days for the extraction of each class of compounds we now and each extraction required a new sample. We are currently using milligram quantities of samples that can be extracted on the laboratory bench. This requires only a small volume of solvent that can be evaporated in 2 hours. Extractions for different compound classes can be piggy-backed using the same sample. At this time the most fruitful area for scrutiny are the unique classes of compounds described above that are known to have strong responses to fungal infection of growing oat plants.

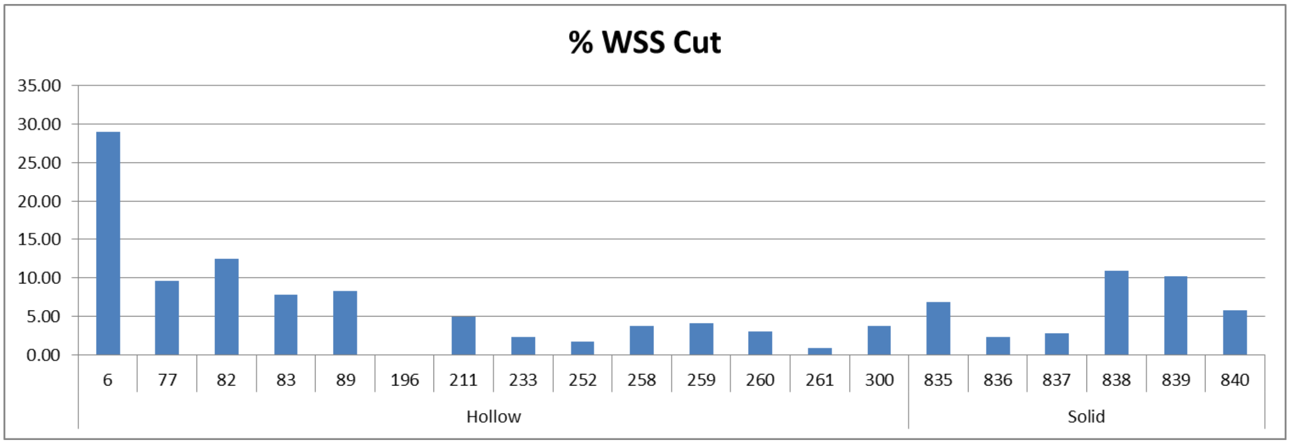
A second part of this project was to follow on the increasing use of oat to manage sawflies. A grower in the Amsterdam area had planted a large number of acres of 'Dane' oat this past year, but these were destroyed by hail before we could collect any samples to see how many sawflies had died. We also reported on crosses of a single 'Ligowo' oat stem that had been sawfly cut with Dane. We have sufficient germplasm for use in hill plots this summer. We also use seed that had been increased from the single cut stem in a laboratory experiment. We exposed 50 stems to 5 female sawflies in cages and scored mortality. Thirty-four stems were infested and all larvae died. The results in the laboratory are not definitive, so we will plant these crosses in hill plots to see if we can see any replication of stem cutting.

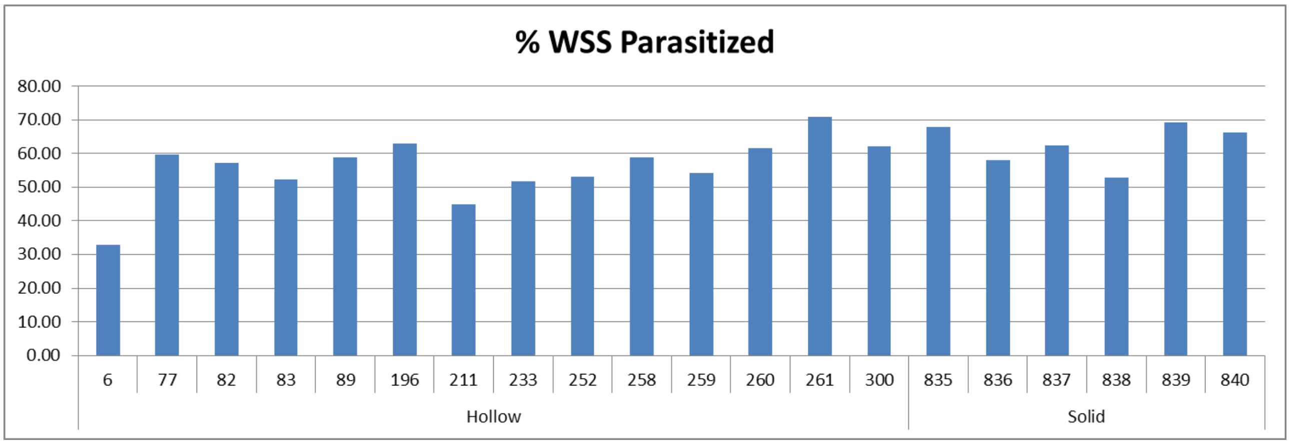
Objective 2.This year we planted two hill plot nurseries with spring wheat and durum landraces. The nursery at Amsterdam was destroyed by hail. At Loma, we planted 160 individual durum land races and replanted 450 hills of landraces that had been identified in 2012 as being either uninfested or all wheat stem sawfly larvae were dead. We excluded any that had solid stems from replanting, since we are looking for new types of resistance. These were collected at maturity. Stem dissection is not completed at this time. This effort will be greatly expanded in the coming year using funds from USDA to screen a much larger set of target landraces. Luther Talbert is the PI on this project (Weaver co-PI).

Objective 3. We planted hill plots of promising lines at both Amsterdam and Loma, but none survived. However, there was a single row observation nursery at Havre that was screened for sawfly cutting. We collected samples from 15 hollow stem and 6 solid stem lines. Infestation was high, averaging 68% in hollow stemmed varieties and 81% in the solid stem wheat.

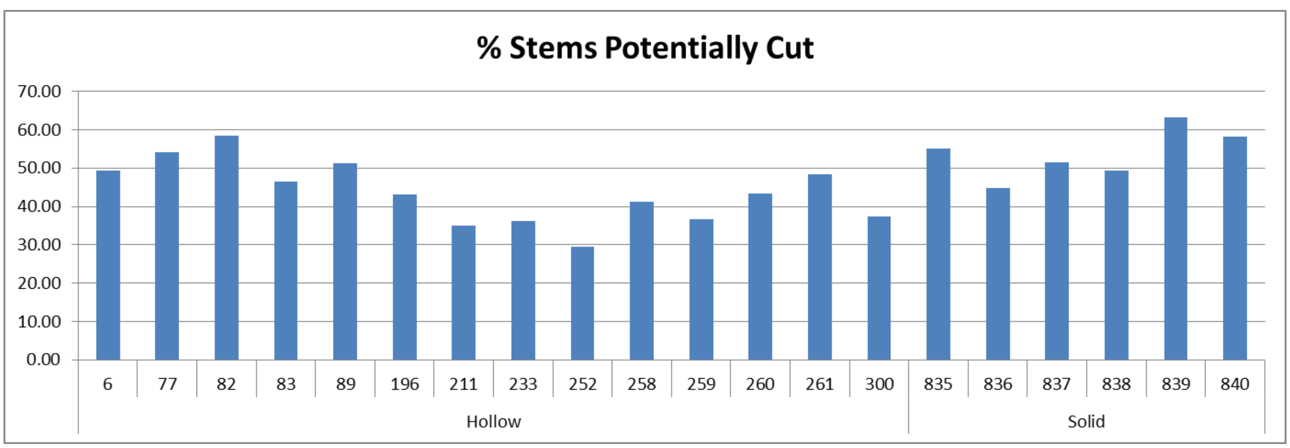


However, stem cutting was quite limited and only exceeded 10% in 3 lines. This was readily explained by very abundant parasitoids.

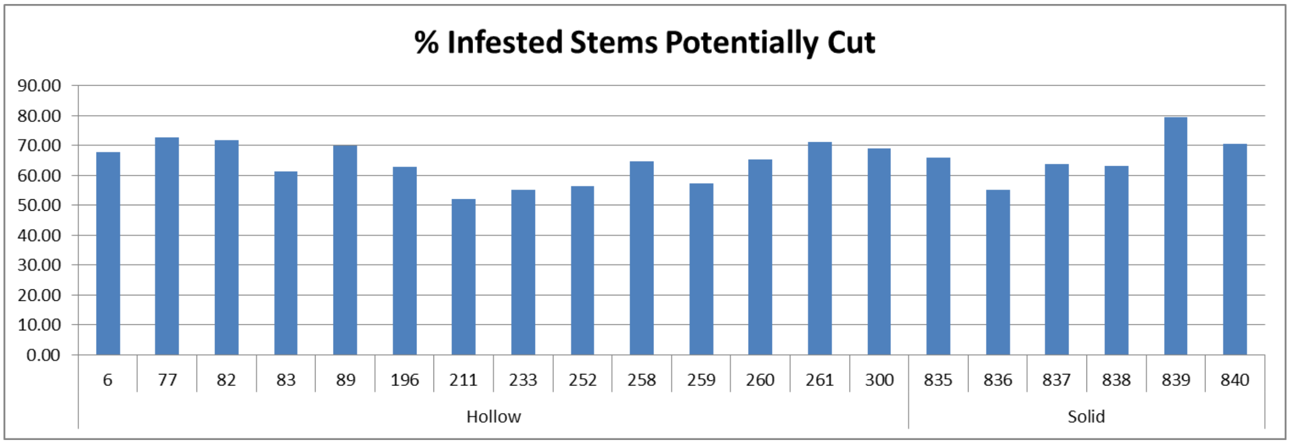




However, looking at stems potentially cut, we see that several lines have less than 40% cutting. This parameter includes sawfly choice as well as mortality, but is corrected for parasitoid caused mortality.



Removing the sawfly choice and only looking at mortality in infested stems and excluding the effect of parasitoids also showed variation in infested stems potentially cut. This parameter varied between 52 – 79% with line 211, 233 and 836 performing best. It is surprising that only one solid stemmed line caused mortality that matched the two best hollow stemmed lines.



Overall, it is evident that there is useful variation among these selected lines. Two surprising findings were the very high infestation of solid-stemmed winter wheat and the unexpectedly high level of parasitism in winter wheat overall. Given that the hill plot nurseries failed, this data set once again indicates that the potential to look at other mechanisms of host plant resistance in winter wheat is viable, but further research must be conducted..

Objective 4. This objective is based on the planting of hill plots of breeding populations that are typically near-isogenic or recombinant inbred lines and using near-isogenic lines in greenhouse cage trials. As mentioned previously, the nursery at Amsterdam was hailed out. However, we planted and harvested 7 different breeding populations totaling 783 hills at Loma. The samples were collected and dissection is not complete.

Greenhouse cage trials focused on oviposition behavior associated with quantitative trait loci located on chromosome 2D, 3B and 4A. Overall, near-isogenic lines varying for three genes that seem to influence sawfly behavior were studied. Lines that varied for only a single gene were paired to determine how they might influence whether or not a female deposited an egg. The results suggest that the genes interact at different levels in the suite of behaviors leading to deposition of eggs. This study will need to be replicated. The lines were planted as hill plots at Loma, so there will be field validation for the greenhouse results when stem dissection is completed.

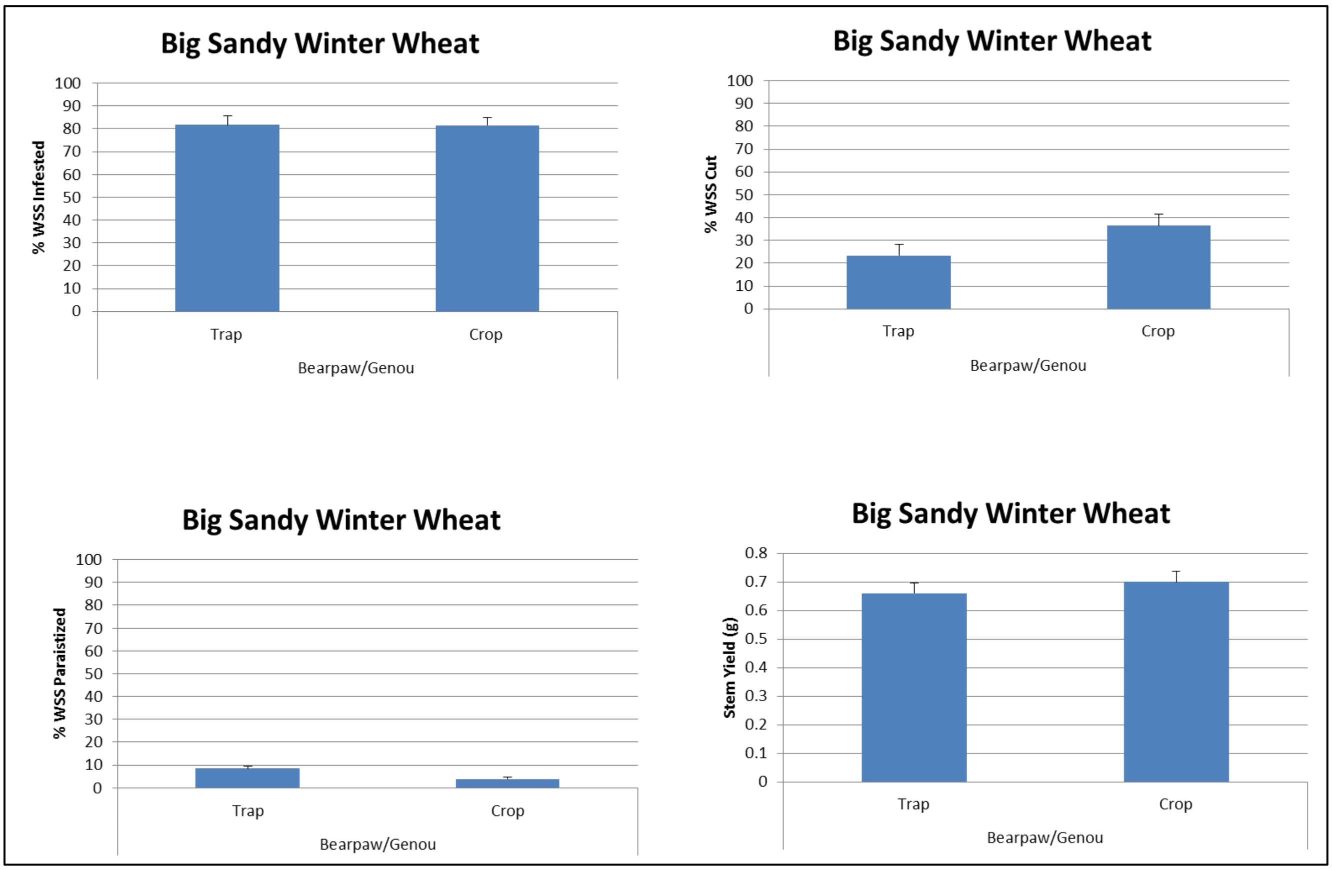
Objective 5. A graduate student who expressed interest in this topic decided not to come to MSU, so another will be recruited. Since stem cutting in barley is increasing, we collected 156 one foot row samples covering 16 varieties or lines in development in two nurseries planted by WTARC personnel. The stem dissection of these is not completed, but the intention is to have this data as preliminary information for the graduate student. Overall, the key goal is to determine if barley is still a viable replacement for winter or spring wheat when wheat stem sawfly populations are large. The data obtained should address this and identify which varieties are most suited for this purpose for growers.

Objective 6. The orange wheat blossom midge has definitely established and increased in the Triangle area, now occurring in the area centered by Valier and spanning three counties. This represents a new challenge for growers who already have wheat stem sawfly problems. The spring wheat breeding program has developed lines with the antibiotic *Sm*1 gene that causes mortality in the midge larvae and one of these is being released this year. The concern is that lines with no midge resistance will get sprayed, which will kill sawfly parasitoids. Lines with midge resistance may not have any resistance to wheat stem sawfly, but several of the lines in development have fairly good stem solidness. So we collected samples from this nursery and dissected these for presence and status of WSS larvae, and we also counted midge exuviae in the heads of the wheat. It was difficult to obtain samples with heads in some plots due to deer or antelope damage. The study was frustrating because the infestation was limited. The plot map below shows how many stems were processed and the level of wheat stem sawfly infestation. The yellow highlight shows the number of stems that were dissected for each plot, while the pale blue-grey highlight shows the number of wheat stem sawflies found. The number of midge found ranged from 0 for lines with *Sm*1 resistance to more than 80 for susceptible checks 'Choteau' and 'Solano'.

105 CAP 34-1(90%)/CHOTEAU(10%) *# Stems: 148* *#WSS: 0* *# Midge: 16*	110 CHOTEAU *# Stems: 135* *#WSS: 0* *# Midge: 84*	205 CHOTEAU *# Stems: 118* *#WSS: 0* *# Midge: 30*	210 CAP 197-3 *# Stems: 80* *#WSS: 0* *# Midge: -*	305 CAP 219-3 *# Stems: 110* *#WSS: 0* *# Midge: 4*	310 CAP 400-1(90%)/SOLANO(10%) *# Stems: 137* *#WSS: 0* *# Midge: 26*
104 CAP 34-1 *# Stems:161* *#WSS: 0* *# Midge: 4*	109 CAP 400-1 *# Stems: 116* *#WSS: 0* *# Midge: 0*	204 CAP 219-3 *# Stems: 120* *#WSS: 2* *# Midge: 0*	209 CAP 400-1(90%)/SOLANO(10%) *# Stems: 103* *#WSS: 0* *# Midge: 0*	304 CAP 400-1(90%)/CHOTEAU(10%) *# Stems: 148* *#WSS: 0* *# Midge: 9*	309 CAP 34-1(90%)/CHOTEAU(10%) *# Stems: 121* *#WSS: 1* *# Midge: 40*
103 CAP 400-1(90%)/CHOTEAU(10%) *# Stems: 161* *#WSS: 1* *# Midge: 0*	108 CAP 400-1(90%)/SOLANO(10%) *# Stems: 103* *#WSS: 1* *# Midge: 0*	203 CAP 34-1(90%)/CHOTEAU(10%) *# Stems: 125* *#WSS: 1* *# Midge: 11*	208 CAP 34-1 *# Stems: 123* *#WSS: 0* *# Midge: 1*	303 CAP 34-1(90%)/SOLANO(10%) *# Stems: 149* *#WSS: 3* *# Midge: 9*	308 CHOTEAU *# Stems: 147* *#WSS: 0* *# Midge: 68*
102 SOLANO *# Stems: 94* *#WSS: 0* *# Midge: 79*	107 CAP 34-1(90%)/SOLANO(10%) *# Stems: 152* *#WSS: 0* *# Midge: 0*	202 SOLANO *# Setms: 76* *#WSS: 0* *# Midge: 57*	207 CAP 400-1(90%)/CHOTEAU(10%) *# Stems: 131* *#WSS: 2* *# Midge: 0*	302 CAP 197-3 *# Stems: 135* *#WSS: 0* *# Midge: -*	307 SOLANO *# Stems: 132* *#WSS: 0* *# Midge: 86*
101 CAP 197-3 *# Stems: 109* *#WSS: 1* *# Midge: -*	106 CAP 219-3 *# Stems 152* *#WSS: 1* *# Midge: 0*	201 CAP 400-1 *# Stems: 96* *#WSS: 4* *# Midge: 0*	206 CAP 34-1(90%)/SOLANO(10%) *# Stems: 93* *#WSS: 0* *# Midge: 0*	301 CAP 400-1 *# Stems: 128* *#WSS: 2* *# Midge: 0*	306 CAP 34-1 *# Stems: 119* *#WSS: 0* *# Midge: 1*

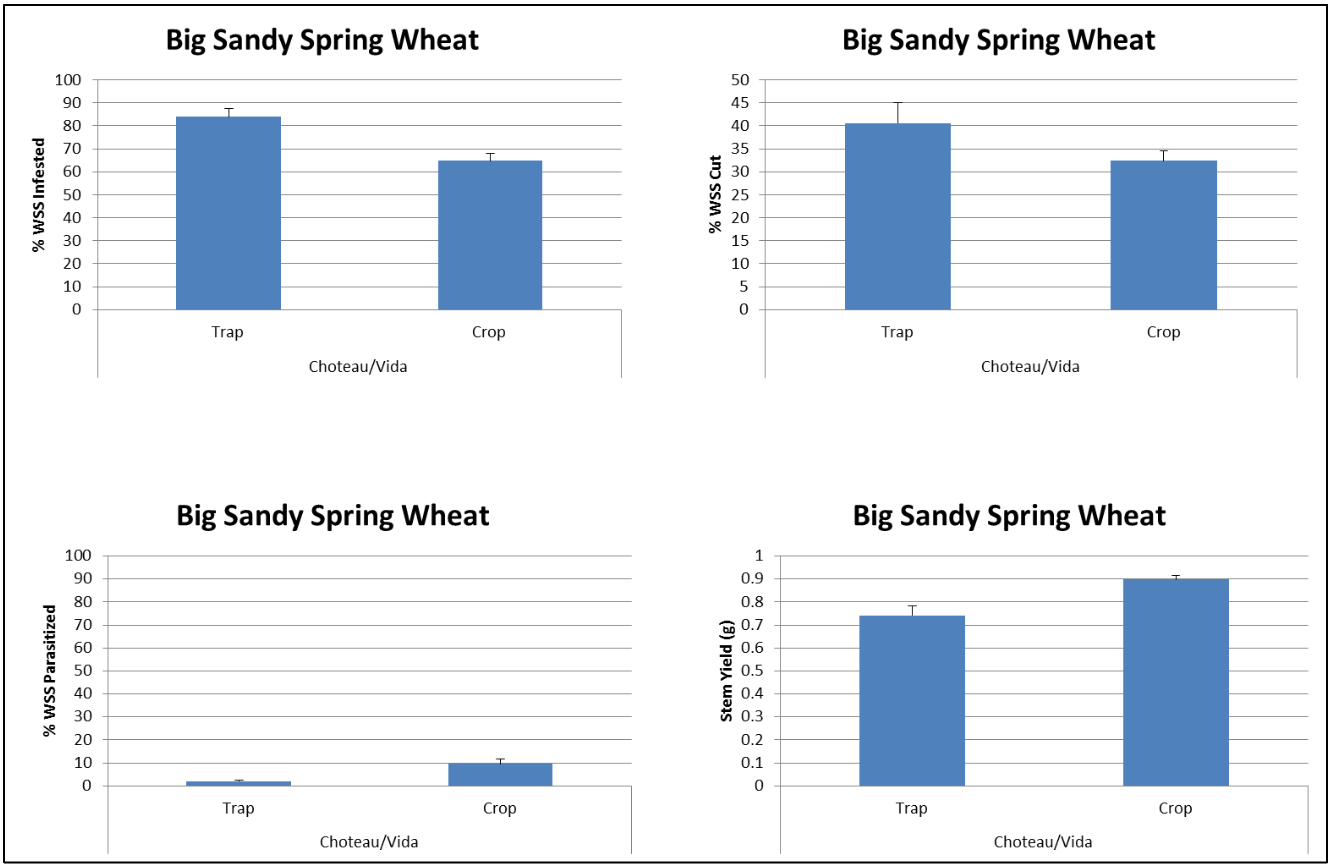
In all, 3722 stems were dissected and there were only 19 sawflies along with 525 midge exuviae. This nursery will need to be planted again in a location where there is greater sawfly pressure.

Objective 7. We evaluated three grower planted trap crops this year. Two of these used two seeder passes of solid stem ‘Choteau’ around unattractive ‘Vida’. These were planted by the growers without a request and a third grower planted an experiment with very solid stemmed ‘Bearpaw’ around less solid-stemmed ‘Genou’ winter wheat. There are differences in preference between these two varieties but Genou is still relatively attractive. The results for the winter wheat trap experiment showed no success, but the spring wheat did. The following charts are for infestation, cutting, parasitism and yield per stem for each trap.



Unfortunately, the Bearpaw and Genou combination did not work very well. There was heavy pressure from a large population and infestation in both the trap and the crop were over 80%. Because both the trap and the crop were solid-stemmed, a lot of larvae died before they could cut the stem and the lower cutting (upper right) in Bearpaw is due to stem solidness, with little contribution from parasitoids (lower left). The yield of both the trap and crop were impacted by the pest pressure. Note that when infestation levels are this high stems on the outer edge of the field are often multiply infested, which can really lower yield.

In contrast a spring wheat trap that was nearby performed better despite being under heavy pressure from a similarly large population of sawflies. The trap was significantly more infested than the Vida crop, which resulted in less cutting in the crop, which also had a bit more parasitism. This is most obvious because the yield in the crop is higher.

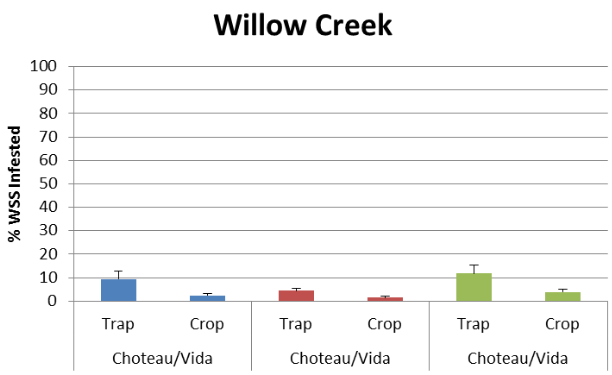


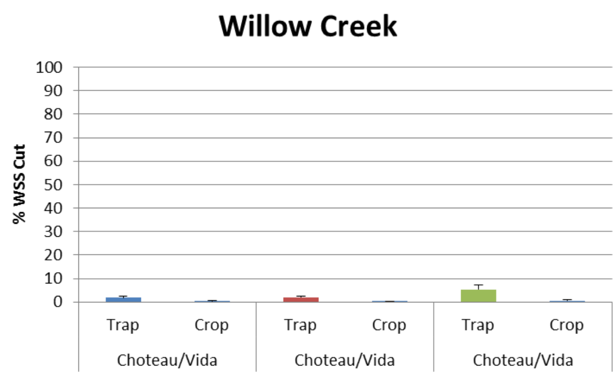
The third site is one where the growers have been using trap crops around multiple fields for several years. The most obvious point is that infestation is less than 15% for each of the three fields and cutting is less than 7% in all three. In part this is because the parasitoid activity was significant, even on such a low number of sawflies. The yield of both trap and crop are unaffected by wheat stem sawfly, although they did vary by field.

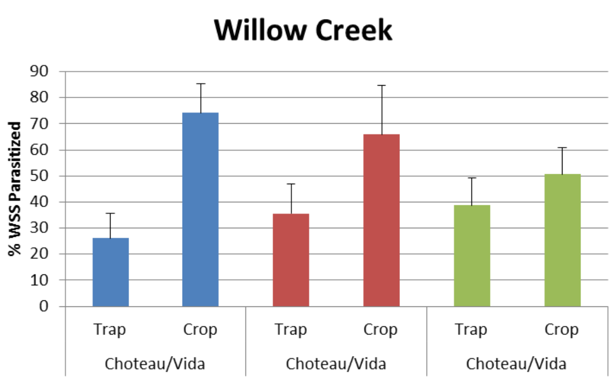
Below the charts for the three fields for 2013, we can see the cumulative effect of repeated trap cropping since 2011. The initially heavy infestations were very effectively trapped resulting in fewer multiply-infested stems and ultimately in more parasitoids.

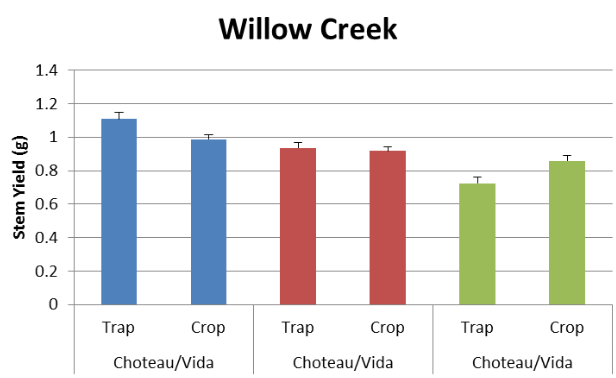
This shows something that we have seen at two other locations, traps for multiple years really have an effect on the size of the ambient sawfly populations.

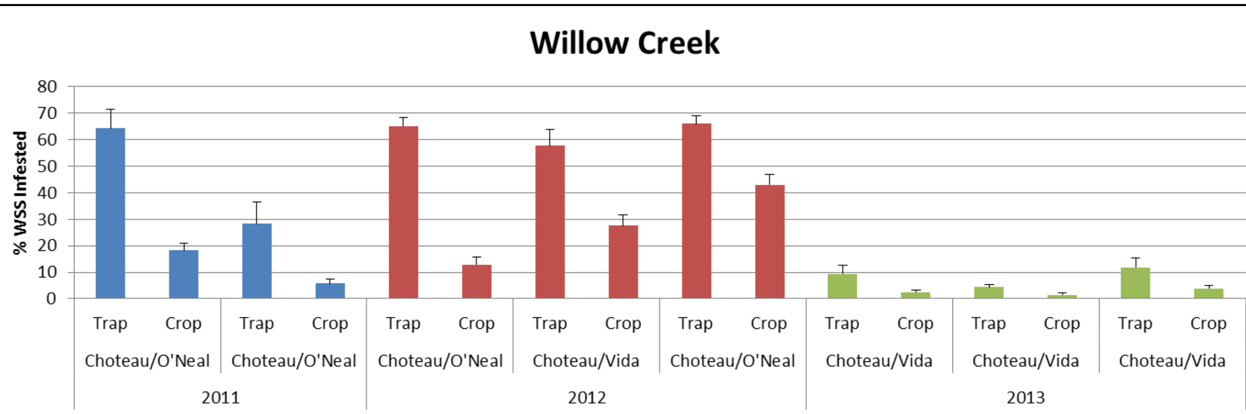
The data for 2013 are just below, while the three charts below that are for multiple years.

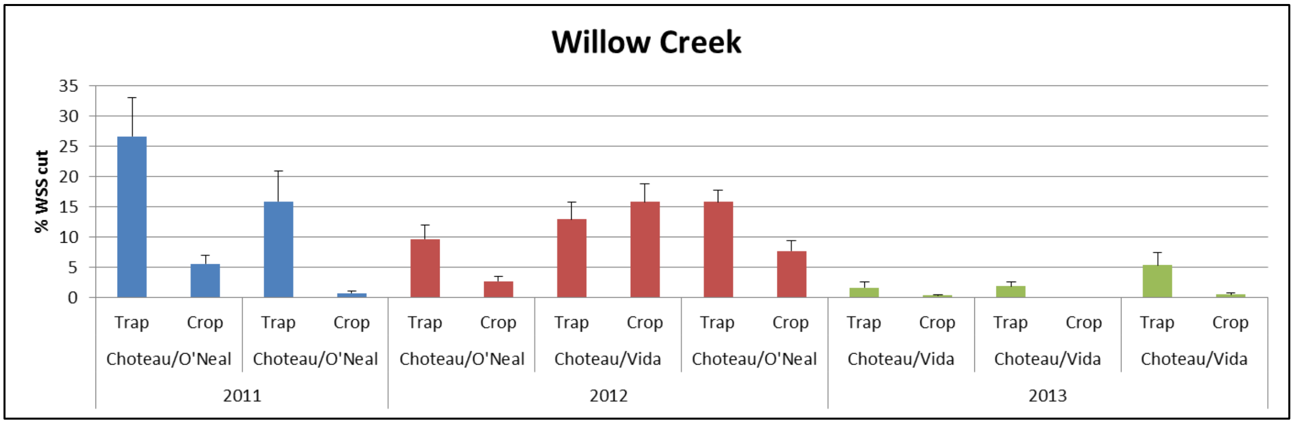


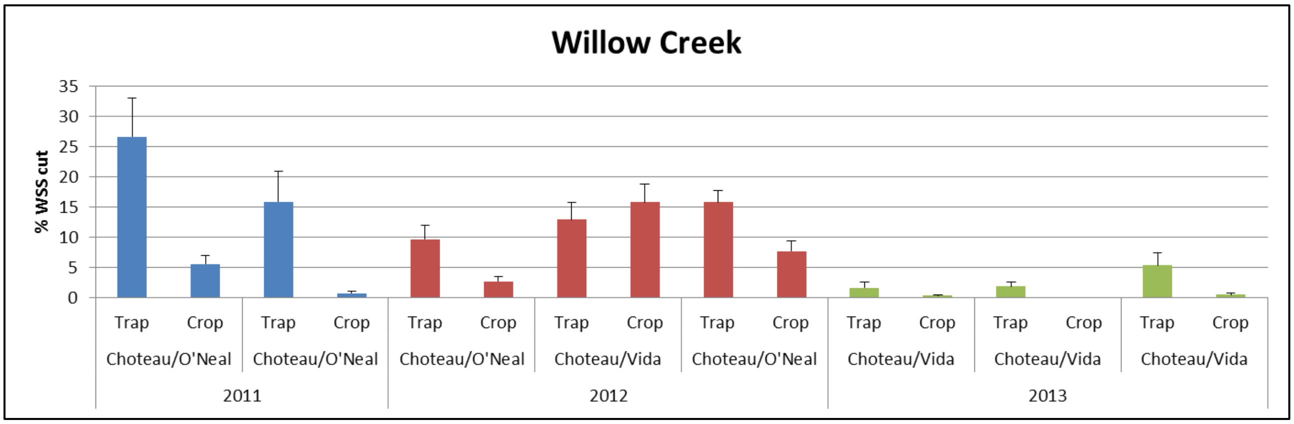










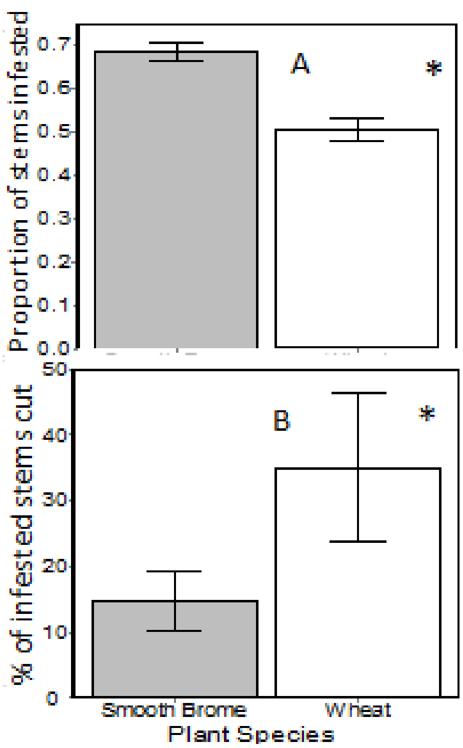


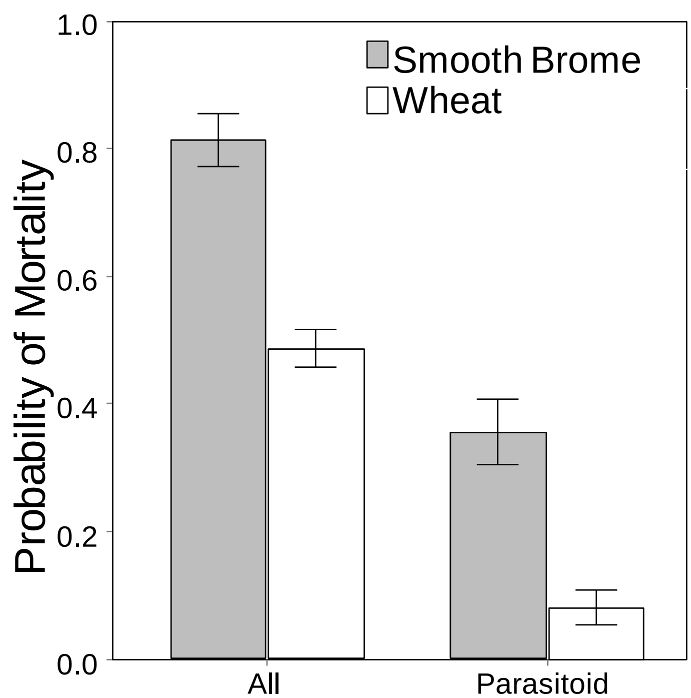
Objective 8. In a preliminary effort with A. Bekkerman from the Department of Agricultural Economics and Economics using 2012 data, we have explored the potential benefit of trap cropping and obtained additional data as part of a larger effort he is leading on economic losses due to wheat stem sawfly.

	Foregone Revenues Relative to No Infestation *(Whole Field)*	**Foregone Revenues Relative to No Infestation** *(Portion Past Trap Crop Edge)*
Trap Crop	$19,079	$0
No Trap: 60% infestation at edge, 0% at center	$26,170	$21,540
No Trap: 75% infestation at edge, 25% at center	$29,665	$22,664
No Trap: 80% infestation at edge, 50% at center	$34,554	$27,456

The Table above shows the savings obtained per 640 acre section at three levels of infestation comparing what would happen with and without a trap of two seeder passes of Choteau around Vida. For each the scenario you save a greater amount per field with the majority of the savings coming from the increased yield of the crop relative to the decreased yield of the trap, which is due to greatly increased sawfly feeding pressure.

Objective 9. A focus has been on the potential of smooth brome to function as trap for wheat stem sawflies on the boundary of a field. It also has the ability to serve as a reservoir for parasitoids. In order to better quantify this, we looked at infestation, survival and parasitism of wheat stem sawflies in smooth brome and adjacent wheat. Infestation in smooth brome was greater than in wheat. Stem cutting was less in smooth brome than in adjacent wheat because many larvae die in smooth brome later in the year. Surviving late season larvae that are parasitized yields a much greater probability of parasitism-caused mortality in smooth brome relative to wheat. Fertilizing naturally-occurring smooth brome on the field perimeter with nitrogen at 100 pounds per acre increases the number of non-reproductive stems, which are infested at the same rate as before fertilization. Although the proportion of infested stems does not change the number of dead sawflies per unit area increases by about 10%.





We also are interested in cover crops which may play a role in WSS management. In collaboration with Darrin Boss at NARC, we included oats as a portion of the seeded blend and then assessed which mixture of seed was most effective. The mixtures assessed were all cool season, early planted with the same proportion of oat seed.

There were three mixtures that included legumes and one mixture that included a greater proportion of other flowering crops relative to flowering legumes. Surprisingly infestation of the oats in the more diverse mixture was about double that for any legume centered combination. The finding that greater diversity of flowering, non-grass plants actually increased utilization of oats by the pest sawflies is unexpected, but valuable since they all die. The added benefit of potential increased parasitism in adjacent wheat due to the supply of nectar in the flowering plants will be assessed by looking at parasitoid numbers in overwintered wheat stubble that can then be dissected in the laboratory in the spring it is likely that parasitoid success will be increased. The mixtures were:

Cool Season Legume #1 - Diakon radish, Purple Top turnip, Columbian pea, Hairy vetch, Rockford oat

Cool Season Legume #2 - Diakon radish, Purple Top Turnip, Hairy vetch, Yellow Blossom clover, Rockford oat

Cool Season Legume #3 - Diakon radish, Purple Top turnip, Hairy vetch, Columbian pea, Essex lentil, 1601 safflower, Rockford oat

Cool Season Diversity - Diakon radish, Purple Top turnip, Columbian pea, Hairy vetch, Yellow Blossom clover, 1601 safflower, Accelerleron canola , Selby flax, Rockford oat

Objective 10. This objective was conducted entirely by WTARC personnel led by Gadi Reddy. The fog treatments of nematodes, fungi and low-impact insecticides listed below were sprayed on elongating ‘Yellowstone’ winter wheat at two locations. This was a preliminary study to determine potential for wheat stem sawfly management.

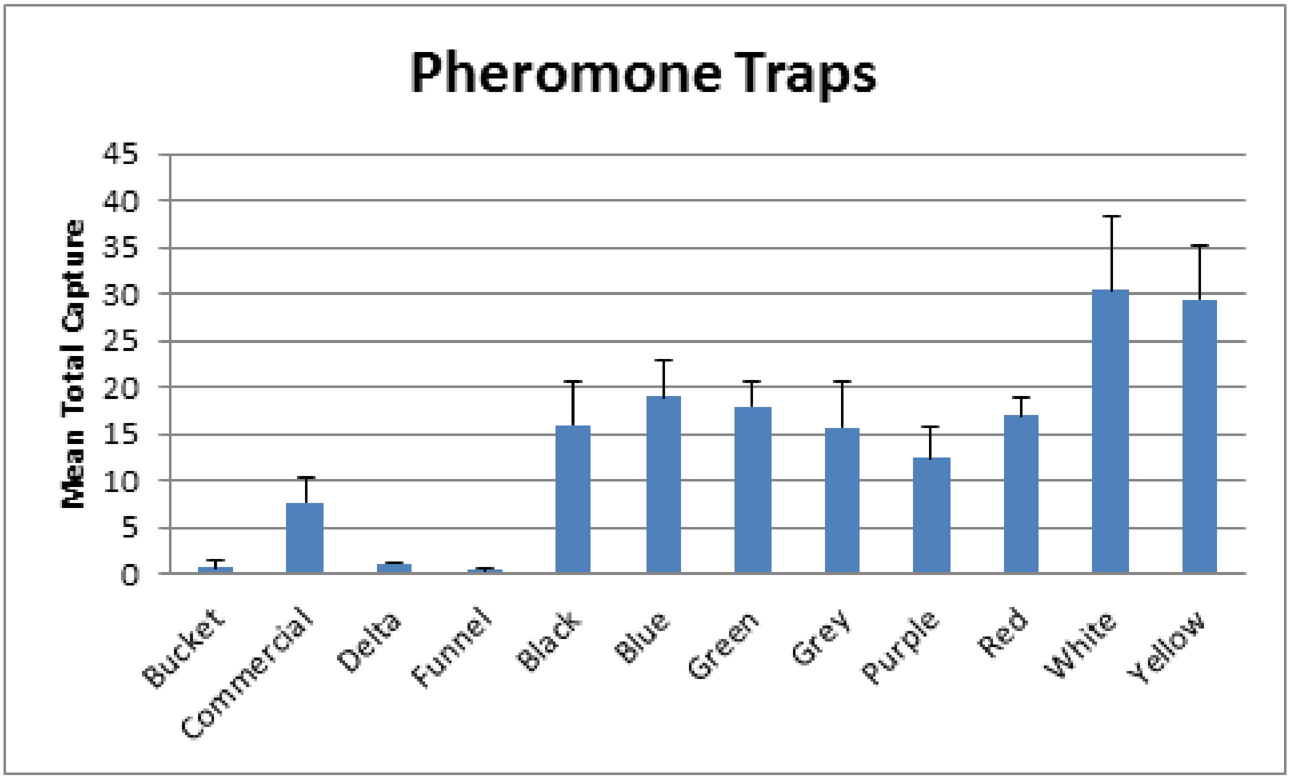
The plot areas were 32 square meters with approximately 142 plants per square meter based on one foot row spacing. The materials were applied using a hand sprayer. Stem cutting before harvest and larval survival in stubble was assessed. Yield was also measured at harvest

All treatments significantly reduced stem cutting and larval survival in stubs relative to the two controls. In addition, a yield increase was seen for all treatments relative to the controls. The reduction in sawfly survival and the increase in yield did not differ between the treatments. However, the impact of the treatments on survival varied as a function of the duration of exposure after spraying.

Treatment	Active Ingredient	Dose	Source
T1: Control	No treatment	-	-
T2: Water spray	-	-	-
T3: Mycotrol® 22WP	*Beauveria bassiana* strain	2.4 g / l (water)	Laverlam International Corporation, Butte, MT
T4: Met 52G	*Metarhizium brunneum* strain F52	5 g / liter	Novozymes, Davis, CA
T5: Millenium®	*Steinernema carpocapsae*	1 ml / 13 liters	Becker Underwood, Ames, Iowa 50010
T6: Nemasys® L	*Steinernema kraussei*	1 ml / 13 liters	Becker Underwood, Ames, Iowa 50010
T7: Nemasys®	*Steinernema feltiae*	1 ml / 13 liters	Becker Underwood, Ames, Iowa 50010
T8: Nemasys® G	*Heterorhabditis bacteriophora*	1 ml / 13 liters	Becker Underwood, Ames, Iowa 50010
T9: Growth Hormone (Dimilin)	Benzoylurea-type insecticide of the benzamide class	0.5 g / liter	Chemtura Company, Middlebury, CT
T10: Neem (Aza-Direct)	Azadirachtin 1.2%	5 ml / liter	Gowan Company, Yuma, AZ

These diverse products are known for efficacy against a variety of pests in greenhouses, high value crops, orchards and stored commodities. This is the first test of these for activity against wheat stem sawfly in the field. The findings are encouraging and the trials should be replicated in the summer of 2014.

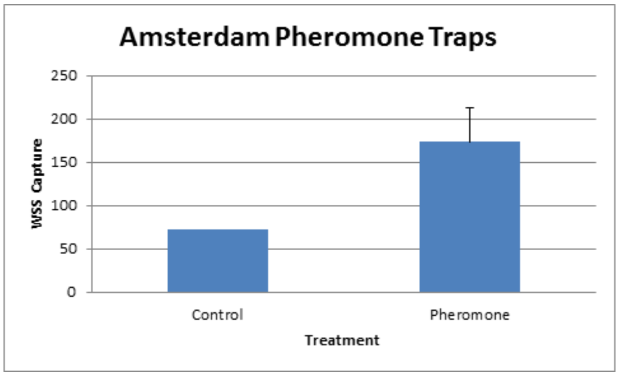
Objective 11. The role of prototype pheromone trap color was assessed in collaboration with Gadi Reddy at WTARC near Conrad. Trap components were manufactured in the Bozeman laboratory and sent to WTARC for assembly along with the 9-acetyloxynonanal lures that are attractive to wheat stem sawflies. These were placed along crop fallow interfaces at several sites. There was heavy precipitation in the area at the time the wheat stem sawfly flight began, so these traps were deployed as soon as conditions would allow. It appears that trap capture varies by color with the lighter colors of yellow and white performing best. The captures from a field near Conrad are shown below.

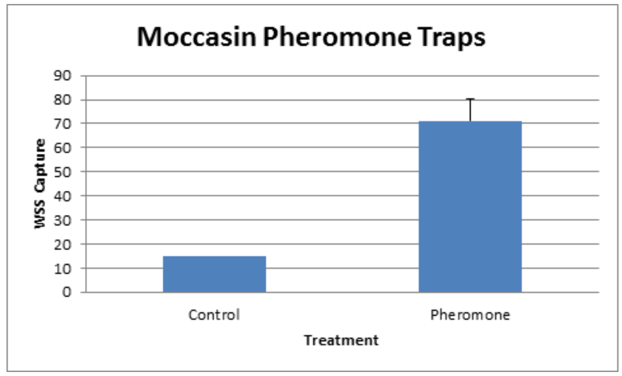


There were eight colors of the prototype trap tested. In addition, Reddy purchased four different trap configurations that are commercially available and placed these in a companion experiment further along the same crop interface. These were also baited with the 9-acetyoxynonanal pheromone lure. Only the larger commercial intercept trap designed for use for flies in feedlots and stables captured any significant number of adult sawflies and still only matched the capture of the purple prototype trap, which caught the least of any color tested. Thus, the prototype design is better, but it is also important to quantify that the commercially available traps are unsuitable for wheat stem sawfly monitoring.

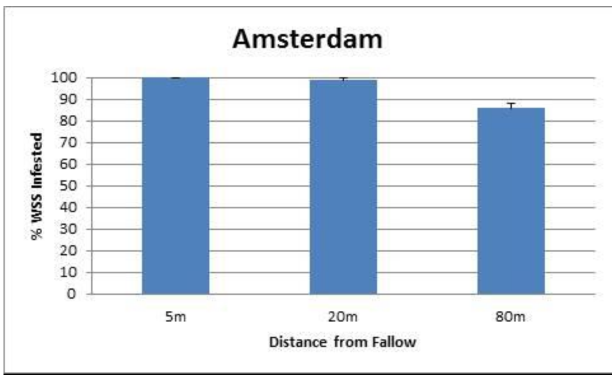
In addition we followed up on a large pheromone trap experiment that was conducted in spring wheat at seven locations in 2012. For 2013, we used yellow prototype traps (also used in 2012) in two winter wheat fields. One was located near Moccasin and the other near Amsterdam. We wanted to assess whether the traps would be equally suitable in winter wheat and more importantly, could we use the same predictive equation for both types of wheat. The crops are at very different stages in development at the time of wheat stem sawfly flight.

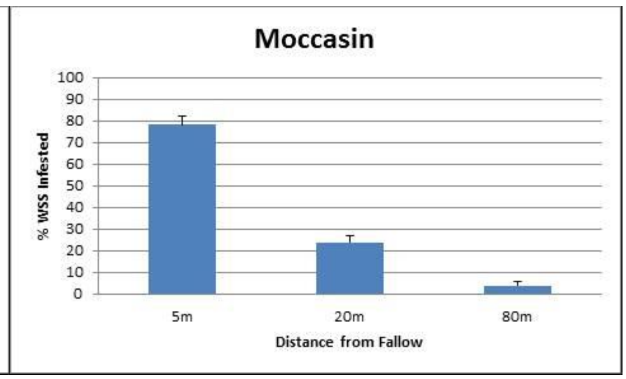
At both locations the traps baited with the pheromone lure captured more sawflies than the unbaited controls.



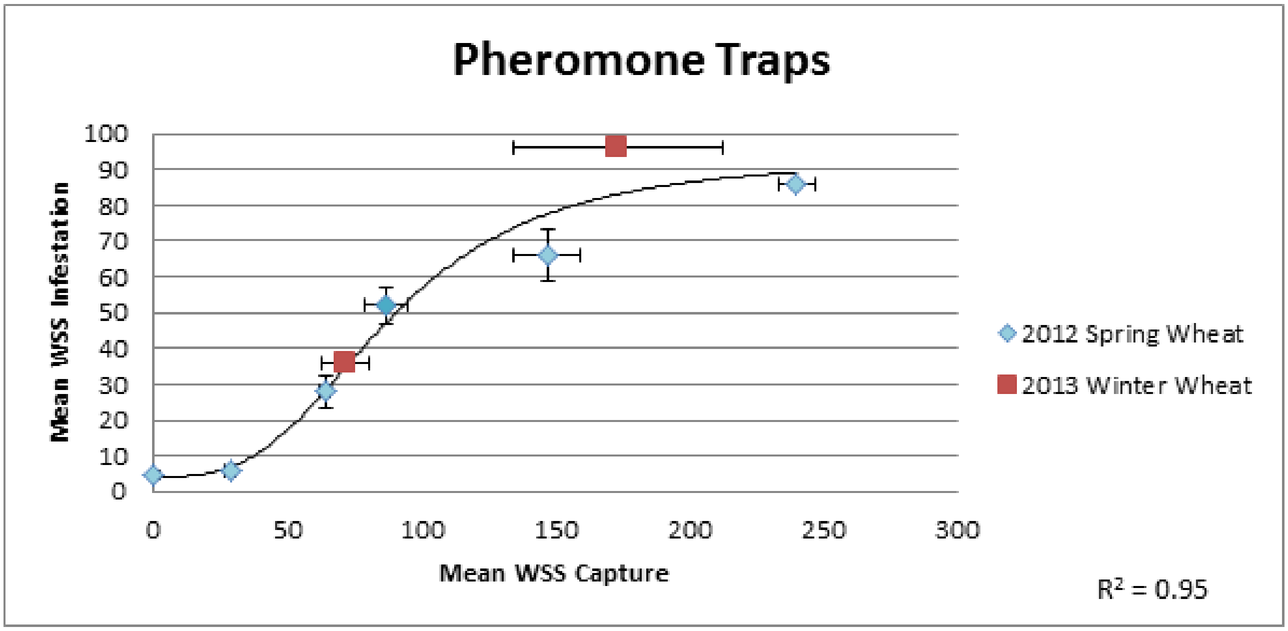


The capture of pheromone baited traps at Amsterdam was more than three times that at Moccasin. As per our 2012 study we used transects that ran 80 m into the field to approximate infestation over the area adjacent to each trap. As expected by trap capture the Amsterdam field was much more heavily infested with almost no decline in infestation at 80 m, while infestation at Moccasin approached zero at the same distance into the field.





Therefore, we had two very different winter wheat fields that we could incorporate into our fitted line that allows us to predict infestation as a function of trap catch. Once again the 2012 traps are in spring wheat fields and the 2013 traps are the two winter wheat fields described above. The result is a nicely fit line with its greatest variability coming when trap captures total 150 or more sawflies. The relationship is still very useful because captures above 150 would indicate a severe problem, while lower capture numbers are more reliable. This will be helpful in monitoring populations that are transitioning through intermediate levels of infestation because this is when a grower is most likely to change management strategies.



Summary:

There is no doubt that the wheat stem sawfly remains the number one insect pest of wheat in Montana, causing an estimated $80 million yield loss in 2012 (Bekkerman and Weaver, unpublished). Across these 11 objectives we are developing a comprehensive package of tools for wheat stem sawfly management. We have upgraded our techniques for isolating the compounds responsible for inducible host plant resistance in oats. This was necessary because some of the potential toxins are not produced in great abundance, so processing enough oat tissue to do bioassays was limiting for determining the activity of these likely toxins. We continue to collect an extensive amount of data targeting on new types of host plant resistance from multiple germplasm sources. We will continue to develop antixenosis in winter wheat. Information on barley varieties most suited as planting alternative when wheat stem sawfly populations increase. Successful trap crops continue to be planted by growers, with the exception of winter wheat .The effect of continued planting of trap crops over multiple years shows a large decline in wheat stem sawfly populations. Evaluation of fungal nematode and alternative mode of action insecticides yielded positive results in the first year of evaluation. Prototype pheromone traps suitable for monitoring wheat stem sawfly adult numbers have been tested for the most effective color and for applicability in winter wheat, which complements the utility in spring wheat. Most of our resources are devoted to discovering or characterizing new sources of host plant resistance from a variety of sources, which is a long term process. In the short term, completing the research on the utilization of pheromone traps for monitoring should

allow growers to make decisions regarding swathing, planting solid stem varieties and using trap crops.

<u>Funding Summary</u>:

Budget information will be provided by OSP. Over the years that this project has been funded, additional funds have come from a variety of federal, state and industry sources. Currently there is a matching USDA competitive grant that supports complementary efforts on a greatly expanded program to screen wheat landraces for other sources of host plant resistance (Luther Talbert is PI).

<u>MWBC FY2015 GRANT SUBMISSION PLANS</u>:

A revised project will be submitted - with modified objectives.

FY2014 MONTANA WHEAT AND BARLEY COMPLIANCE MIDYEAR REPORT

TITLE: Integrating multiple agronomic tactics for suppression of severe wheat stem sawfly infestations: Field-scale grower implementation (4W4608)

PRINCIPAL INVESTIGATOR**:** David Weaver, with Peggy Lamb, Perry Miller, Anton Bekkerman and Gadi Reddy

Initial Objectives:

1. Identify and characterize fields with heavy wheat stem sawfly infestations using postharvest fall sampling of crop residue and ensure that these fields are bordered on either side by land that was no-till fallowed and is destined for wheat planting in the coming spring.
2. Plant a small perimeter of smooth brome around these fields in the autumn (see the figure below for planting details and dimensions).
3. Plant a re-crop combination of peas with an outer oat perimeter in the severely infested field; the oat will be positioned within the smooth brome border that was planted in the fall.
4. Plant a conventional spring wheat trap crop consisting of a narrow border of attractive solid-stem spring wheat around an unattractive variety in the adjacent fallow fields already targeted for a spring wheat crop.
5. Quantify wheat stem sawfly infestation, stem cutting and levels of parasitism of WSS larvae in all four host (cereal and grass) crop areas.
6. Collect replicated harvest data using a plot combine in the pea, oat and two spring wheat varieties, and measure all standard quality parameters.
7. For each of three sites record all input and production costs, including annual and permanent trap planting, and then also obtain yield and sale value of the crops.
8. Conduct an initial economic assessment of net profits on the re-crop field and account for foregone revenues the adjacent spring wheat fields that would have occurred if infestation remained high.
9. Measure WSS infestation and cutting levels in bordering spring wheat fields at the 2015 harvest (a longer term objective made possible by this project).

Results:

A number of fields were explored for potential implementation of this project. After identifying potential grower cooperators for this project during 2013, we have hit roadblocks on confirmation in the past month. Issues with chemical carryover, rotations and qualifying for government payments have all been factors. Growers were reluctant to increase the grass borders on their fields because most are trying to optimize production area, so objective 2 has been dropped. We are hopeful to identify and contact additional growers by the end of January as their winter vacations and travel for meetings subsides.

Summary:

This project is viable, but coordination of planting the specific configuration has been a challenge for growers that were initially identified as cooperators. We are currently actively engaged in locating fields that might work from an earlier list of alternative cooperators.

Funding Summary:

Budget information will be provided by OSP. There are no matching or leveraged funds

MWBC FY2015 GRANT SUBMISSION PLANS:

No resubmission is planned. This was a one-time special request.

FY2014 MONTANA WHEAT AND BARLEY COMPLIANCE MIDYEAR REPORT

TITLE: Parasitoids of the Wheat Stem Sawfly: Augmentation, Impact and Education (4W4616)

PRINCIPAL INVESTIGATOR**:** David Weaver, with Gadi Reddy

Objectives:

1. Establish 15 parasitoid release sites throughout Montana to further continue the process of translating parasitoid redistribution and conservation to Montana wheat growers with assistance from County Extension offices

2. Target 5 County Extension Personnel Release sites from 2009 for collection of populations of braconid parasitoids to determine overall abundance, species composition and genetic variation (in cooperation with USDA-ARS NPARL in Sidney)

3. Develop pheromone traps for monitoring the presence and abundance of the two braconid parasitoid species

4. To develop demonstration parasitoid and wheat stem sawfly training modules for presentation at High Schools in three counties

Results:

Objective 1. Fourteen parasitoid releases were made in 2013. We do not yet have records for all counties, but parasitoids were delivered and released. This continues to be a popular and well recognized effort. There were several vacancies or new hires of County Extension personnel.

County	Grower	GPS	Crop	Cultural Method
Phillips	Mavencamp	N 48° 40.554' W 107° 76.524'	Winter Wheat	Chem Fallow
Liberty	Ferderickson	N 48° 38.348' W 111° 13.979'	Winter Wheat	Chem Fallow
Valley	Pattison	N 48° 46.825' W 106° 22.718'	Spring Wheat	Tilled
Hill	Kaercher	N 48° 32.374' W 109° 56.257'	Winter Wheat	Chem Fallow
Pondera	Banka	N 48° 01.799' W 111° 35.465'	Winter Wheat	Chem Fallow
McCone	Schillinger	N 47° 44.353' W 105° 35.979'	Spring Wheat	Chem Fallow
Fergus	Weinheimer	N 47° 00.750' W 109° 28.733'	Winter Wheat	Chem Fallow

Toole	Steinbacher	N 48° 30.647' W 110° 21.088'	Winter Wheat	Chem Fallow
Custer	Ballinsky	N 46° 18.571' W 106° 03.360'	Spring Wheat	Chem Fallow
Chouteau	Arganbright	N 47° 48.027' W 110° 57.034'	Winter Wheat	Chem Fallow
Gallatin	Flikkema	N 45° 46.365' W 111° 23.433'	Winter Wheat	Tilled
Cascade	*	*	*	*
Glacier	*	*	*	*
Garfield	*	*	*	*

Objective 2. Wheat residue was collected in spring 2013 from fields that received parasitoids in 2006, 2008 or 2009. The release years vary because we wanted the sites to have received parasitoids no sooner than 2009 and we also wanted sites that were quite well separated, if possible. In addition, we collected two remote control sites in MT, another in WY, as well as the location for the source population for all those releases which were made. At each site, approximately 75 feet of residue from randomly-selected rows were collected. The material was held in cold storage until July. At that time the residue material was placed in emergence barrels at room temperature and parasitoids were collected daily until no more individuals emerged. Collected parasitoids were identified and sexed while they were still alive. They were then placed in 95% ethanol for shipment to USDA-ARS in Sidney, MT for genetic analysis.

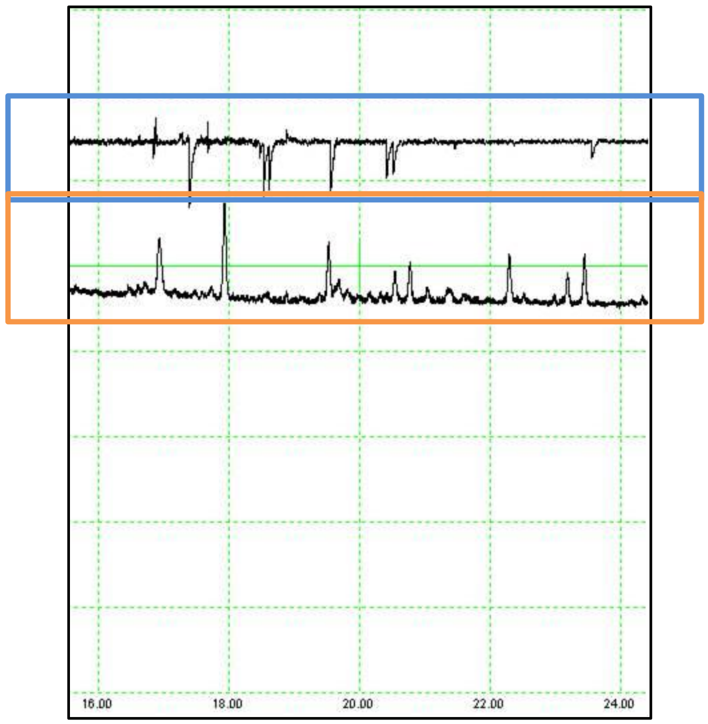
Locations and year where parasitoid residue was obtained in spring 2013.

- Judith Basin 2009: 47° 08.506’, 109° 53.626’
- Garfield County 2009: 47° 07.553’, 106° 34.721’
- McCone 2008: 47° 26.157’, 105° 37.785’
- McCone 2009: 47° 37.302’, 105° 40.402’
- Valley 2006: 48° 04.487’, 106° 10.608’
- Valley 2009: 48° 39.500’, 106° 20.118’
- Gallatin County 2008: 45° 45.018’, 111° 25.089
- Petroleum County Control: 46° 57.275’, 108° 21.175’
- Blaine County Control: 47° 52.951’, 108° 45.825’

- Torrington, WY Control: 42° 00.126’, 104° 12.212’

- Pondera County Source: 48° 04.974’, 112° 03.844’

Objective 3. We have continued progress on the pheromone system of the two congeneric parasitoids that are specialists on wheat stem sawfly larvae, *Bracon cephi* and *B. lissogaster*. Groups of male or female *B. cephi or B. lissogaster* are placed in VCS tubes and purified air is passed over them for 48 hours. The sample is then eluted and injected into a gas chromatograph that is synchronized with a recording electrode attached to the insect antenna.

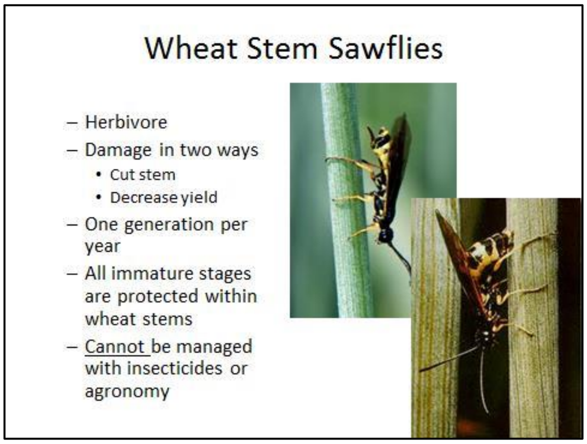


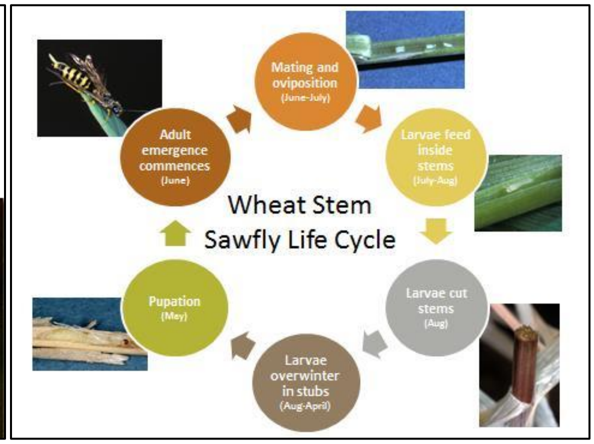
In the recording above the spikes that go down from the baseline (blue box) are the firing of insect receptors in response to compounds that are shown as peaks in the trace from the gas chromatograph output (gold box). Since these are synchronized, this indicates that the antennal receptors are firing at points where there is basically no discernible peak, although one might be an aldehyde. Attempts to concentrate these using pooled aerations results in increased background noise, so we cannot better resolve the peaks.

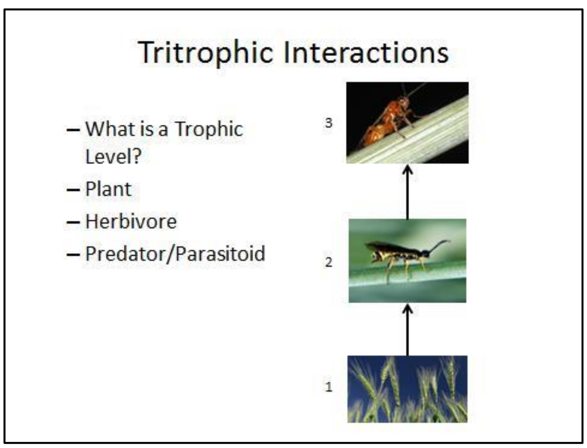
To address this we will have to use solvent extractions of the insects and then use purification chromatography to get peaks that will provide material sufficient enough for purification and identification. We are doing this now.

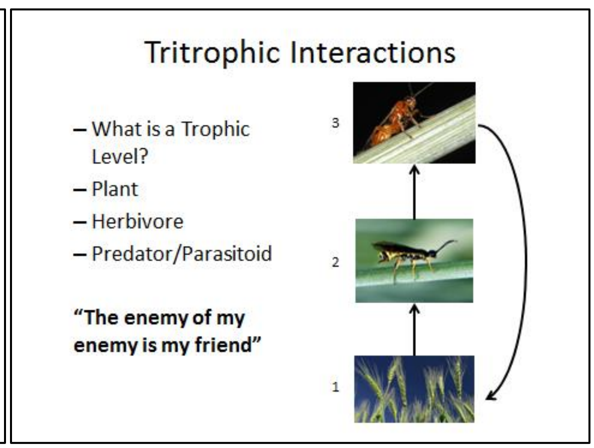
Objective 4. We prepared a demonstration package where brought in collected wheat residue and laboratory dissecting tools to high school biology and vocational agriculture students at Conrad and Sunburst High Schools. The teachers we coordinated with were Ula Omdahl in Sunburst and Steve Lockyer in Conrad. We visited Sunburst on the morning and we then visited Conrad in the afternoon. Megan Hofland and Ryan Bixenmann of the Wheat Stem Sawfly Laboratory at MSU participated along with the PI on this grant. Our goals were: 1) to have a combination of background information on wheat stem sawfly and the benefits of its parasitoids to Montana wheat production; 2) hands-on laboratory sample processing.

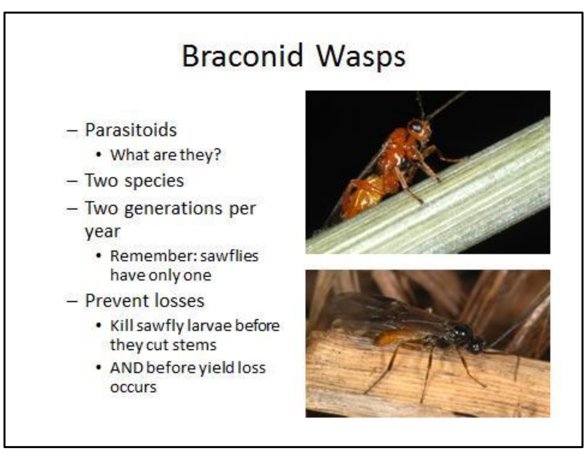
This is the background information:

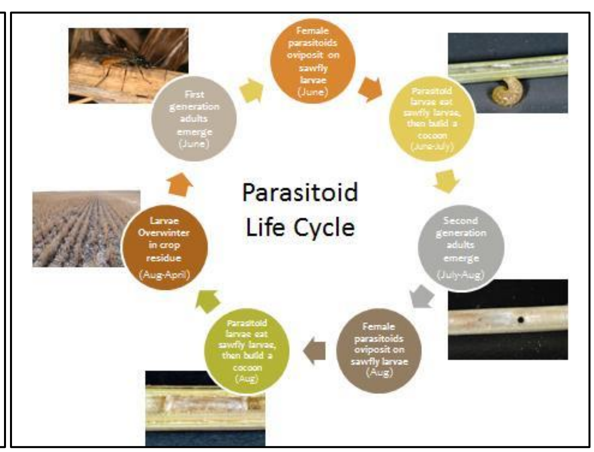


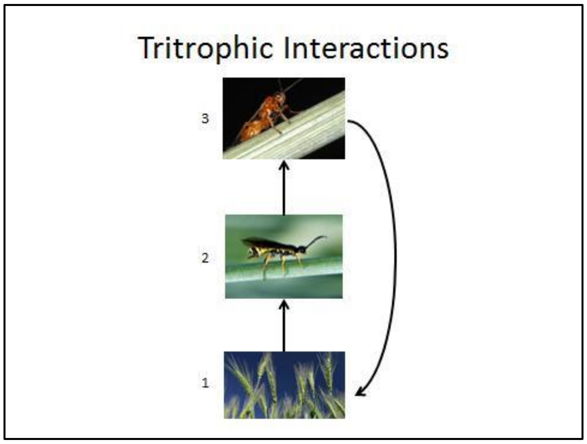


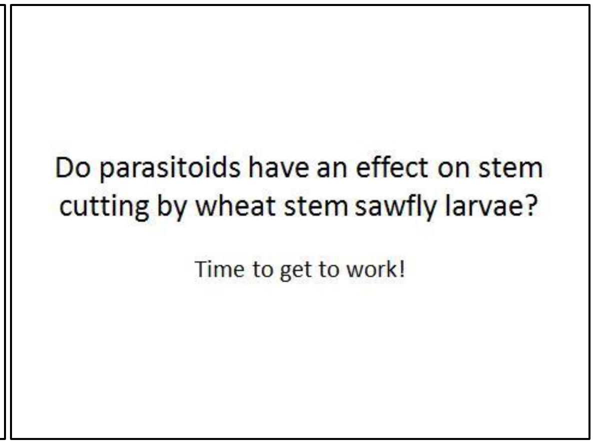


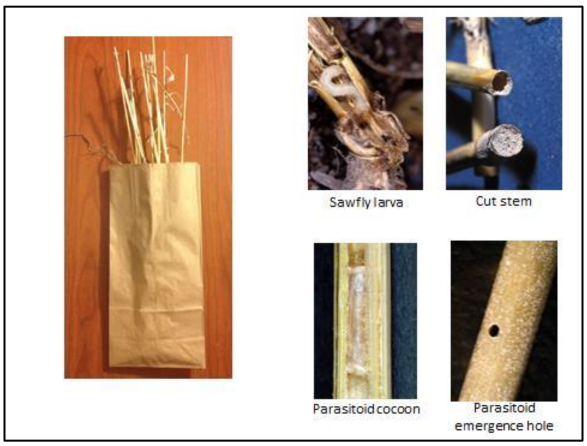






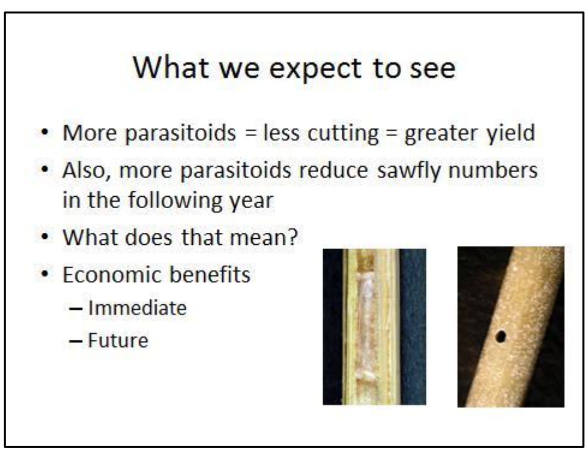


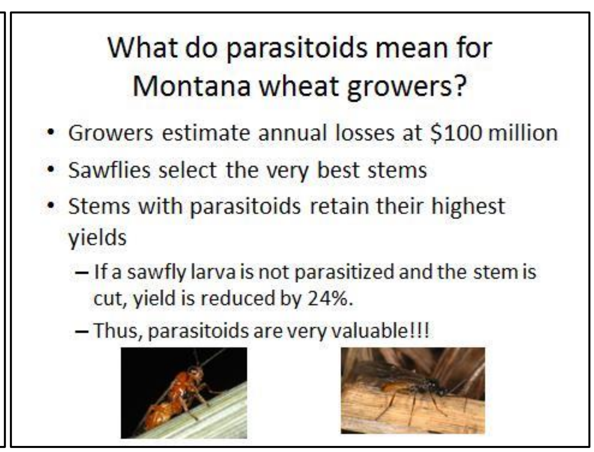




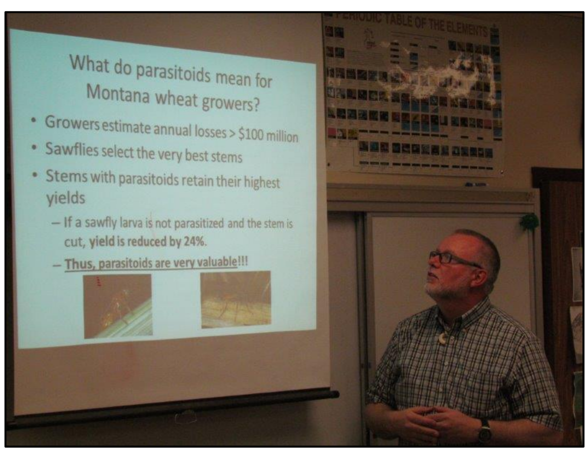
Here, we would have the students working alone or in pairs. They would dissect the stems, just as we would for collecting data in our laboratory. Next they would record the numbers of dead, parasitized or living sawfies (in overwintering stubs) they counted.

Next, we evaluated the numbers and explained the value of the parasitoids:





This was enjoable. In Conrad we were joined by Gadi Reddy and other WTARC personnel, as well Dan Picard, MSU – Extension. Dan took a few pictures.



This presentation was well received and we received correspondence expressing appreciation from both teachers and students. The intention of this was to make the students more aware of wheat production and the very interesting biology of the insects involved. It appears that this has lasting value because it was entirely new to most of the students and memorable because it was unique.

Summary:

Continuing to work on parasitoid redistribution seems desirable and continuously engages MSU Extension personnel in local County offices. Collection of parasitoid s from redistribution points has been completed and genetic assessment of the impact of the redistributions will be highly informative. The identification of the parasitoid pheromone is progressing, but is quite challenging. Efforts are ongoing to collect more of the biologically active compounds. Outreach and marketing knowledge of the important biology (pest and beneficial insects in this case) that is happening in wheat fields helps to fill a void, which is the connection of students to food production and its challenges.

Funding Summary:

Budget information will be provided by OSP. Over the years that this project has been funded, additional support has come from other state or federal sources. Currently there are no matching or leveraged funds

MWBC FY2015 GRANT SUBMISSION PLANS:

A resubmission is planned.

Managing wireworm damage to wheat and barley. (4W4620)

PI: Dr. Kevin Wanner, Assistant Professor of Entomology & Extension Specialist, Department of Plant Sciences & Plant Pathology, Montana State University

Objectives:

1. Conduct statewide wireworm surveys of wheat and barley cropland to determine whether wireworm populations are increasing and to raise awareness with producers.
2. Generate laboratory and field data to support the potential registration of fipronil as an additive (at 1.0, 2.5 and 5.0 grams active ingredient per 100 kg seed rates) to currently registered products, to provide better mortality of wireworms in the soil.

Results:

Objective 1: During 2013 we surveyed the complex of wireworm species damaging commercial small grain crops using canister-type bait traps that we developed in 2010 (Figure 1). This was the third year of a three year survey project. The traps were mailed to collaborating producers who buried them in selected crops for 10-14 days and then returned them to Montana State University for insect collection and species identification. Two hundred custom Berlese traps installed at the MSU post farm were used to process these large numbers of samples. The results for 2013 are presented in Figure 1, that summarize all results for the period of the survey, 2011-2013. The prairie grain wireworm, *Ctenicera aeripennis destructor*, was previously thought to be the most common species in the region. However, in this survey, *Limonius californicus* and *Hypnoidus bicolor* were identified as the most common species infesting Montana's cropland. There other species were found less frequently, *Aeolus melillus*, *L. infuscatus* and *C. aeripennis destructor*. Species often co-occurred in the same field.

Participating collaborators submitted information about the field history including the past occurrence of wireworms. The results from 2013 are summarized in Table 1 that includes the results from 2011 & 2012 also. We trapped large numbers of wireworms from fields with a reported history of wireworms. In these situations the damage is obvious and producers have diagnosed the problem. However, we trapped small numbers of wireworms in 37% of field with <u>no prior known history of wireworms</u>. This suggests that sub economic populations of wireworms are common in Montana's cropland, and they have not been noticed because damage is not yet visible. *Whether these low populations will continue to increase in severity and cause more damage in the future in an important question.*

The results from this three year survey are being prepared for publication and are being used in extension outreach efforts to educate producers of the risk of wireworm damage to their crops.

Figure 1. A) Counties of Montana surveyed for wireworms 2010-2013. Numbers within each symbol represent the number of crop fields surveyed in each county. B) Species of wireworm trapped within each county of Montana. The shape of the symbol represents the year of the survey and the color represents the species trapped. Overlapping symbols indicate that more than one species was trapped within the same field.

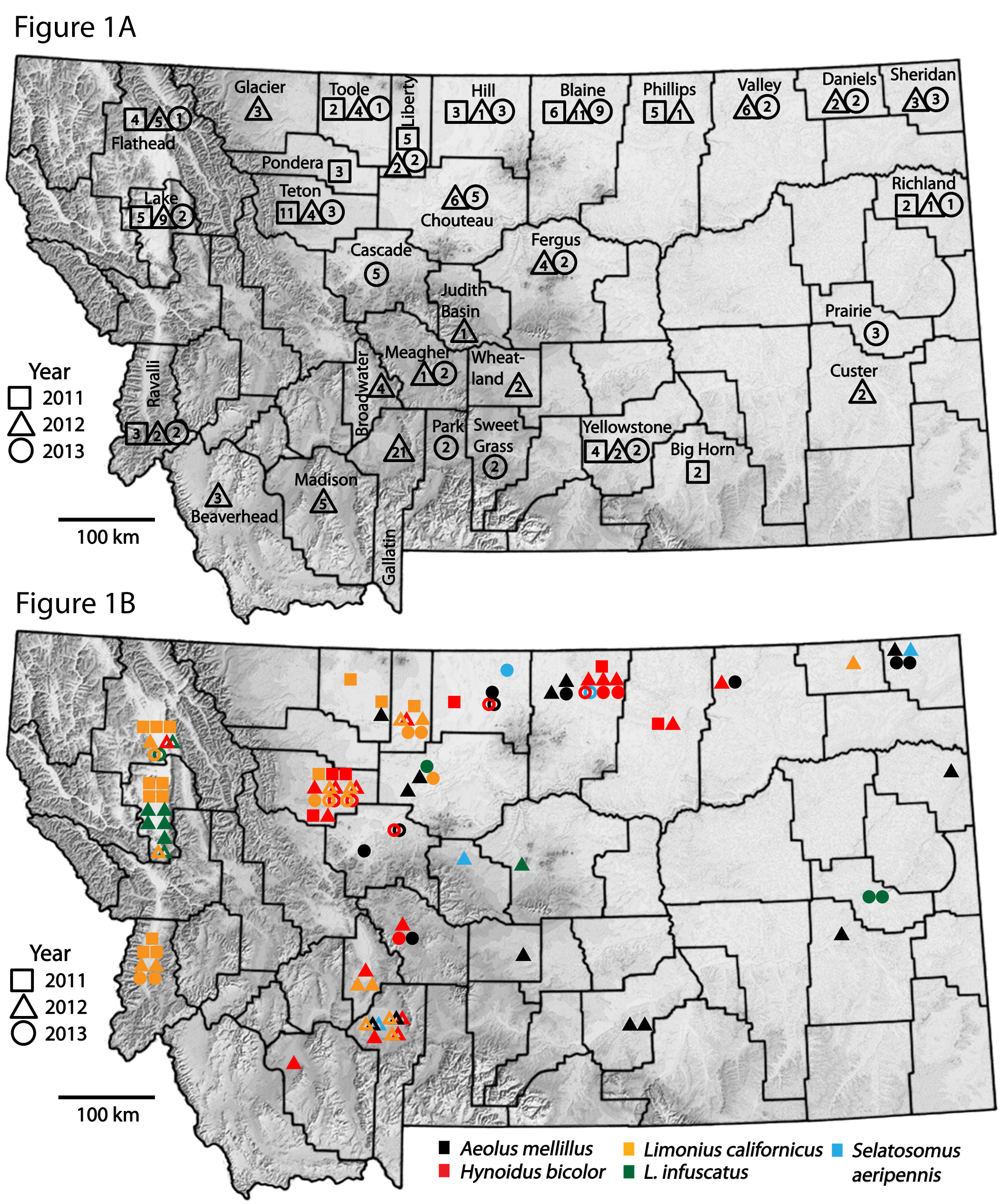


Table 1. Incidence of wireworms in 214 crop fields surveyed across Montana, during 2011 – 2013. The number of fields positive for wireworms (at least 1 wireworm/five traps) is tabulated separately based on the reported history of wireworms. The average number of wireworms/field (five traps/field) was calculated for fields positive for wireworms.

Reported History of Wireworms	No. Fields Surveyed	No. Positive Fields (%)	Wireworm Positive Fields	
			Count Range	No. Wireworms Mean ± SD
Yes	59	37 (63)	1 - 224	20.57 ± 43.89
No	125	46 (36.8)	1 - 10	2.61 ± 2.18
No Answer	30	12 (40.0)	1 - 15	4.83 ± 4.62
TOTAL	214	95 (44.4)	1 - 224	9.82 ± 28.59

Objective 2:

Field Study: Wheat seed was treated with (g a.i. per 100 kg seed): 1) untreated check, 2) 39g thiamethoxam, 3) 39g thiamethoxam + 1g fipronil, 4) 39g thiamethoxam + 2.5g fipronil, and 5) 39g thiamethoxam + 5g fipronil. The 39g thiamethoxam per 100 kg wheat seed rate is equivalent to 1.3 ounces of Cruiser® per 100 pounds seed, the highest label rate of Cruiser®. The seed was planted in experimental plots measuring 12' x 12' in size for each treatment in a commercial wheat field near Kalispell MT in the spring of 2013. These plots will be sampled for wireworm populations during the spring and summer of 2013. The ability of fipronil at 1, 2.5 and 5 gram rates to suppress wireworms in the field will be used to support registration attempts.

Lab studies: The treated seed used in the field trail was to also be used in laboratory and greenhouse trials to generate supporting data under controlled conditions. To conduct these studies living wireworms are collected from bait traps placed in commercial fields. During the spring of 2013 we deployed 500 baits traps in each of four different fields. These bait traps were stored in two walk in coolers in the Marsh laboratory. A power fluctuation tripped a breaker and the coolers were not functional for 3 days over a July weekend. The samples spoiled and the wireworms died, all 2,000 samples and the living wireworms were lost. PI Wanner filed an insurance claim with the Risk Management & Tort Defense Division of the State of Montana for funds to recover the lost samples in 2014. This claim was approved, and samples will be collected again in 2014 so that the lab and greenhouse trials can be completed.

Funding Summary: In addition to funding from the MWBC aspects of this project have been supported by a USDA Crops at Risk grant. This grant supports a graduate student (Frank Etzler) who works in Dr. Mike Ivie's lab to resolve taxonomic questions and identify wireworm species. This grant also contributed to the 200 custom Berlese funnels installed at the MSU post farm.

9/10 – 8/13. USDA Crops at Risk (CAR). DNA Barcoding to Unlock the Puzzle of Wireworm Pest Identities in the Northern Great Plains Region. Wanner (PI), Ivie and Johnson. $218,419.

MWBC FY2015 Grant Submission Plans: I intend to submit a proposal with new objectives related to managing Montana's cropland.

FY2014 Montana Wheat and Barley Compliance Midyear Report (Grant # 4W4621.

Title: Control of glyphosate resistant kochia in fallow with soil active herbicides.

Principal Investigator: Dr. Fabian Menalled.

Co-Principal Investigator: Edward Davis

Objectives:

- Evaluate several soil active herbicides for controlling glyphosate resistant kochia (*Kochia scoparia*) during a fallow year when applied in the early spring of the fallow season, or in the fall following harvest of the previous crop and prior to the upcoming fallow season.
- Evaluate crop response of cereal grains planted the year following the fallow period for potential carry-over effects of the soil active herbicides.
- Determine which site characteristics influence level and duration of kochia control during the fallow season and degree of crop response measured during the following growing season.

Results:

- A chemical fallow field trial was established in the spring of 2013 at three locations; Amsterdam, Bozeman, and Guildford, Montana (Table 1). The trials investigated 12 herbicide treatments for kochia control throughout the summer of 2013. In the fall of 2013 the Bozeman and Amsterdam sites were planted with winter wheat and the Guildford site will be planted to spring wheat in 2014. All three sites will be monitored for crop injury and yield response to the spring 2013 applied herbicide treatments. Kochia was not present at the Bozeman or Guildford sites in 2013. Treatments 2-12 provided 95-100% control of kochia at the Amsterdam site when evaluated on July 12, and September 10, 2013.

- Post-harvest trials were established at six locations in the fall of 2013; Bozeman, Townsend, Denton, Guildford, Havre, and Miles City (Table 2). Twelve treatments were applied at each location and evaluations will be taken through 2014 to measure kochia control throughout the fallow period. Each location will be planted to either winter wheat in the fall of 2014, or spring wheat in the spring of 2015. Crop response and yield data will be collected from each trial location. Soil and weather data will be collected to correlate data results with environmental conditions.

Summary:

- The selection and spread of glyphosate resistant kochia represents a threat to Montana's small grain production
- In this research project we assess different fall and spring applied herbicides to provide farmers across Montana alternative management option.
- All proposed activities have been conducted following the proposed schedule

- We will be collecting result during the 2014 and 2015 growing season.

Funding Summary:

- MWBC grant expenditures; grant funding provided by the MWBC has not been utilized to date since the grant was opened on September 13, 2013 which occurred after the initial field work was already established. Funding for this initial work was provided by grant support from private industry. MWBC funds will be utilized for the continuation of this project in the spring.
- Other funding support for this research: Syngenta - (4,200.00), Bayer Crop Science – ($4000.00), FMC – ($4,200), BASF – ($5,000)

MWBC FY2015 Grant Submission Plans:

- Continuation of this research project to plant, gather crop response data, and harvest cereal grain from all six field sites in 2015.
- Proposed funding request from MWBC - $28,500.
-

Trt No.	Type	Treatment Name	Form Conc	Form Unit	Form Type	Rate	Rate Unit	Other Rate	Other Rate Unit	Appl Code	Appl Description
1	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	A	Early Spring
2	HERB	Spartan	4	LBA/GAL	FL	0.125	lb ai/a	4	fl oz/a	A	Early Spring
3	HERB	Spartan Charge	3.5	LBA/GAL	FL	0.104	lb ai/a	3.8	fl oz/a	A	Early Spring
4	HERB	Sencor 4 FL	4	LBA/GAL	F	0.5	lb ai/a	16	oz/a	A	Early Spring
	HERB	Atrazine	4	LBA/GAL	F	0.5	lb ai/a	1	pt/a	A	Early Spring
5	HERB	Prowl H2O	3.8	LB/GAL	SC	1.42	lb ai/a	3	pt/a	A	Early Spring
6	HERB	Corvus	2.63	LB/GAL	FL	0.082	lb ai/a	4	fl oz/a	A	Early Spring
	HERB	Sencor 4 FL	4	LBA/GAL	F	0.375	lb ai/a	12	oz/a	A	Early Spring
7	HERB	Corvus	2.63	LB/GAL	FL	0.082	lb ai/a	4	fl oz/a	A	Early Spring
	HERB	Atrazine	4	LBA/GAL	F	0.5	lb ai/a	1	pt/a	A	Early Spring
8	HERB	Sencor 4 FL	4	LBA/GAL	F	0.375	lb ai/a	12	oz/a	A	Early Spring
	HERB	Spartan Charge	3.5	LBA/GAL	FL	0.104	lb ai/a	3.8	fl oz/a	A	Early Spring
9	HERB	Spartan Charge	3.5	LBA/GAL	FL	0.104	lb ai/a	3.8	fl oz/a	A	Early Spring
	HERB	Atrazine	4	LBA/GAL	F	0.5	lb ai/a	1	pt/a	A	Early Spring
10	HERB	Fierce	76	%AW/W	WG	0.143	lb ai/a	3	oz/a	A	Early Spring
11	HERB	Linex	4	LBA/GAL	F	0.5	lb ai/a	16	fl oz/a	A	Early Spring
	HERB	Sencor 4 FL	4	LBA/GAL	F	0.375	lb ai/a	12	oz/a	A	Early Spring
12	HERB	BAS 850	4.168	LB/GAL	SC	0.067	lb ai/a	2.05	fl oz/a	A	Early Spring
13	HERB	BAS 850	4.168	LB/GAL	SC	0.134	lb ai/a	4.11	fl oz/a	A	Early Spring

Replications: 4, Untreated treatments: 1, Design: Randomized Complete Block (RCB), Treatment units: US standard, Treated 'Plot' experimental unit size Width: 10 feet, Treated 'Plot' experimental unit size Length: 40 feet, Application volume: 10 gal/ac, Mix size: 2 liters, Mix overage: 20%, Format definitions: G-All7.def, G-All7.frm

Table 1. Evaluating pre-emergence herbicides applied in early spring for control of glyphosate resistant kochia in fallow. Treatments were applied at the locations in Montana: Bozeman, Amsterdam and Guilford in early Spring 2013.

Trt No.	Type	Treatment Name	Form Conc	Form Unit	Form Type	Rate	Rate Unit	Other Rate	Other Rate Unit	Growth Stage	Appl Code	Appl Description
1	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest
2	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	Lorox FL	4	LBA/GAL	F	0.75	lb ai/a	24	fl oz/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest
3	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	Spartan Charge	3.5	LBA/GAL	FL	0.209	lb ai/a	7.62	fl oz/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest
4	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	Sencor 75DF	75	%AW/W	DF	0.5	lb ai/a	10.7	oz/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest
5	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	Spartan Charge	3.5	LBA/GAL	FL	0.104	lb ai/a	3.8	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	Alion	1.67	LBA/GAL	FL	0.026	lb ai/a	2	oz/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest
6	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	Paramount	75	%	DF	8	oz/a	8	oz/a	POSTHA	A	Fall Post Harvest
	HERB	Distinct	70	%	WDG	4	oz/a	4	oz/a	POSTHA	A	Fall Post Harvest
	ADJ	MSO	100	%	EC	2	pt/a	2	pt/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest
7	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	Valor	51	%AW/W	WDG	0.128	lb ai/a	4	oz/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest
8	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	Sencor 75DF	75	%AW/W	DF	0.375	lb ai/a	8	oz/a	POSTHA	A	Fall Post Harvest
	HERB	Spartan	4	LBA/GAL	FL	0.125	lb ai/a	4	fl oz/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest
9	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	Alion	1.67	LBA/GAL	FL	0.052	lb ai/a	4	oz/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest
10	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	Sencor 75DF	75	%AW/W	DF	0.375	lb ai/a	8	oz/a	POSTHA	A	Fall Post Harvest
	HERB	Corvus	2.63	LB/GAL	FL	0.082	lb ai/a	4	fl oz/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest
11	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	BAS 850	4.168	LB/GAL	SC	0.067	lb ai/a	2.05	fl oz/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest
12	HERB	RT3	4.5	LBAE/GAL	SC	1.13	lb ae/a	32	fl oz/a	POSTHA	A	Fall Post Harvest
	HERB	BAS 850	4.168	LB/GAL	SC	0.134	lb ai/a	4.11	fl oz/a	POSTHA	A	Fall Post Harvest
	FERT	BRONC	100	%	SL	5	gal/100 gal	5	gal/100 gal	POSTHA	A	Fall Post Harvest

Table 2. Evaluating pre-emergence herbicides applied in post harvest to wheat for control of glyphosate resistant kochia in fallow. Treatments were applied at the locations in Montana: Bozeman, Towsend, Denton, Guilford, Havre, and Miles City

MONTANA WHEAT AND BARLEY REPORT

PROJECT TITLE: Early Generation Durum Selection and Germplasm Improvement – 2013 (4W4629)

PRINCIPAL INVESTIGATOR:

Dr. Joyce Eckhoff, MSU Eastern Agricultural Research Center, Sidney, MT 59270
phone: (406)433-2208 fax: (406)433-7336 e-mail: joyce.eckhoff@ars.usda.gov

Personnel:

Calla Kowatch-Carlson, laboratory aide
Dr. Elias Elias, NDSU durum breeder, Fargo, ND
Dr. Jae Ohm, USDA/ARS cereal quality, Fargo, ND

OBJECTIVE:

- To develop improved durum germplasm and varieties for Montana production

RESULTS:

Four experimental lines were tested in the statewide durum yield trial. This trial was tested in eight locations, Sidney irrigated, Sidney dryland, Conrad, Bozeman, Havre, Huntley, Moccasin, and Williston, ND. Both sites at Sidney were severely damaged by hail, so yield data were not valid. Results averaged across sites are shown in Table 1. Alzada was the highest yielding variety across sites. Viterra Peak had the highest test weight and protein across sites. Samples from all lines tested at all sites in these trials were sent to the Cereal Quality Lab in Fargo for quality testing of semolina and pasta production. Those quality data are not available at this time.

Four experimental lines were evaluated in six dryland off-station durum yield trials. Locations were Wibaux County, Roosevelt County, Daniels County, Valley County, Phillips County, and Blaine County. The Wibaux site was not harvested because of poor stands. Results across sites are shown in Table 2. Experimental line MT06584 yielded most across sites. Experimental line MT05157 had the highest test weight across sites, and Strongfield had the highest protein content across sites.

We tested 97 F_8, F_9, and F_{10} lines in early yield trials in 2013 under irrigated and dryland conditions at Sidney. These included 16 solid-stemmed lines and 49 low-cadmium accumulating lines. Plots were badly damaged by hail on August 10. Samples from all lines tested in these trials were sent to the Cereal Quality Lab in Fargo for quality testing of semolina and pasta production. Those quality data are not available at this time.

We are currently growing in the greenhouse 60 F^8 lines with stem solidness ratings of 20 or greater on a scale of 5 to 25, with 5 being completely hollow and 25 being completely solid. Also in the greenhouse are 54 F^8 lines that are homozygous for the low Cd gene, 12 4X lines from a Choteau/Mountrail cross developed by Luther Talbert, and an increase of “Silver” durum.

SUMMARY: Durum acreage in Montana has the potential to expand greatly. European pasta companies are looking seriously at Montana as a source of durum. This project is developing germplasm with the low-Cd accumulation character necessary for export to Europe, and which is appropriate to Montana conditions. The development of solid-stem lines was initiated because wheat stem sawfly is a serious problem in some of the durum-producing areas of Montana.

FUNDING SUMMARY: Expenditure information to be provided by OSP. No other grants support this project.

MWBC FY2015 GRANT SUBMISSION PLANS: It is planned to submit this project for funding consideration in the next fiscal year.

Table 1. Statewide durum yield trial averages across sites, 2013. Quality data are not yet available from the ARS Cereal Quality Lab in Fargo, ND.

entry	Heading*	Height, in	Test wt, lb/bu	Grain protein, %	100-seed wt, gm	Yield, bu/ac[1/]	sawfly cutting, %[2/]
Mountrail	66.0	31.0	59.1	14.86	3.61	47.4	2.3
Divide	66.3	32.1	60.0	14.64	3.74	47.0	1.0
Alkabo	65.6	30.7	60.5	14.34	3.74	50.9	2.3
Grenora	64.8	30.3	59.6	14.69	3.60	50.0	2.3
Tioga	65.7	33.9	60.3	14.66	**3.99**	48.6	2.3
Carpio	66.5	32.2	59.2	14.78	3.68	46.3	3.7
Silver	63.5	26.0	60.0	14.90	3.59	51.3	2.3
Alzada	63.8	27.2	59.6	14.19	3.71	**51.9**	2.3
DG Max*	64.3	32.0	60.7	14.82	3.91	49.8	2.3
VT Peak*	65.2	31.0	**60.8**	**15.04**	3.88	48.8	1.0
Normanno*	65.0	24.3	58.9	14.52	3.67	47.3	**0.3**
Kronos*	62.7	23.8	58.3	14.46	3.94	50.0	1.0
APB D7-12*	65.9	26.8	58.0	13.86	3.52	44.4	1.0
APB D6-419*	64.1	28.1	59.6	14.85	3.81	48.4	0.7
MT06584	64.6	24.5	59.4	14.21	3.63	49.6	**0.3**
MT05157	66.0	25.2	**60.8**	14.33	3.69	49.5	**0.3**
MT06578	65.5	25.3	59.3	14.17	3.74	48.5	0.7
MT07707	66.2	25.2	57.1	14.90	3.47	49.4	**0.3**
overall average	65.1	28.3	59.5	14.57	3.72	48.8	1.5

*days from planting
[1/]Sidney dryland and irrigated sites badly damaged by hail, so yield data from those sites not included
[2/]Havre site only

Table 2. 2013 off-station durum yield trial, averages across sites.

entry	height, in	sawfly damage, %[1]	grain protein %	test wt, lb/bu	yield, bu/ac
Mountrail	30.1	5.3	13.88	61.3	48.2
Alkabo	30.3	7.7	13.54	62.2	47.9
Carpio	30.9	3.0	13.39	61.5	49.7
Tioga	32.4	5.2	13.63	61.7	49.6
Grenora	28.1	5.2	13.39	61.5	46.8
Divide	31.6	2.8	14.01	61.1	43.7
Alzada	26.3	1.7	13.57	60.5	45.2
Strongfield	30.2	0.5	**14.56**	61.9	46.6
Normanno	24.5	0.5	14.29	59.4	44.9
Silver	26.1	3.0	14.35	60.8	44.3
MT06584	25.2	0.3	13.57	60.4	**49.8**
MT05157	25.5	**0.0**	13.26	**63.1**	45.8
MT06578	25.2	0.5	13.50	60.5	48.2
MT07707	24.7	0.3	12.85	58.8	47.7
	27.9	2.6	13.70	61.1	47.0

1/ Turner and Loring sites only

Hail damage sustained at Eastern Agricultural Research Center on August 10, 2013.

FY2014 MONTANA WHEAT AND BARLEY MIDYEAR COMPLIANCE REPORT

I. TITLE: Sensor-Based Nitrogen Fertilization Algorithm for Winter Wheat Varieties

II. PRINCIPAL INVESTIGATOR: Olga S. Walsh, Assistant Professor, Soil Nutrient Management, Western Triangle Agricultural Research Center, Montana State University, Conrad, Montana

III. OBJECTIVES:

1. Establish predictive equation for winter wheat yield potential (YP) using early to mid-season sensor readings
2. Establish sensor-based estimate of winter wheat response to applied nitrogen (N)
3. Estimate YP achievable with added N fertilization
4. Investigate the effect of three winter wheat varieties on sensor-based YP prediction

IV. RESULTS:

This study has been originally initiated in fall of 2011; the data from the 2012-2013 growing season has been reported in the FY2013 Montana Wheat and Barley Final Compliance Report. The study was funded for the third growing season (FY2014) and this report summarized the progress achieved so far. In order to increase and improve the data collection, we expanded the study throughout the state of Montana in 2013-2014 growing season. The five experimental sites seeded in fall of 2013 were: Western Triangle Agricultural Experiment Center (WTARC) near Conrad, Western Agricultural Research Center (WARC) near Corvallis, Southern Agricultural Research Center (SARC) near Huntley, Central Agricultural Research Center (CARC) near Moccasin, and Northern Agricultural Research Center (NARC) near Havre. Prior to establishment, composite soil samples were collected, processed and analyzed for soil texture, and all major and minor essential plant nutrients. At each site, 6 N rates were applied depending on the yield goal for the experimental site and following the current MSU guidelines for N fertilization in winter wheat. Nitrogen was applied at the time of seeding as urea, sidebanded. At WTARC, the soil test showed 35 lb N/ac in the soil; for the yield goal of 115 bu/ac, the following rates were applied: 0, 40, 80, 120, 160, 200 lb N/ac. At WARC, the application rates were: 0, 30, 60, 90, 120, 150 lb N/ac, based on the yield goal of 80 bu/ac and almost 70 lb N/ac soil residual N. At SARC, we had 74 lb N/ac in the soil and applied 0, 50, 100, 150, 200, 250 lb N/ac according to a yield goal of 120 bu/ac. Finally, at CARC, with 54 lb N/ac in the soil and a yield goal of 45 bu/ac, the applied rates were: 0, 15, 30, 45, 60, 75 lb N/ac.

Six winter wheat varieties: Genou, Judee, Rampart, Bearpaw, Yellowstone, and Decade were planted at each location. Treatments 1, 7, 13, 19, 25, and 31 will be used as the unfertilized reference plots, and Treatments 6, 12, 18, 24, 30, and 36 will be used as non-limiting N-Rich reference plots for each of evaluated varieties. The plot size was 5'x 25'.

Each treatment was replicated 4 times. Appropriate weed and pest management control was employed when necessary.
As the data will be collected, the research results will be reported in the FY2014 Montana Wheat and Barley Final Compliance Report.

V. SUMMARY:

There is a need to develop a research program that would allow to generate accurate, crop - specific and site - specific fertilizer rates that account for temporal and spatial variability (natural and acquired), improve fertilizer use efficiency, increase and make grain protein in wheat uniform, save time, money and labour for crop producers, increase crop yields, and maintain environmental integrity. Precision sensing technologies will allow establishing state-of-the-art soil nutrient management field-oriented research program that will meet the needs of Montana producers. Precision sensing will enable to focus on strategies that optimize economic and environmental sustainability of small cereal grain production.
The first part of the **Objective 1. - Predict winter wheat yield potential (YP) mid-season– (1-a) N Rate Experiments** has been initiated in the fall of 2011 and continued in 2012.

As it has been proposed, the steps described below will be followed in 2012-2013 growing season to achieve the **Objectives 1** through **4** of this project.

1-b. Obtaining NDVI measurements
The GreenSeeker™ Hand Held Sensor (NTech Industries, Ukiah, CA) will be utilized to obtain NDVI values computed as $NDVI = \frac{(\rho_{NIR} - \rho_{\mathrm{Red}})}{(\rho_{NIR} + \rho_{\mathrm{Red}})}$.
The NDVI readings from each plot will be collected at Feekes 5 growth stage. Feekes 5 has been identified in a course of multiple field studies as the most appropriate sensing time for wheat because it provides reliable prediction of both N uptake and biomass. No N fertilizer will be applied mid-season, or anytime after sensor readings are collected to eliminate the effect of fertilizer input on achieved yield.

Nitrogen rate field experiments will provide the necessary foundation for collection of spectral reflectance measurements. The NDVI readings collected from research plots will be used to generate the YP prediction equation. This equation will define the relationship between the sensor-based in-season estimated YP and actually harvested grain yield. This will allow to access the efficacy of using sensor-based data to predict winter wheat YP.

1-c. Computing days from planting to sensing, where GDD>0
In order to generate an equation that functions over sites and years, the planting date will be recorded. The planting date will be later used to compute the number of days from planting to sensing where growing degree days is greater than 0. This will enable to account for days where for days during the cropping season when plant

growth was not possible due to low temperatures. The growing degree days is calculated as: GDD = (Tmin + Tmax)/2 – 4.4°C.

1-d. Estimating YP attainable with no added N fertilizer (YP_0)

To estimate YP_0, the In-Season Estimated Yield (INSEY) will be computed as the amount of biomass produced per day. This will be done by dividing NDVI (estimate of total biomass) by the number of days from planting to sensing where GDD>0. The INSEY index has been reported as an excellent predictor of YP likely to be obtained with no added inputs.

1-e. Generating the YP Prediction Equation

The relationship will be established between INSEY and collected grain yield. The early- to mid-season NDVI data collected from each plot for each growth stage will be regressed with yield. The model that will best fit the data points will be used to predict crop YP, a parameter required to estimate crop demand for N. At harvest, data on N use efficiency will be compiled. The N use efficiency will be determined using the difference method (Varvel and Peterson, 1990). For each winter wheat variety evaluated, the relationship between final winter wheat grain yield and INSEY will be accessed by plotting harvested grain yield against computed INSEY.

1-f. Determining of % N in the grain

For each winter wheat variety evaluated, grain samples will be obtained and analyzed for % N from each plot.

1-g. Additional data for improved accuracy of YP Prediction

Previous winter wheat studies showed that soil moisture knowledge, especially at 2 and 10 inches below ground, at the time of sensing, can be useful in improving the accuracy of YP prediction, when combined with mid-season NDVI measurements. In the spring Soil moisture sensors will be installed at each experimental location at 2 depths (2 and 10 inches) – which will help to account for possible moisture stress effect. Soil moisture data, in combination with NDVI sensor readings, could be useful in improving the accuracy of YP prediction in semi-arid environment of Montana no-till wheat production systems.

Plant height will be determined at Feekes 5 growth stage by measuring the height of 15 randomly selected plants within each plot. Also, at Feekes 5, within each plot, whole-plant samples will be obtained by collecting all above-ground biomass from 1 foot of row. The plant count within each 1 foot of row will be determined, and number of tillers will be recorded for each plant. The biomass weight for each plot will be determined after drying and the samples will be sent for total N analysis to estimate N uptake. These measurements will help to assess to validate the accuracy of GreenSeeker sensor as an indicator of crop vigor and plant stand and will assist in assessing biomass production differences associated with varieties.

Objective 2. Predict potential response of winter wheat to applied N

2-a. Recording the Response Index (RI) at each Site

The response index (RI) as proposed by Johnson et al. (2000) projects the actual crop response to applied fertilizer N. Crop's response to applied N fertilizer can be quantitatively determined as the yield ratio of the highest-yielding N-fertilized plot and the unfertilized check plot ($RI = \frac{NDVI_{N-Rich Plot}}{NDVI_{Check Plot}}$). NDVI values from Treatments 1, 11, and 21 will be used as $NDVI_{\text{Check Plot}}$, and NDVI values from Treatments 10, 20, and 30 will be used as $NDVI_{\text{N-Rich Plot}}$. Response index values will help to identify responsive and non- responsive site-years and assist in determining of N fertilizer needs. Research results suggest that the magnitude of response cannot be predicted from year to year; thus, fertilizer management decisions should be made in-season (Johnson and Raun, 2003).

Predicted RI values will help to identify responsive and non- responsive site-years and assist in ultimately determining of N fertilizer needs. This will permit to adjusting fertilizer N recommendations according to actual crops' need for N.

Objective 3. Estimate YP achievable with added N fertilization (YP_N)

3-a. Predicting YP_N

The predicted attainable YP with added N will be calculated as: $YP_N = YP_0 * RI$, where the response index, calculated as described in 2-a.

Estimating YP achievable with added N fertilizer will help to determine the potential benefit of applying fertilizer N in a specific site-year taking into an account crops' nutrient status mid-season. It will help to make an educated prognosis of how profitable N fertilization will be at a particular site-year.

3-b. YP_0 and RI are independent of one another

Yield Potential Achievable with no added N fertilization (YP_0) is independent of the Response Index (RI). This approach entails application of fertilizer N based on responsiveness, but with the specific YP in mind.

Objective 4. Evaluate the effect of winter wheat varieties on sensor-based YP prediction

4-a. To evaluate whether the varieties had an effect on sensor-based YP prediction, appropriate statistical analysis will be carried out to determine whether YP prediction equations (generated in 1-e) were statistically significantly different depending on winter wheat variety evaluated.

This step will provide the necessary information whether and to what extend the sensor-derived N fertilizer recommendations will vary from one winter wheat variety to another. This will help to make a decision about whether the N fertilizer rates should be calibrated according to what variety the producer chooses to grow.

VI. FUNDING SUMMARY:

Expenditure information to be provided by OSP
There are no other research funds currently available to support this project.

VII. MWBC FY2014 GRANT SUBMISSION PLANS:

This project will provide the vital information about the efficacy of utilizing ground-based remote sensors to predict winter wheat yield potential mid-season. Adjusting fertilizer N recommendations based on crops' need for N will result in greater fertilizer use efficiency. Accurate knowledge about crops nutrient status and crops responsiveness to N fertilization will enable for more profitable production of winter wheat. Investigating the effect of winter wheat varieties on sensor-based fertilizer N recommendations will allow to further increase nutrient use efficiency. It will also supply Montana producers with information needed to successfully apply precision sensor-based technologies according to what varieties they choose to grow. Recent work by Walsh et al. (Western Triangle Agricultural Research Center) in spring wheat showed that sensor-based N fertilization algorithms developed in other regions did not perform well in Montana. Using three different algorithms developed in Midwest US, Canada and other countries for prescribing topdress N rates for spring wheat in 2011 - 2013 growing season did not allow to achieve maximum yield potential, and protein levels were not optimized. If these algorithms were used by the producers who rely on the precision agriculture tools and software they invested in to make their N rate recommendations, the results would be devastating in terms of both wheat yields and quality. There is no reason to believe that algorithms developed for winter wheat based on the data accumulated elsewhere would perform better for Montana conditions than tested spring wheat algorithms. Interactions with the wheat growers during the Precision Agriculture Seminar organized by Walsh and Western Triangle Ag. Research Center's precision nutrient management group (Great Falls, MT, October 24, 2013) and other regular interactions with agricultural clientele emphasized the need to continue sensor-based work. A proposal will be submitted to Montana Wheat and Barley Committee to continue this study for one more year (growing season of 2014-2015).

Project Title: Evaluation commonly grown barley cultivars for post harvest seed dormancy.

Project Leader: D. M. Wichman CARC Research Agronomist, Moccasin, MT

Project Personnel: S.J. Dahlhausen CARC Seasonal Field Tech, Moccasin, MT

Objective:
Identify those barley cultivars with higher or lower levels of post harvest seed dormancy.

Background
Knowledge of the relative postharvest dormancy of barley and wheat cultivars can be instrumental in variety selection by growers and by grain buyers. Some growers want more post-harvest dormancy to minimize sprouting in the head, while other growers want less post-harvest dormancy to reduce the chances of volunteer crop plants in subsequent crops or fallow period. The shatter viable seed on the soil surface has the potential to produce a weedy volunteer plant in the subsequent growing season. Non-dormant shattered seed can sprout promptly and be controlled by postharvest herbicide application, tillage, or in some cases fall freeze. Seed with postharvest dormancy will not sprout till it has experienced "dry ripening" or "after ripening" a process of growing out of dormancy. Sufficient moisture and suitable germination temperatures must be present for the seed to sprout, once dormancy is overcome. Seed remaining dormant beyond fall freeze-up remain viable for germination in the spring. Plants of spring germinating seed can produce volunteer grain plants, weeds, in the next crop. End users of grain, malt houses and others, that sprout the grain as part of their value added processing need to know the postharvest dormancy character of their chosen cultivar so as to not attempt to malt or sprout the grain too soon after harvest.

Results:
Barley cultivars and development lines were evaluated for post-harvest dormancy in 2013. The central Montana crop experience much above average temperatures in late July and early August, with the CARC experience 14 days with temperatures over 90 F and one day had a high of 100F. These higher temperatures may have influenced the post-harvest germination scores. It is speculated such conditions may post-harvest dormancy- will be evaluated in future fall dormancy evaluations in this project.

Mid plump seed of 16 barley cultivars and development lines was placed in germinators on saturated blotter paper at 10^{o}C (50^{o}F). Initial germination scores were recorded 96 hours after the seed was placed in the incubator. The barley seed was grown in agronomic performance trials conducted at CARC-Moccasin in an April and May seedings, Denton and Geraldine.

There was more variability in the 2013 results than was noted in prior years. However, trends were similar. Tradition, Harrington and Metcalfe were cultivars that exhibited a higher number of germinated seed during the initial 96 hours in the germinator. Haxby and Conrad were two intermediate cultivars, while Eslick, Geraldine and Gallatin had the fewest germinated seed.

Champion was inconsistent in its ranking (Tables 1-4). Experimental line MT 070159 and MT 070158 had high 96h germination counts

Funding Summary:

Expenditure information to be provided by OSP.

No other grant support was provided for this project. MAES funds provided salary for PI & RA.

MWBC FY2014 Grant Submission Plans:

It is planned to submit this project for funding consideration in the next fiscal year. However, it will be limited to 2014 barley cultivar trials.

Table 1 2013 Post harvest germination, to evaluate post harvest dormancy,
Exp1336700g for 16 barley cultivars grown at four locations in central Montana.

Cultivar	Reps	23-Sep 96 h	24-Sep 120h	27-Sep 192h	96&120h	144h
	#	#	#	#	#	#
TRADITION	12	37.0	7.0	0.3	44.0	47.1
HAXBY	12	36.9	8.6	0.4	45.5	48.5
MT070159	12	38.6	6.3	0.7	44.9	47.5
MT070158	12	38.7	6.6	0.8	45.2	48.2
HOCKETT	12	37.4	6.4	0.9	43.8	47.1
HARRINGTON	12	39.1	5.9	0.9	44.9	47.7
GALLATIN	12	37.5	7.2	1.0	44.7	47.7
METCALFE	12	37.0	6.3	1.1	43.3	46.6
MT090180	12	34.7	9.6	1.1	44.3	47.1
COWBOY	12	34.9	9.3	1.2	44.1	47.2
CHAMPION	12	40.1	6.0	1.2	46.1	47.9
GERALDINE	12	37.3	6.2	1.2	43.5	46.9
MT090190	12	35.8	8.7	1.3	44.5	46.9
ESLICK	12	36.2	7.6	1.3	43.8	47.2
CONRAD	12	34.7	8.6	1.4	43.3	47.1
MT080279	12	35.2	7.7	1.4	42.9	46.9
Mean		36.94	7.37	1.03	44.30	47.35
P-value		0.988	0.954	0.984	0.995	0.993
CV1		25.3	84.6	179.8	12.4	6.5
LSD(0.05)		ns	ns	ns	ns	ns

Table 2 2013 Post harvest germination, to evaluate post harvest dormancy,
Exp1336700g for 16 barley cultivars grown under no-till recrop near Moccasin.

Cultivar	Reps	23-Sep 96 h	24-Sep 120h	27-Sep 192h	96&120h	144h
	#	#	#	#	#	#
CHAMPION	3	46.5	1.0	0.0	47.5	49.2
HARRINGTON	3	44.9	3.3	0.0	48.3	49.3
HOCKETT	3	44.5	3.8	0.0	48.2	49.9
CONRAD	3	43.0	4.5	0.0	47.5	49.2
MT070158	3	44.6	4.7	0.0	49.3	50.0
MT080279	3	42.6	4.7	0.4	47.2	48.3
METCALFE	3	42.3	4.8	0.0	47.1	49.2
ESLICK	3	43.1	5.2	0.0	48.2	48.9
GALLATIN	3	42.5	5.8	0.0	48.3	49.7
TRADITION	3	36.1	7.9	0.0	44.0	47.5
MT070159	3	38.0	8.4	0.3	46.4	47.5
GERALDINE	3	39.8	9.1	0.0	48.9	49.9
MT090180	3	37.9	10.9	0.0	48.7	49.5
COWBOY	3	35.2	12.0	0.0	47.1	49.2
MT090190	3	36.4	12.6	0.0	49.0	50.0
HAXBY	3	30.7	15.7	0.0	46.4	48.8
Mean		40.49	7.15	0.044	47.64	49.13
P-value		0.533	0.398	0.482	0.318	0.175
CV1		19.3	92.6	473.9	4.3	2.3
LSD(0.05)		13.01	11.04	0.35	3.44	1.90

Table 3 2013 Post harvest germination, to evaluate post harvest dormancy,
Exp1336700g for 16 barley cultivars grown under no-till recrop near Denton.

Cultivar	Reps	23-Sep 96 h	24-Sep 120h	27-Sep 192h	96&120h	144h
	#	#	#	#	#	#
TRADITION	3	41.7	1.7	3.3	43.3	46.0
METCALFE	3	44.7	2.3	1.7	47.0	48.0
HARRINGTON	3	43.3	2.3	1.3	45.7	48.0
HOCKETT	3	41.7	2.7	3.7	44.3	45.7
CONRAD	3	42.0	3.0	3.7	45.0	46.0
MT070158	3	44.0	3.0	1.3	47.0	48.7
MT080279	3	43.3	3.0	2.0	46.3	47.3
CHAMPION	3	41.0	3.3	3.0	44.3	46.7
ESLICK	3	38.0	3.3	4.7	41.3	44.3
HAXBY	3	37.0	3.7	5.0	40.7	43.3
MT070159	3	40.7	3.7	3.3	44.3	45.7
GALLATIN	3	38.3	4.3	4.0	42.7	45.7
MT090180	3	39.3	4.7	2.7	44.0	46.3
COWBOY	3	37.7	5.0	4.3	42.7	44.7
MT090190	3	37.3	5.3	3.0	42.7	46.7
GERALDINE	3	33.0	7.7	4.0	40.7	43.3
Mean		40.19	3.687	3.188	43.88	46.02
P-value		0.3942	0.2135	0.7212	0.6684	0.5548
CV1		12.9	58.35	71.49	8.967	6.155
LSD(0.05)		8.642	3.588	3.8	6.561	4.723

Table 4 2013 Post harvest germination, to evaluate post harvest dormancy,
Exp1336700g for 16 barley cultivars grown under no-till recrop near Geraldine.

Cultivar	Reps	23-Sep 96 h	24-Sep 120h	27-Sep 192h	96&120h	144h
	#	#	#	#	#	#
TRADITION	3	40.5	2.5	0.0	42.9	45.8
MT070159	3	45.1	2.5	0.0	47.6	49.4
HARRINGTON	3	43.8	3.1	0.4	47.0	48.7
METCALFE	3	44.2	3.2	0.4	47.3	48.4
MT090180	3	42.5	3.3	0.7	45.8	47.8
CHAMPION	3	42.0	3.9	0.7	45.9	48.4
MT080279	3	41.7	4.3	0.0	46.0	48.1
HOCKETT	3	35.5	4.9	0.0	40.3	44.5
HAXBY	3	40.9	5.0	0.0	45.8	48.6
ESLICK	3	40.7	5.2	0.0	45.9	48.8
CONRAD	3	40.2	5.4	0.0	45.6	49.4
MT090190	3	39.3	6.4	0.0	45.7	48.0
MT070158	3	39.1	6.6	0.0	45.6	48.2
COWBOY	3	37.9	8.6	0.0	46.5	48.3
GALLATIN	3	37.5	8.9	0.0	46.4	48.5
GERALDINE	3	37.0	8.9	0.0	46.0	48.1
Mean		40.49	5.158	0.1354	45.64	48.06
P-value		0.96	0.49	0.39	0.94	0.96
CV1		17.51	73.88	313.7	9.529	6.705
LSD(0.05)		11.82	6.355	0.7084	7.253	5.374

Carbon and water exchange in fallow *versus* wheat or cover crops: Are there any carbon and water benefits to fallow?

Principal Investigators:
Dr. Paul C. Stoy
W. Adam Sigler, MS
Dr. Stephanie A. Ewing

This proposal is motivated by the Land Grant mission of Montana State University, in particular the mission of the Department of Land Resources and Environmental Sciences to generate knowledge about local and global environments that can be disseminated to meet the needs of students, agricultural producers, land owners and managers, the general scientific community, and the citizens of Montana.

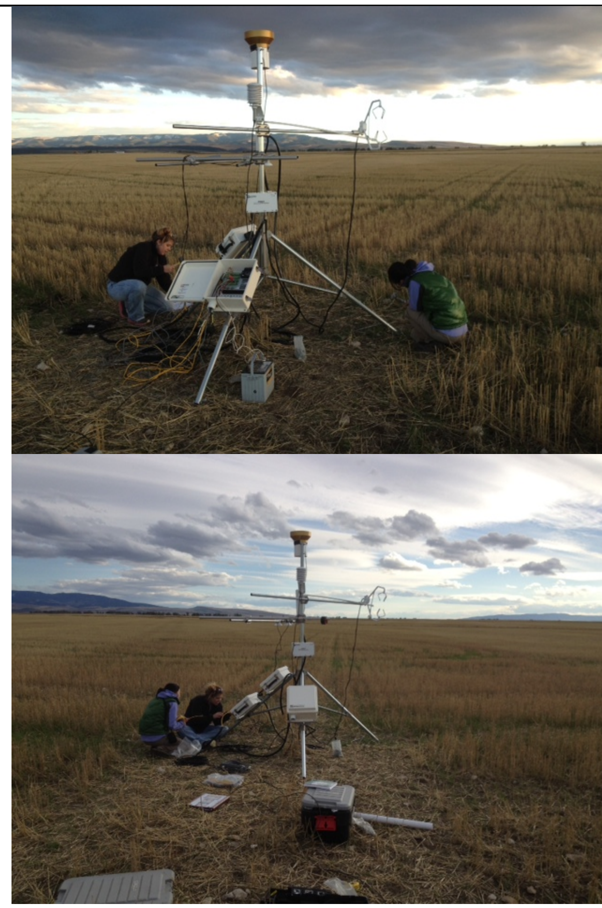


Figure 1: Project masters student Elizabeth Harris and visiting professor Dr. Lin Hua (Xishuangbanna Tropical Botanical Gardens, China) installing the new eddy covariance tower in a field transitioning to fallow near Moore, MT.

The **goal** of the present project is to quantify differences in evapotranspiration and carbon exchange in paired spring wheat and fallow fields to understand the hydrologic and carbon cycle consequences of fallow. The study compares measurements from two eddy covariance towers with Montana Wheat and Barley Committee support. The **objectives** of the present project are to:

1) Measure carbon dioxide and water vapor flux from surface to atmosphere and in response to meteorological drivers at adjacent spring wheat and fallow fields in central MT;
2) Train graduate students from diverse educational backgrounds on applied aspects of MT agriculture, with a focus on wheat cropping systems;
3) Communicate results to producers in conjunction with outreach efforts from the Judith Basin Nitrogen Project (JBNP), led by project collaborator Stephanie Ewing.

Background

Wheat cropping rotations in Montana often include fallow every two to three years, under the notion that fallow confers water savings, limits weeds, and provides pathogenicity benefits that outweigh the deleterious economic impacts of an unproductive field that is likely losing both soil organic matter and nutrients. We argue that economic, biogeochemical and hydrological disadvantages of fallow likely outweigh the benefits. We hypothesize that rotation practices that avoid or minimize fallow will likely improve soil fertility at the field scale and increase economic benefits at the farm scale, and will contribute to the long-term sustainability of cereal production in Montana.

To make the argument that fallow is disadvantageous to soil organic matter storage and of negligible advantage to soil hydrology and aquifer recharge, we have initiated measurements at paired spring wheat and fallow systems near Moore, MT in the Judith Basin (Figure 1). These measurements include carbon inputs through photosynthesis, carbon outputs through respiration, water loss through evapotranspiration, soil moisture (at two depths) to quantify recharge of deep water pools, incident and outgoing long- and shortwave radiation, and air and soil temperature. An eddy covariance measurement system was recently installed in a field transitioning to winter wheat from fallow in 2013, with MWBC support. This field will transition to spring wheat for the 2014 growing season, and eddy covariance/micrometeorological measurements are ongoing throughout this transition. Measurements in the nearby fallow field (currently under spring wheat) will commence this summer after harvest, and the paired comparison will proceed for at least one year.

The new instrumentation was procured in summer, 2013 and installed in late September, 2013 to begin measurements before the start of the water year on October 1. Data collection is ongoing and will focus on the spring, 2014 period when differences in soil moisture drawdown are likely to impact evapotranspiration, water drainage, and carbon uptake.

Title of Project: Water use and carbon sequestration in MT wheat fields: Connecting tower and satellite measurements to understand field-to-statewide dynamics

PI: Paul Stoy
Graduate Students: Elizabeth S. K. Harris, Aiden Johnson

This project is motivated by the Land Grant mission of Montana State University, in particular the mission of the Department of Land Resources and Environmental Sciences to generate knowledge about local and global environments that can be disseminated to meet the needs of students, agricultural producers, land owners and managers, the general scientific community, and the citizens of Montana.

The **objective** of this project is to measure water use and carbon sequestration in a typical MT wheat field at half-hourly intervals before, during, and after the growing season. We are also contributing to ongoing efforts to understand the hydrology of the Judith Basin to improve nitrogen management (PI Stephanie Ewing). We also link field-scale measurements to remote sensing observations to improve our ability to measure wheat water use and carbon uptake from satellites. This report focuses on the following project **goals**:

1) Measure water use (evapotranspiration) by a typical Montana winter wheat field at half-hourly intervals before, during and after the growing season to better-understand the magnitude and duration of water limitation to crop growth;

2) Measure the net carbon sequestration by a wheat field at half-hourly intervals before, during and after the growing season for potential carbon credit allocation;

3) Compare field observations of carbon and water fluxes to estimates from publicly available satellite observations;

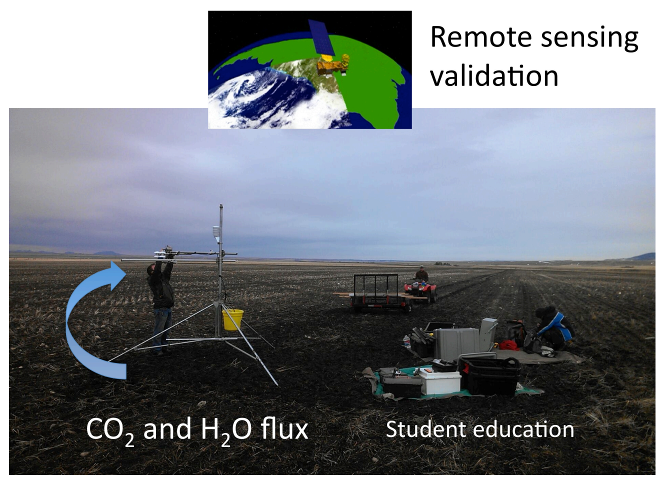


Figure 1: A description of the project objectives. Students are installing an eddy covariance tower in a Judith Basin, MT, wheat field. Half-hourly fluxes of carbon dioxide and water are currently being measured and findings have been linked to remote sensing estimates of carbon dioxide and water flux

4) Train graduate students from diverse educational backgrounds on applied aspects of MT agriculture, with a focus on wheat cropping systems.

Background

Previous observations in Europe demonstrate that wheat fields often represent a small annual source of CO_2 to the atmosphere, depending on management and crop history (Anthoni et al., 2004). These same fields represent a strong growing-season carbon sink, suggesting that wheat fields can potentially serve as net carbon sinks and be credited for carbon sequestration

(Kruger et al., 2010). In the dryland wheat cropping systems of Montana, it is important to understand the annual water balance to quantify the period of time that the crop is under water stress and to develop strategies to maximize crop growth when water is available.

The flux of CO_2 and water vapor (i.e. evapotranspiration, also called latent heat flux when converting to energy flux units) can be measured using the eddy covariance system. Eddy covariance systems have been used to measure evapotranspiration and carbon dioxide flux from wheat fields and northern Great Plains grassland ecosystems before (Gilmanov et al., 2010), but measurements from the present tower (Figure 1) represents the first eddy covariance measurements made in northern Great Plains wheat fields to date.

Carbon sequestration and evapotranspiration can also be estimated remotely by satellites. Ground-based measurements from eddy covariance systems are useful for validating these remote sensing products (Heinsch et al., 2006; Mu, Zhao, & Running, 2011). Eddy covariance measurements can thus be used to help understand not only carbon sequestration and crop water use, but can also improve the accuracy of remote sensing products that are freely available for public use (Figure 1). Here, we summarize results from the 2013 measurement campaign using data presented by project graduate students Elizabeth Harris at the 2013 American Geophysical Union meeting in San Francisco, and Aiden Johnson at the Montana Chapter of the American Water Resources Association meeting.

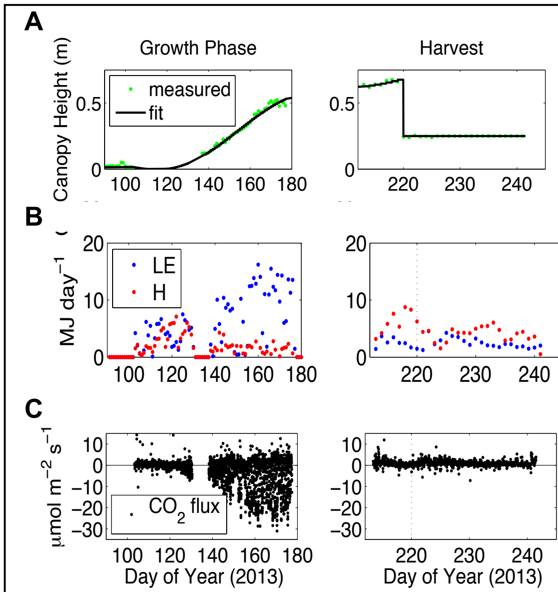


Figure 2: A: Canopy height change of the winter wheat crop. B: Daily sums of latent and sensible heat flux. LE dominates during the growing season and is changed little by harvest. C: Substantial CO_2 uptake (negative values) is observed during the growing season. Harvest has a minor impact on flux.

Methods

Measurements are being made on a field located between Moore and Lewistown in the Judith Basin Watershed (Figure 1). The field was seeded to winter wheat in September of 2012. As is characteristic for the terrace landforms in the Judith, the field has a thin veneer of clay loam soil (16 to 125 cm) overlying gravel. Extensive hydrologic measurement infrastructure was installed by project collaborator Adam Sigler and colleagues in 2012, who maintain existing soil moisture, soil temperature, and lysimeter measurements.

1. Eddy covariance flux and subcanopy wind speed measurements

An eddy covariance system with CSAT-3 triaxial sonic anemometer (Campbell Scientific, Logan, UT) and LI-7200 closed path infrared gas analyzer (LI-COR, Lincoln NE) was mounted at 2 m on a 3 m tall measurement tower (Figure 1). Three dimensional wind speed, carbon dioxide concentration, and water vapor concentration measurements are being made at 20 Hz. Half-hourly wind speed, sensible heat flux (thermals), water vapor flux (evapotranspiration), and carbon dioxide flux values are being calculated using EddyPro software (LiCor, Lincoln, NE). We further partitioned evapotranspiration into transpiration (i.e. water that enters the atmosphere via the plant stomata) and evaporation using the approach of Scanlon and Kustas (2012) to understand if water transport to the atmosphere was occurring from the surface or from deeper in the rooting zone.

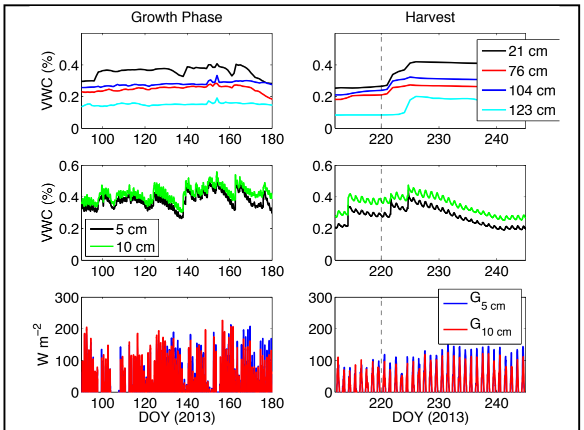


Figure 3: A: Volumetric water content (VWC) from a soil pit at the field site at 21, 76, 104, and 123 cm measured by project collaborator Adam Sigler. B: VWC at two depths below the tower at 5 and 10 cm. C: Soil heat flux (G) measured at 5 and 10 cm below the soil surface.

2. Micrometeorological measurements

Half-hourly averages of relative humidity, air temperature, and soil temperature are being measured using a HMP45C temperature/relative humidity sensor (Vaisala, Helsinki, Finland) and copper-constantan thermocouples created in lab. The full surface energy balance of incident and outgoing shortwave and longwave radiation, including surface temperature, are being measured using a NR01 four-component net radiometer (Hukseflux, Delft, The Netherlands) and two Hukseflux HFP01SC self-calibrating soil heat flux plates. All instruments are being logged using Campbell Scientific CR3000 and CR1000 dataloggers housed in electrically-isolated enclosures. Measurement systems are being powered by four 80W solar panels connected to a bank of four 78 Ah ACG batteries via a SunSaver TriStar MPPT charge controller.

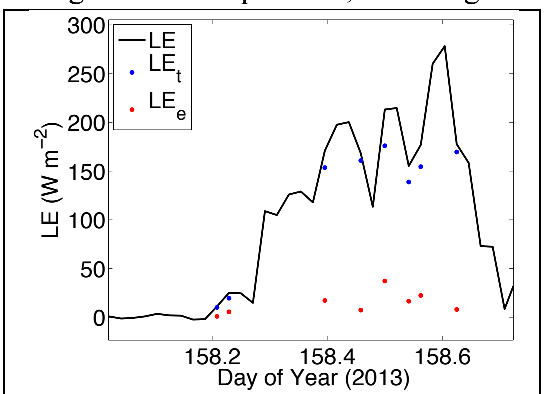


Figure 4: Latent heat (LE, i.e. evapotranspiration in energy flux units) measured by the eddy covariance system and transpiration (LE_t) and evaporation (LE_e) estimates for a day in the middle of the growing season, June 7, 2013.

3. Plant growth measurements

A Campbell Scientific SL50 sonic depth sensor is measuring wheat growth over time. An eight megapixel PlantCam® camera has been mounted to the tower to track wheat height growth at half hourly increments, to validate the sonic depth measurements, and to create time-lapse movies for public education.

4) Remote sensing

Land surface temperature (LST) and normalized difference vegetation index (NDVI, a metric of greenness) was downloaded from the newly-lauched Landsat 8 satellite. Landsat 8 has additional surface temperature measurement capabilities, and we are testing if this new information reduces uncertainties in the estimate of evapotranspiration from space. Data from the entire Judith Basin watershed for 2013 was downloaded and analyzed; results here focus on the Moccassin Terrace.

Results and Discussion

We focus on observations of CO_2 and water vapor flux during the main crop growth phase and immediately after harvest (Figure 2). The plant canopy grew to over 0.5 m from an initial height of near 0 cm, as the winter wheat rotation followed a year of fallow. Stubble remained at about 0.25 m after harvest (Fig. 2A).

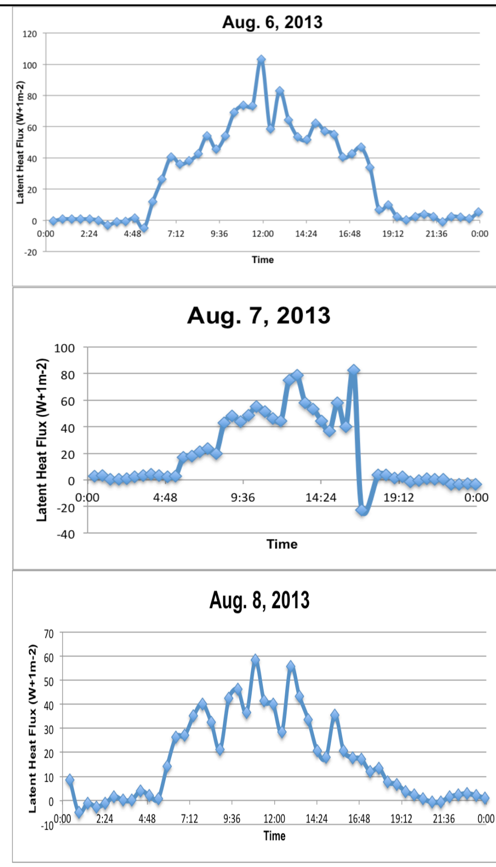


Figure 5: Latent heat flux measurements before, during, and after the wheat harvest in early August, 2013.

The ratio of latent heat flux (LE) to sensible heat flux (H) increased throughout the growing season (Figure 2B). In other words, available energy from the sun that did not enter the soil (soil heat flux, Figure 3) was used almost entirely for evapotranspiration. Most water entered the atmosphere through transpiration rather than evaporation during a typical growing season day (Figure 4). In other words, the wheat crop was highly efficient at using available energy to transpire water. A careful examination of soil moisture measurements reveal that the roots began to tap soil moisture pools between 0.76 m and 1.04 m after about June 9 (day of year 160) (Figure 3). Soil moisture pools at 1.23 m were depleted before harvest (Figure 3). Rooting depths in winter wheat can exceed 2 m (Thorup-Kristensen, Cortasa, & Loges, 2009), but it appears that the crop here mostly tapped soil moisture reserves above 1 m for most of the growing season.

CO_2 flux reached values up to -30 micromoles per square meter per second (with negative values indicating carbon sequestration) during the peak of the growing season (Figure 2). These values are as high as many forests, and it will be interesting to measure annual CO_2 uptake or loss from an entire year of measurements to see if the results of Anthoni et al. (2004), that wheat represents a small source of CO_2 to the atmosphere, also holds on these dryer colder fields where ecosystem respiration (i.e. loss to the atmosphere) is low. The field was a small source of CO_2 to the atmosphere after harvest, and CO_2 flux values changed little after the harvest date, indicating that the dry, dead standing crop was decomposing slowly. In contrast, the maximum latent heat measured over the course of a day decreased from about 100 Watts per square meter before harvest to about 60 Watts per square meter after harvest (Figure 5). As the harvest occurred during a period when the standing crop was dead and no longer transpiring, these observations reflect the change in evaporation, specifically a decrease in surface roughness and an increase in resistance to water transport to the atmosphere after the crop was harvested (Figure 2).

Ongoing collaboration with Adam Sigler and the Judith Basin Nitrogen Project (PI Stephanie Ewing) have revealed that models of evapotranspiration from AgriMet and other sources may overestimate the amount of evapotranspiration that occurs during crop development in spring. The eddy covariance evapotranspiration measurements are being used to improve evapotranspiration models. The springtime and early growing season period is of particular interest for understanding how much water leaches below the rooting zone to recharge aquifers, and for understanding how nitrogen transported in this water source contributes to nitrate levels in groundwater.

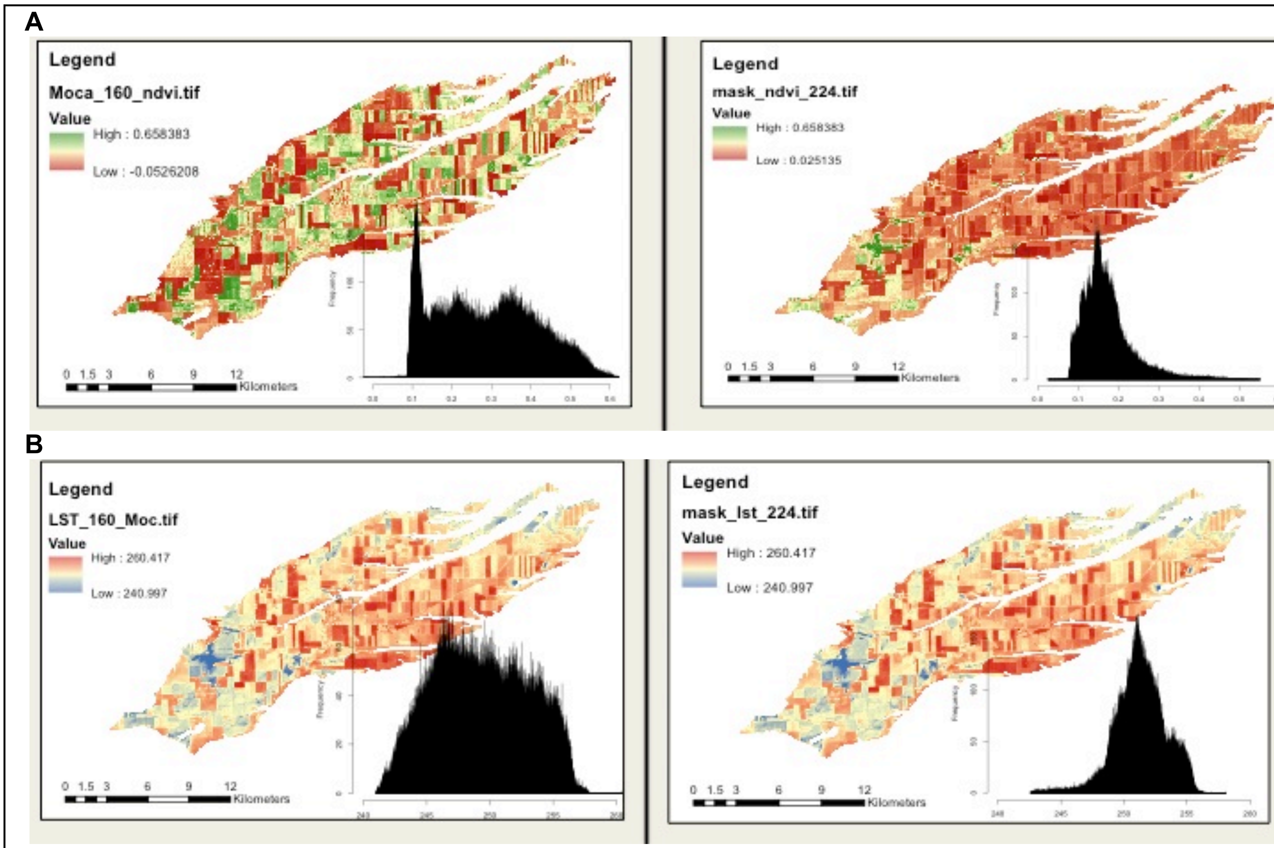


Figure 6: A: The normalized difference vegetation index (a metric of vegetation greenness) in June (left) and August (right) across the Moccassin Terrace, Judith Basin, MT. B: Same as A but for the land surface temperature in degrees Kelvin. Temperatures differ by 20 K across the landform during both periods.

Remote sensing observations (Figure 6) demonstrate how vegetation and surface temperatures differ as a function of crop rotation across a section of the Judith Basin. Ongoing work seeks to model evapotranspiration as a function of the normalized difference vegetation index, land surface temperature, and surface albedo with a critical analysis of uncertainties. The eddy covariance towers located near Moore will be used to validate the remotely sensed estimates of evapotranspiration.

MWBC FY2014 Grant Submission Plans: Resubmission is planned for a minor funding request to support personnel to maintain towers and interpret data through summer and fall, 2014 and spring 2015. We are specifically interested in measuring the transition from winter wheat to spring wheat that is ongoing in the field, particularly given findings that spring wheat has a far shallower rooting depth than winter wheat (Thorup-Kristensen et al., 2009). The winter wheat to spring wheat transition has not been studied from the evapotranspiration and carbon dioxide flux standpoints to date, nor has fallow. By comprehensively studying water and carbon flux across a typical wheat rotation, we can recommend strategies for minimizing fallow and maximizing yield while conserving water and contributing to soil fertility via ecosystem carbon uptake.

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FY2013/2014 MONTANA WHEAT AND BARLEY MID-YEAR COMPLIANCE REPORT

TITLE (4W4151): Support for Montana Ag Live!

PRINCIPLE INVESTIGATORS: Dr. Jack Riesselman, Professor Emeritus Montana State University and Chris Seifert, Director of Outreach, Montana PBS.

OBJECTIVES: We plan on continuing this popular program and are examining ways of expanding its reach. For example, this year we used the annual Montana Grain Growers conference in Great Falls to test the feasibility of broadcasting a real time Montana Ag Program from that meeting or similar agriculture venues within Montana. Our basic goal is to provide timely information relative to all phase of Montana Agriculture to both Montana consumers and producers. Additionally, we are always searching for new sponsors which would allow Montana Ag Live to produce additional programs.

RESULTS: The program is shown live at 6:00 p.m. on ten Sundays in the spring and six in the fall. It is also rebroadcast throughout the rest of the year on Sunday mornings. The 11:00 a.m. Sunday morning rebroadcasts are shown 51 weeks per year. It is available in most areas of the state via over-the air, cable, Direct, and Dish Television where available. New technology also allows us to offer all of this spring's programs via the Montana PBS website. The program addresses a wide variety of agricultural issues via special guests. It has proven to be a highly effective educational tool that not only is a service to agricultural interests but has also provided an opportunity to inform the general public of the importance of agriculture to the state and discussing many of the issues that the agriculture industry faces. This past year our special guests addressed various issues including oil and gas leasing, farm bill, the impact of the legislative session on Montana agriculture, new methods of grain marketing, pesticide carryover as influenced by dry conditions, pulse production in Montana, glyphosate resistant kochia and school safety in rural Montana. Several other topics of interest to viewers were also featured during the 16 week session.

SUMMARY: The entire grant, $3,500, was used for the production of 16 live Montana Ag Live programs, as well as Sunday morning re-broadcasts throughout the entire year.

FUNDING SUMMARY: This grant was dedicated entirely to production costs. All guests, panel members and the moderator donate their time. In addition to the support from the Montana Wheat and Barley Committee, the program is also supported by the Montana Bankers Association, Montana State Universities, Agricultural Experiment Station and Extension Service, Montana Department of Agriculture and the Gallatin Gardener's Club.

MWBC FY2014 GRANT SUBMISSION PLANS: The program was initiated in the fall of 1994. With the exception of one year, the MWBC has provided consistent support which is greatly appreciated. We plan to continue submitting grant proposals to you for the continuance of the program. Thanks again for your continuing support.

FY2014 Montana Wheat and Barley Final Compliance Report

Title (Grant Number): Ag Appreciation Weekend (W4632)

Principal Investigator: Glenn Duff

Objectives: Showcase agriculture and outstanding agriculturists in Montana during *Celebrate Agriculture!! Weekend*. Provide an opportunity for the agricultural community of Montana to gather together and celebrate agriculture.

Results: The entire weekend was very successful as attested to by comments, smiles, laughter. It drew people involved in agriculture from across our state and nation, allowing them not only to reconnect with old friends and colleagues but to forge new relationships.

This was the third year for the Ag Fair and attendance was up. The addition of lunch and recognition of awardees - Outstanding Ag Leaders 2013: Bing Von Bergen of Moccasin, Tom and Mary Kay Milesnick of Belgrade - added to the festive mood and increased the number of participants. Local bluegrass band “Unusual Suspects” played throughout the day, bringing smiles to faces and a few dancers to the floor. Our academic departments and several state agricultural organizations, including MWBC’s own Steve Becker, hosted educational and interactive booths, all of which demonstrated to our guests the unique, innovative, diverse and fun aspects of agriculture. A PowerPoint presentation with logos of our 23 sponsoring organizations was played throughout the afternoon, and sponsors’ logos were also printed on the programs located at each placesetting. Tote bags handed out at the entrance sported large pins with Montana Wheat & Barley Committee’s, as well as the Montana Beef Council’s, logo as an attention-getting acknowledgement to our Palladium Sponsors.

No less than 340 people enjoyed the Ag Fair and Awards Luncheon. The menu was a Montana Made Buffet, including blueberry brats from Big Timber Meats, Fat Cat buns made with Wheat Montana flour, wedge potatoes from Bosch Potatoes in Manhattan, Montana barley salad and a dessert of blueberry oatmeal bars. Individual bags of Warhorse seed, Phil Bruckner’s 2013 release of new winter wheat, were scattered across the luncheon tables for our guests’ taking.

Note: blueberries were added to all menus as an acknowledgement to Carl Casale, blueberry farmer and President and CEO of CHS, Inc. He was the keynote speaker/M.L. Wilson Guest Lecturer during our Outlook Conference on Friday.

On Friday evening, forty people attended the intimate dinner for Outstanding Ag Leaders Bing Von Bergen and Tom & Mary Kay Milesnick, with a menu of Montana products: baby arugula salad with sliced beet salad and radishes, whole grain dinner rolls with butter balls, filet mignon with chipotle blueberry sauce, Yukon mashed potatoes, green beans and blueberry mousse. Enhancements to the setting included a menu and sponsor-list card at each placesetting along with classical guitar music by Mark Logan.

Saturday morning featured MSU President Waded Cruzado at the Blue and Gold Breakfast. The buffet included: buttermilk biscuits with chipped beef gravy, scrambled eggs, breakfast potatoes and sausage links. The program kicked off with a touching presentation of colors by our Air Force ROTC cadets, made complete with the delightful voice of our own Ag Ed major Sarah Snow belting loudly and proudly our national anthem. The Spirit of the West Marching Band followed close behind with a rousing rendition of the MSU Fight Song. The fun continued with comments by two of our stellar Ag Ambassadors, Environmental Horticulture senior Hannah Estabrooks and Ag Business senior Mandy Wiley, as well as recognizing the Von Bergens and Milesnicks as our awardees. Interim Dean and Director Glenn Duff emceed the presentations. Over 370 people enjoyed the breakfast event in Shroyer Gym. Sponsor logos looped continuously on the big screen and were also printed on the placemats at each table setting. Individual bags of Warhorse seed, Phil Bruckner's 2013 release of new winter wheat, were at each placesetting as gifts.

The Outstanding Ag Leaders were again recognized during the first half of the football game against UC-Davis (a Bobcat win!).

Summary: Celebrate Ag!! Weekend serves as a key recognition event for the College of Agriculture. Sponsors are continually recognized throughout the Weekend and at other events throughout the year through PowerPoint presentations, event programs and posters. Without a doubt, we have raised the awareness of agriculture's importance on campus and throughout the state. With sponsor support and through the activities of the Weekend, we highlight agriculture's impact in Montana and promote the College of Agriculture to agricultural industries, ag and consumer groups, parents, alumni and potential students.

Funding Summary: Additional sources of funding for this project included 22 other sponsors. They were:

Palladium Sponsors ($3000): Montana Beef Council.

Platinum Sponsors ($1500): Wilbur-Ellis.

Gold Sponsors ($1000): MSU Office of the President, Montana Agricultural Business Association, Montana Land Reliance, Stockman Bank Montana Farmers Union, Murdochs, MSU Extension Service.

Silver Sponsors ($500): Montana Farm Bureau Federation, Montana Livestock Ag Credit, First Interstate Bank, Montana Department of Agriculture, First Security Bank, Montana Grain Growers Association, Montana Independent Bankers Montana Meat Processors Association, Montana Stockgrowers Association, Northwest Farm Credit Services, Northern Seed, MillerCoors.

Other Sponsors: Montana Wool Growers Association, Northern Pulse Growers Association.

MWBC FY2015 Grant Submission Plans: The College of Agriculture and Montana Agricultural Experiment Station will be submitting a grant proposal for sponsorship of the annual MSU agricultural event.