MONTANA STATE UNIVERSITY
College of AGRICULTURE & MONTANA AGRICULTURAL EXPERIMENT STATION

Department of Research Centers

The 38th ANNUAL RESEARCH REPORT

WESTERN TRIANGLE AGRICULTURAL RESEARCH CENTER

Montana Agricultural Experiment Station

Conrad, MT

2015 Crop Year

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INTRODUCTION

The information and data reported are a collaboration of ongoing or new research projects located at or near Western Triangle Agricultural Research Center (WTARC) of Montana State University, College of Agriculture, Conrad, Montana. Many projects are conducted in cooperation with faculty members, research associates and Post-doctoral fellows from the Depts. of Plant Science and Plant Pathology (PSPP) and Land Resources and Environmental Science (LRES) located on the campus of Montana State University (MSU), and Agricultural Research Centers: Central (CARC), Northern (NARC), Eastern (EARC), Northwestern (NWARC) Southern (SARC) and Western (WARC) of the Dept. of Research Centers.

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Summary of climatic data by month for the '14-15 crop year (September thru August) at the Western Triangle Agricultural Research Center, Conrad, MT.

Month	Precipitation (inches)		Mean Temperature (^oF)	
	Current Year	Average (29-yr)	Current Year	Average (29-yr)
September, 2014	0.82	1.12	54.8	57.0
October, 2014	0.57	0.63	48.5	44.8
November, 2014	0.53	0.28	24.0	31.9
December, 2014	0.38	0.19	24.4	23.9
January, 2015	0.57	0.20	23.9	23.2
February, 2015	0.10	0.22	26.8	24.3
March, 2015	0.23	0.41	40.0	32.6
April, 2015	0.22	1.01	43.1	42.6
May, 2015	2.07	1.89	48.9	51.6
June, 2015	0.95	3.03	63.8	59.2
July, 2015	1.52	1.35	66.1	66.9
August, 2015	1.06	1.28	66.3	66.1
Total	9.02	--	--	--
Average	--	11.6	44.2	44.5

Last killing frost in Spring (32^oF)
2015--------------------------------- May 18
Average 1986-2015-------------- May 16

First killing frost in Fall (32^oF)
2014--------------------------------- September 10
Average 1986-2014-------------- September 26

Frost free period (days)
2015------------------------------- 122
Average-------------------------- 131

Maximum summer temperature------- 97^oF (August 8, 2015)

Minimum winter temperature------- -20^oF (December 30, 2014)

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Agronomy and Soil Nutrient Management Program

During the spring and winter cropping seasons of 2015, the Agronomy and Nutrient Management Program conducted four experiments in the fields of study of nitrogen and water use efficiencies, fertilizer management, pulse-cereal cropping systems, and soil salinity.

STUDY 1: Varietal nitrogen and water use efficiency differences in two Montana cropping systems

Principal Investigators: Dr Olga Walsh; Dr Roger Ondoua, Western Triangle Agricultural Research Center.

Collaborators: John H. Miller, Research Associate; Debra Miller, Research Assistant, Western Triangle Agricultural Research Center.

Farmer Cooperators: Cory Crawford (Valier, MT); Aklestead (Devon, MT)

1.1. Objective: this study aimed at evaluating both nitrogen and water use efficiencies of five varieties of spring wheat (Vida, Duclair, O'Neal; WB9668; and Fortuna) as related to two Montana cropping systems, Continuous Cropping, and Crop-Fallow.

1.2. Methods: the experiment was conducted in the spring 2015 at two locations of the Montana Western Triangle, Valier and Devon. At each location, the experimental site included two adjacent fields, one of which was a spring wheat fallow, and the other a recently-cropped field. The experimental design was a split-split-plot in a randomized complete block design with four repetitions. The main plot factor was cropping system with two levels (Fallow-crop, Continuous Cropping), the sub-plot factor was spring wheat variety with five levels, and the sub-sub-plot factor was nitrogen rate with four levels (0; 40; 80; and 120 lbs N/ac).

1.3. Results

This study successfully determined that:

- The crop-fallow cropping system out yielded the wheat-wheat continuous system by 67% when the average annual precipitation in the preceding (2014) and the growing year (2015) was less than 14" (Figure 1).

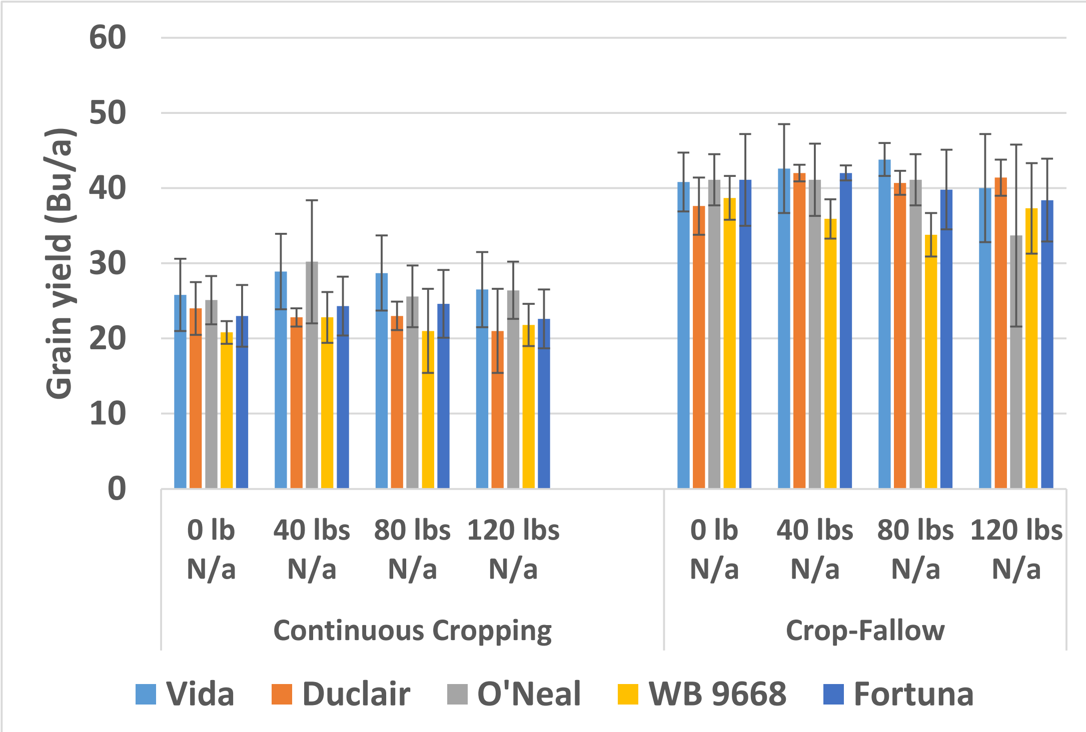
- The spring wheat variety Vida was the most stable across various levels of soil fertility and cropping systems with respect to grain yield.
- The spring wheat variety WB9668 consistently had the highest protein content across various levels of soil fertility and the two cropping systems evaluated (Figure 2).

Unfortunately this study had some setbacks as well. The initial principal investigator Dr Olga Walsh left Montana State University in the fall of 2014, before the implementation of the experiment. A new agronomist, Dr Roger Ondoua, was hired in July 2015. The project was solely implemented by two technicians, and as a result, experimental sites with low residual nitrogen were not selected, and precipitation and moisture data were improperly recorded. We could not use these data to scientifically estimate nitrogen and water use efficiencies of the various varieties under the two cropping systems evaluated.

Research Follow up

The objectives of this study were partially attained due to reasons mentioned above. A second year of this study is scheduled in the spring 2016 under the supervision of the new MSU agronomist Dr Roger Ondoua (Grant 27143). To offset for the 2015 missing data, the number of locations shall be increased from two to four; and science-grade rain-gauges and lysimeter tubes will be installed at each location, and in each plot in order to calculate water balance, and therefore water use efficiency. The four on-farm experimental sites will be selected based on their reported low residual nitrate in order to increase the likelihood of nitrogen response, which in turn will allow proper estimation of nitrogen use efficiency.

Figure 1: Effect of cropping system, N rate, and cultivar on grain yield of 5 spring wheat varieties grown in Valier and Devon.



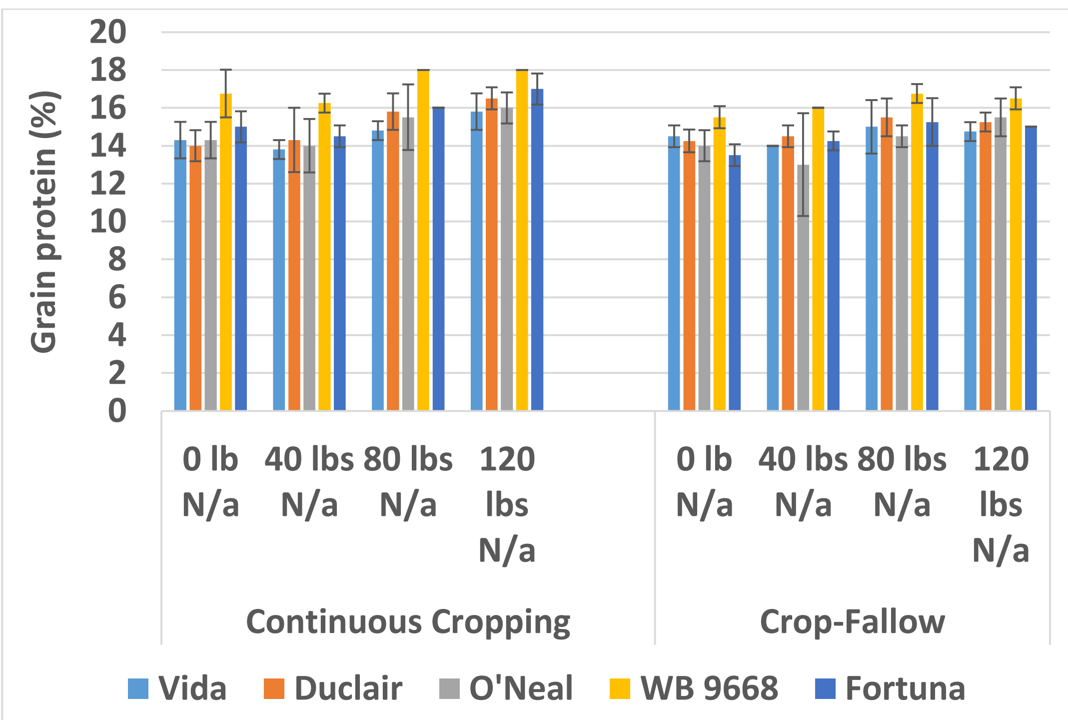


Figure 2: Effect of cropping system, N rate, and cultivar on grain protein of 5 spring wheat varieties grown in Valier and Devon.

Project Potential Outcomes

Pending confirmation following the second year of study, some important guidelines can already be anticipated for the farmers in the Golden Triangle of Montana.

1- The spring wheat cultivar Vida appears to be the most stable grain yield-wise under variable conditions of soil fertility and soil water storage (34 Bu/a; 15% protein).
2- The spring wheat WB9668 produces the highest protein yield under variable conditions of soil fertility and soil water storage (17%; 29 Bu/a).

Practically, depending on the price of protein premiums, Montana farmers may have to choose between Vida and WB 9668.

STUDY 2: Potassium management for improved dryland spring wheat grain yield and quality

2.1. Objective: This was a collaborative study between The Western Triangle Agricultural Research Center (Dr Roger Ondoua), the Northern Agricultural Research Center (Dr. Kefyalew G Desta), and the North Western Agricultural Research Center (Dr. Jessica Torrion). The objective was to determine the optimum K_2O fertilizer rate for improved grain yield and increased grain protein content in dryland hard red spring wheat.

2.2. Methods: The study was conducted at four sites in 2014 and 2015 thanks to the collaboration of four farmer cooperators: Christiaens (Shelby, MT), G. Orcutt (Conrad, MT), D. Rouns (Brady, MT), and K. Fauque (Sunburst, MT). Choteau red hard spring wheat variety was planted at 60 lb/ac pure live seed (PLS) - seeding rate recommended for spring wheat in Montana. At each location, a two-way factorial arrangement (factorial combinations of N x K_2O rates plus a control treatment outside the factorial) of treatments in a randomized complete block design with four replications was utilized. Fertilizer N was side-banded as urea (46-0-0) with the seed at planting at seven rates (0, 45, 90 135, 180, 225 and 270 lb/ac) in 2014 and five rates (0, 45, 90 180, 270 lb/ac) in 2015. The amount of residual N determined from the pre-plant soil test N was credited for calculation of the application rates.

2.3. Results:

2.3.1. 2014 CROPPING SEASON

In 2014, Christiaens' field (Shelby, MT) was a low-yielding site, compared to Orcutt (Conrad, MT). Yields at Christiaens ranged from 14.8 to 38.4 bu/ac, and at Orcutt – from 87.2 to 110.9 bu/ac (Tables 1 and 2).

Table 1. Treatments, and mean grain yield, test weight, protein content, biomass N and biomass K at Christiaens, Shelby, MT, 2014.

Trt #	N rate, lb/ac	K_2O rate, lb/ac	Grain yield, bu/ac	Grain test weight, lb/bu	Grain protein content, %	Biomass total N, %	Biomass total K, %
1	0	0	14.8	57.7	9.9	0.92	0.81
2	0	10	15.4	56.0	11.2	0.89	0.83
3	45	10	16.0	56.6	10.4	1.08	0.74
4	90	10	33.5	56.6	10.1	0.72	1.01
5	135	10	35.6	56.3	11.6	1.24	0.80
6	180	10	38.4	55.6	11.3	1.22	0.99
7	225	10	32.2	57.1	11.2	1.23	0.86
8	270	10	33.0	56.0	11.4	1.34	1.12
9	0	20	20.4	56.6	11.1	0.95	0.80
10	45	20	25.3	57.3	11.6	0.83	0.78
11	90	20	28.2	57.3	10.7	0.82	0.92
12	135	20	35.1	56.4	13.0	1.09	0.87
13	180	20	36.7	58.0	12.6	1.21	0.98
14	225	20	26.7	57.2	9.9	1.48	1.02
15	270	20	29.5	58.3	10.9	1.55	1.07
16	0	30	15.3	57.0	12.7	0.85	0.70
17	45	30	15.7	57.0	11.0	0.87	0.72
18	90	30	34.0	56.7	11.7	1.01	0.77
19	135	30	35.0	55.2	11.1	1.02	0.92
20	180	30	30.4	55.8	12.0	1.57	1.16
21	225	30	32.1	56.6	12.0	1.24	1.12
22	270	30	31.0	57.3	9.2	1.51	0.88

Table 2. Treatments, and mean grain yield, test weight, protein content, biomass N and biomass K at Orcutt, Conrad, in 2014.

Trt #	N rate, lb/ac	K_2O rate, lb/ac	Grain yield, bu/ac	Grain test weight, lb/bu	Grain protein Content (%)	Bio-mass total N (%)	Bio-mass total K (%)
1	0	0	87.5	56.8	10.6	1.14	1.08
2	0	10	87.2	56.2	10.1	1.10	1.12
3	45	10	88.8	53.0	10.8	1.26	1.15
4	90	10	93.3	55.2	11.0	1.35	1.38
5	135	10	101.5	52.1	12.6	1.18	1.44
6	180	10	105.9	52.3	13.3	1.37	1.44
7	225	10	101.3	53.0	14.5	1.46	1.44
8	270	10	105.3	52.7	14.9	1.62	1.28
9	0	20	92.2	56.9	10.7	1.10	1.01
10	45	20	90.2	57.0	10.7	1.33	1.15
11	90	20	101.0	55.3	12.2	1.14	1.31
12	135	20	109.6	55.6	13.1	1.54	1.30
13	180	20	102.1	53.9	14.0	1.74	1.31
14	225	20	109.5	54.8	14.0	1.47	1.48
15	270	20	95.7	52.5	14.5	1.57	1.34
16	0	30	90.5	52.9	10.6	1.35	1.00
17	45	30	90.1	53.7	10.8	1.00	1.35
18	90	30	103.8	53.3	11.8	1.31	1.30
19	135	30	110.9	56.4	12.7	1.48	1.00
20	180	30	106.2	53.4	14.1	1.69	1.14
21	225	30	103.4	54.4	14.1	1.58	1.30
22	270	30	109.1	54.9	14.0	1.66	1.25

Generally, grain yield increased with increasing rates of available nitrogen up to a critical soil nitrogen concentration. Thus, at Christiaens (Shelby), grain yields increased from 16.5, with no nitrogen application, to 35.2 bu/ac with application of 135 lb N/ac; the yields reached plateau between 135 and 180 lb/ac rate and then declined slightly to 30.3 and 31.2 bu/ac at 225 and 270 lb N/ac rates. At Orcutt (Conrad), yields increased from 89.4 with no N to 107.3 bu/ac with 135 lb N/ac rates, the plateau of 104.7 bu/ac was reached between 180 and 225 lb N/ac, then declined slightly to 103.4 bu/ac with 270 lb N/ac.

With respect to the potassium factor, analysis of variances at both locations showed that there were no significant differences among potassium treatments for the variables grain yield, protein content, test weight, biomass total N and K (Table 3)

Table 3. Analysis of variance of the effect of N and K rates on spring wheat grain yield, protein content, test weight, biomass total N and K from two studies in Shelby and Conrad laid out as a factorial experiment in a completely randomized design.

	Christiaens (Shelby)				
N rate, lb/ac	Grain yield, bu/ac	Protein, %	Test weight, lb/bu	Biomass total N, %	Biomass total k, %
0	16.5	11.2	56.8	0.90	0.79
45	19.0	11.0	57.0	0.93	0.75
90	31.9	10.8	56.9	0.85	0.90
135	35.2	11.9	56.0	1.12	0.86
180	35.2	12.0	56.5	1.33	1.04
225	30.3	11.0	57.0	1.32	1.00
270	31.2	10.5	57.2	1.47	1.02
Prob>F	***	ns	ns	**	*
Linear Trend	***	-	-	***	-
Quadratic Trend	***	-	-	ns	-
K_2O rate	ns	ns	ns	*	*
N x K_2O rate	ns	ns	ns	ns	ns
	Orcutt (Conrad)				
N rate, lb/ac					
0	89.4	10.5	55.7	1.17	1.05
45	89.7	10.8	54.6	1.20	1.22
90	99.4	11.7	54.6	1.27	1.33
135	107.3	12.8	54.7	1.40	1.25
180	104.7	13.8	53.2	1.60	1.30
225	104.7	14.2	54.1	1.50	1.41
270	103.4	14.5	53.4	1.62	1.29
Prob>F	***	***	ns	***	ns
Linear Trend	***	***	-	***	-
Quadratic Trend	**	ns	-	ns	-
K_2O rate	ns	ns	ns	ns	ns
N x K_2O rate	ns	ns	ns	ns	ns

*, **, and *** designate significant, very significant, and highly significant effect; ns designates no significance at 95% confidence level.

2.3.2. 2015 CROPPING SEASON

In 2015, the same study was repeated in Brady (Rouns' field) and Sunburst (Fauque's field). The results are presented in table 4

Table 4. Treatment means and significance of the of the effect of N and K rates on spring wheat grain yield, protein content, and test weight in Sunburst and Brady.

Trt #	N rate, lb/ac	K_2O rate, lb/ac	Fauque (Sunburst) Grain yield, bu/ac	Fauque (Sunburst) Protein, %	Fauque (Sunburst) Test weight, lb/bu	Rouns (Brady) Grain yield, bu/ac	Rouns (Brady) Protein, %	Rouns (Brady) Test weight, lb/bu
1	0	0	14.8	13.3	57.4	36.0	15.3	55.0
2	0	10	15.3	13.5	57.3	35.4	14.9	55.8
3	45	10	27.3	14.5	56.6	39.5	16.0	55.1
4	90	10	25.1	16.6	55.4	34.7	17.1	54.3
5	180	10	20.6	17.9	55.3	32.5	17.0	54.0
6	270	10	21.7	18.4	55.8	19.9	18.0	53.8
7	0	20	13.9	13.2	57.5	38.7	15.6	55.6
8	45	20	25.3	15.1	55.7	40.5	16.5	55.1
9	90	20	26.8	16.6	55.9	40.0	16.2	55.1
10	180	20	25.4	17.7	55.3	37.4	16.9	54.4
11	270	20	18.7	18.6	55.1	20.3	17.7	53.7
12	0	30	14.1	13.1	57.0	31.7	16.0	55.0
13	45	30	26.3	15.0	56.0	39.5	15.9	55.4
14	90	30	25.6	16.9	55.6	40.8	16.4	54.9
15	180	30	25.6	17.9	55.0	34.6	17.0	54.2
16	270	30	25.4	18.3	55.5	19.9	18.4	53.1
Mean			22.0	16.0	56.0			
SED			3.5	0.5	0.5	4.6	0.5	0.5
	Prob>F		***	***	***	***	***	***

*** designates highly significant overall treatments effect; ns designates no significance at 95% confidence level.

The analysis of variance performed on the factorial combinations of the five N rates and three K_2O rates showed that N, unlike K, had a significant effect on all dependent variables. No significant N x K_2O interaction was found. Grain yield had a quadratic trend with increase in N rates from 0 to 270 lb/ac at Fauque and Rouns. At both Fauque and Rouns grain yield has increased with an increase in N rate from 0 to 45 lb/ac and then decreased after that rate (quadratic estimate -29.1 and -41.0 at Fauque and Rouns, respectively). Whereas, grain protein and test weight had a linear relationship with increase in N rates. Grain protein linearly increased with increase in N rates from

0 to 270 lb/ac (estimate= 13.3 and 5.9 at Fauque and Rouns, respectively). Grain test weight decreased with increase in N rates from 0 to 270 lb/ac.

Significance of the Study

In this study it was hypothesized that the application of K_2O along N might improve yield and quality of spring wheat. Results suggest that there was not consistent and statistically significant effect of K_2O or N x K_2O interaction effect on most of the measured variables. However, compared with no fertilizer, the application of K_2O fertilizer at the rate of 10 to 20 lb K_2O/ac may have the potential to improve grain yield and increase grain protein content in dryland hard red spring wheat in Montana. The positive results from K_2O application are likely to be more pronounced in higher yield potential areas than low yield potential areas.

In 2015, the poor response to added K_2O might be attributed to soil K content. From 2015 pre-plant samples, K contents at Fauque and Rouns was above 300 ppm. This amount can provide adequate K for the crop. Additionally, 2015 cropping season was characterized by sub-optimal growing conditions, mainly precipitation. The lack of consistent response to K_2O fertilizer suggests that farmers need to monitor their field closely before investing on K fertilizer.

STUDY 3: Effect of soil water storage and evapotranspiration on total grain and protein yields of pea-winter wheat, lentil-winter wheat, and winter barley-wheat crop sequences.

Principal Investigators: Dr Roger Ondoua, Assistant Professor, Agronomy and Nutrient Management, MAES/Western Triangle Agricultural Research Center (WTARC).

Collaborator: Phillip Hammermeister, Research Assistant, Western Triangle Agricultural Research Center.

3.1. Objectives:

1- To determine grain and protein yield responses of pea-winter wheat, lentil-winter wheat, and barley-winter wheat sequences to soil water storage.

2- To determine the relationships between grain and protein yields of pea-winter wheat, lentil-winter wheat, and barley-winter wheat sequences and the independent variables soil moisture, in-season precipitations, and evapotranspiration.

3- To determine the relationships between grain and protein yields of pea-winter wheat, lentil-winter wheat, and barley-winter wheat sequences and the independent variables soil moisture, in-season precipitations, and evapotranspiration.

4- To study the profitability of pea-winter wheat, lentil-winter wheat, barley-winter wheat, winter wheat-fallow, and continuous winter wheat crop sequences under different scenarios of soil moisture.

3.2. Background and justification:

Primarily due to low annual quantity and poor distribution of precipitations, dryland crop production risk in Montana is high. Winter wheat-fallow agricultural systems have been widely adopted to reduce the risk of crop failure. However, reduced risk goes along with reduced profit potential. Intensification of the winter wheat-based cropping systems offers the potential for increased profitability while increasing farmer risk as well. This research project aims at improving the economic and environmental sustainability of croplands in the drylands of Montana through the intensification of winter wheat-pulse and winter wheat-barley cropping systems. This goal could be attained through cropping pulse or barley on 4.6 million acres of Montana lands left fallow between crops. Moreover, including pulse crops in a rotation has been shown to improve soil quality and nitrogen content, break pest and disease cycles.

The matter in issue is the perception that leaving land fallow (4.6 million acres) is required to store soil moisture rather than grow crops. This perception stems from cases of pulse failure across Montana attributed to severe atmospheric (solar radiation, heat, precipitations) and soil (moisture, temperature) climate conditions. A large proportion of pulse failure in Montana can be attributed to the year-to-year variation in climate. It is therefore of paramount importance to develop tools that would enable farmers to determine which year to skip fallow through the prediction with greater accuracy of responses of pea-winter wheat, lentil-winter wheat, and barley-winter wheat crop sequences to soil water storage a few months before the onset of the cropping season when most input management decision are made.

3.3. Methods:

At the Western Triangle Agricultural Research Center, we have successfully Fall-recharged and created a soil moisture gradient along a 400 x 100-feet field using a differential line irrigation method. Thus, five 55 x 100-feet blocks (soil moisture block) with average gravimetric soil moisture contents ranging from 8% (control-block with no supplemental recharge) to 40% were created through the 0-4 feet soil profile.

The treatments, laid out in a randomized complete block design, consist of five crop sequences: pea-winter wheat, lentil-winter wheat, barley-winter wheat, continuous winter wheat, and winter wheat-fallow. They will be repeated four times in each of the soil moisture block (Table 1). A sixth block will be summer-irrigated and will help normalize the yields recorded in the five recharge-blocks (relative yields) to allow assumptions and applicability of the results to differing locations and ecosystems. Individual plots, seeded on 12 inch spacing, are 5 x 25 ft in size. Field edge effects will be minimized by the seeding of border plots.

In September 2015, winter wheat plots destined for the two control crop sequences (continuous winter wheat, and winter wheat-fallow) were soil-sampled at 0-1; 1-2; 2-3; and 3-4 ft depth before they were seeded, and gravimetric soil moisture contents were determined along the 0-4 feet soil profile (Figure 1, Figure 2). In the spring of 2016, pea, lentil, and barley plots will be soil-sampled and gravimetric soil moisture contents determined prior to seeding. In Each plot, 2 soil moisture sensors (Spectrum Technologies, Inc., Aurora, IL) will be buried at 1 and 2 feet respectively to continuously record volumetric soil moistures and soil temperatures at these soil depths. Evapotranspiration gauges (Spectrum Technologies, Inc., Aurora, IL) will be installed on all plots to continuously monitor and record evapotranspiration occurring in each plot. Winter wheat will succeed spring barley, pea, and lentil in fall 2016 and the first cycle of the evaluation will complete in the summer of 2017. The second cycle of evaluation of the crop sequences will start in fall of 2017 with the second recharge of the five blocks. The treatment structure of the study is depicted on Table 1. In addition to the on-station experiment, the five crop sequences described above will be on farm-evaluated on larger plots (20 ft x 20 ft) in three farm cooperator fields located in HighWoods, Choteau, and Valier. The results will help in the validation of the response model obtained on-station.

Table 1. ***Treatment structure of the soil water storage and evapotranspiration experiment. Blocks of gravimetric soil moisture content (%) were artificially created through differential irrigation in the 1-4 ft soil profile. Crop sequences are laid in a randomized complete block design with four repetitions within each block. Average soil moisture contents of blocks ranged from 10 to 40% (gravimetric soil moisture content). B-WW; barley-winter wheat; P-WW: pea-winter wheat; L-WW: lentil-winter wheat; WWf: winter wheat-fallow; WWc: continuous winter wheat***.

Block I (8%)			**Block II** (15%)			**Block III** (27%)	
Rep I	**Rep II**		**Rep I**	**Rep II**		**Rep I**	**Rep II**
B-WW	P-WW		WWf	WWc		P-WW	L-WW
WWf	WWc		B-WW	P-WW		B-WW	WWc
WWc	B-WW		L-WW	WWf		WWc	P-WW
L-WW	WWf		WWc	L-WW		WWf	B-WW
P-WW	L-WW		P-WW	B-WW		L-WW	WWf
Rep III	**Rep IV**		**Rep III**	**Rep IV**		**Rep III**	**Rep IV**
WWf	B-WW		P-WW	L-WW		WWc	L-WW
L-WW	P-WW		B-WW	WWc		L-WW	WWf
P-WW	WWf		L-WW	B-WW		WWf	WWc
WWc	WWc		WWc	WWf		P-WW	B-WW
B-WW	L-WW		WWf	L-WW		B-WW	P-WW

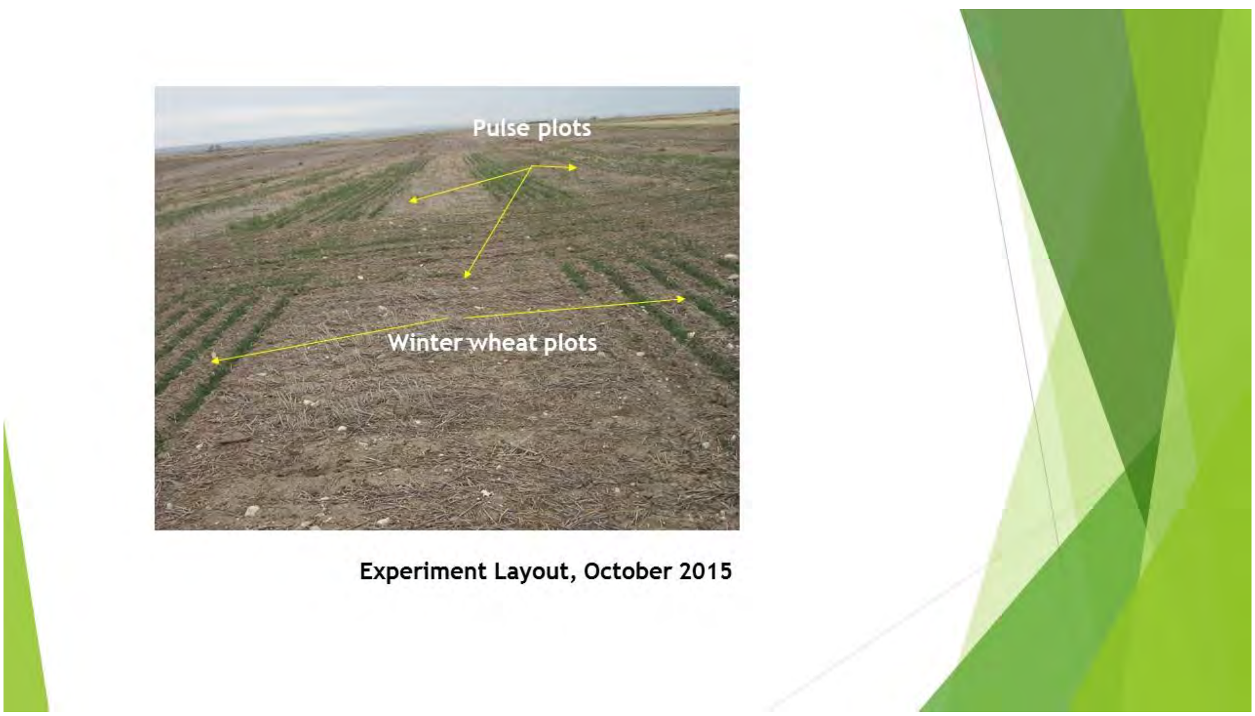
Block IV (33%)			Block V (40%)	
Rep I	**Rep II**		**Rep I**	**Rep II**
P-WW	WWf		L-WW	WWc
L-WW	B-WW		WWc	P-WW
WWc	P-WW		B-WW	L-WW
B-WW	L-WW		WWf	WWf
WWf	WWc		P-WW	B-WW
Rep III	**Rep IV**		**Rep III**	**Rep IV**
B-WW	WWc		WWf	L-WW
WWc	WWf		B-WW	P-WW
L-WW	B-WW		L-WW	WWc
P-WW	L-WW		P-WW	WWf
WWf	P-WW		WWc	B-WW

3.4. Potential outcomes

- This project will enable us to develop five predictive grain and protein yields models for cropping pea-winter wheat, lentil-winter wheat, and barley-winter wheat sequences in the drylands of Montana.
- It will allow us to quantify relative contribution of soil moisture, soil temperature, and evapotranspiration to grain and protein yields of pea-winter wheat, lentil-winter wheat, and barley-winter wheat crop sequences in the drylands of Montana.
- This study will provide a better and more accurate understanding of soil water dynamics in semi-arid agricultural systems.
- The development of a decision-support tool to assist Montana farmers in the management of fallow lands.

Figure 1. Hydraulic soil sampling for the determination of the gravimetric soil moisture content in September 2015 at the WTARC

Figure 2. Experiment layout in the fall 2015 showing emerged winter wheat plots interspersed between future pulse and barley plots at the WTARC.



STUDY 4: Evaluation of four seed coating compounds for the establishment of winter wheat in saline soils.

Principal Investigators: Dr Roger Ondoua, Assistant Professor, Agronomy and Nutrient Management, MAES/Western Triangle Agricultural Research Center (WTARC).

Collaborator: Phillip Hammermeister, Research Assistant, Western Triangle Agricultural Research Center;

Institution Cooperator: Montana Salinity Control Association

Farmer Cooperator: Barry Wharram, Highwood, MT.

4.1. Objective: to test prototype seed coating compounds designed to enhance the establishment of winter wheat in saline soils.

4.2. Methods: four seed coating compounds from P.I. Bioscience Limited were applied to seed of Yellowstone winter wheat variety at the rate of 5 litres/ton seed (Figure 3) at the WTARC's seed laboratory. The trial was located around the Wharram saline seep in September 2015, in Highwood, Chouteau County of Montana (Figure 4). The experimental design was a split-split-plot in a randomized complete block design with four repetitions. The main factor was soil electrical conductivity (EC) with two levels (High and Low EC); the sub-plot factor was seeding rate with two levels (normal and late seeding dates); and the sub-sub-plot factor was seed coating compound with four levels (A, B, C, D). Four high EC blocks, with EC values ranging from 3-7 mmhos/cm, were set up around the eye of the saline seep; while four low EC blocks, with an average EC value of 0.3 mmhos/cm, were set up further inland (Figures 5, 6, 7).

4. 3. Data to be collected: the following variables will be measured and assessed: seedling emergence, tiller number, phytotoxicity, grain yield and quality.

Figure 3. Chemically-coated and non-coated Yellowstone seeds

Figure. 4. Dr Roger Ondoua and Philip Hammermeister checking out seed germination around the Wharram seep (background) in Highwood, Chouteau County, Montana.

Figure 5: emergence of winter wheat seeds at 0.3 mmhos/cm

Figure 6: emergence of winter wheat seeds at 4 mmhos/cm

Figure 7: emergence of winter wheat seeds at 8.0 mmhos/cm

MONTANA STATE UNIVERSITY
College of AGRICULTURE & MONTANA AGRICULTURAL EXPERIMENT STATION

Entomology/Insect Ecology Program

Determining the prevalence of the entomopathogenic fungus, *Beauveria* spp., in diapausing wheat stem sawfly larvae

Principle Investigators: Dr. Gadi V.P. Reddy[1] and Dr. Stefan T. Jaronski[2]

Project personnel: Amber Ferda[1] William Franck[2] Rob Schlothauer[2]

[1]Western Triangle Agricultural Research Center, Montana State University, 9546 Old Shelby Rd., P.O. Box 656, Conrad, MT 59425, USA

[2]United States Department of Agriculture, Agricultural Research Service, Northern Plains Agricultural Research Laboratory, 1500 N. Central Avenue, Sidney, MT 59270

Introduction

In 2013 Jaronski and Reddy discovered a number of WSS larvae with infections by the insect pathogenic fungus, *Beauveria* infection in the course of some laboratory observations. This is the first record of *Beauveria* infecting WSS in North America; there is an obscure report from Romania about *Beauveria* from *Cephus pygmaeus*.

The resulting 8 isolates were genotyped by USDA ARS in Sidney MT, and identified as being in three clades of *B. pseudobassiana*. In addition, three isolates were made of *Metarhizium*, subsequently identified by ARS as *M. pemphigi*. Subsequently, a limited survey was conducted in two fields in Fall of 2013 and processed by USDA in Sidney. From this survey 22 of 25 live larvae extracted from their hibernacula in one sample and 5 of 5 larvae from the second sample were positive for *Beauveria* (*Fusarium* spp. on the other hand, was rare, 1/25 in the first, 0 in the second USDA fall sample. These isolates have also been isolated and genotyped by USDA; these isolates fall into several clades of *B. bassiana* as well as *B. pseudobassiana*.

This report parallels and overlaps that of Dr. Jaronski for his grant from the wheat and barley Committee. This ongoing study is funded through spring 2015, although the parallel grant to USDA ARS in Sidney extends to December 31, 2015, and has been extended through 2015.

Methods

Fields were sampled in the Spring and Fall of 2014. In Spring 2015 the fields where the *Beauveria* was originally recovered were sampled. In each field approximately 100 stubs (wheat stem sawfly hibernacula) were collected along a transect parallel to the field edge. These stubs were shipped to ARS Sidney MT for processing. There the larvae were extracted. Dead and live larvae were decontaminated by immersion in 0.5% NaOCl, followed by two rinses in sterile water after which the excess liquid was blotted off and the larvae placed on water agar for incubation at 25° C. Any insects developing white fungal outgrowth, esp. those that had previously turned a pink color, characteristic of *Beauveria* infection, were isolated for further fungal outgrowth and sporulation.

In the fall of 2014 the WTARC research team collected wheat stubbles from 20 different locations across five counties in north central Montana (Figure 1). In addition, USDA made parallel collections in 15 fields in eastern Montana. Every effort was made to collect at least 100 stubs from each field along transects to accommodate potential heterogeneous distribution of the fungus. In some heavily infested fields this was easy. In others, where sawfly populations were lower, considerable effort was needed to collect the desired number.

Additional collections were made in the Spring and Fall of 2015, in or adjacent to fields from which we had isolated *Beauveria* in 2013 and 2014. Stubs collected by WTARC were then sent to the USDA insect pathology lab of Dr. Stefan Jaronski, the Co-PI, in Sidney, MT. WSS larvae were carefully dissected from their hibernacula, surface decontaminated (1 minute immersion in 0.5% NaOCl followed by two rinses in sterile water), and incubated on 20% water agar for 7-10 days. Any larvae turning pink (a diagnostic sign for *Beauveria* infection) or otherwise dying were transferred to individual plates to allow any *Beauveria*, if present, to emerge and sporulate. Larvae were then placed on selective media for fungal isolation, then transferred to separate culture dishes and catalogued for identification and long-term storage. Molecular typing for assignment of isolates to *Beauveria* species and subspecies clade, as well as evaluation of infectivity/mortality followed initial isolation. Approximately 3,500 sawfly larvae were processed by ARS in this survey.

Seventeen new *Beauveria* isolates were obtained from the Fall 2014 samples. Another 41 isolates were made in 2015 from the original (2013, 2014 positive) fields. Few *Fusarium* spp. infections were seen. Overall prevalence of these fungi was very low — 2 of 35 fields sampled — but when present the prevalence was very high. Unexpectedly, infections by the entomopathogenic fungi were not immediately evident in living larvae, but only after one or two days. All fungi infecting larvae were isolated, cultured and accessioned into the USDA ARS Entomopathogenic Fungus Collection (Ithaca NY) as well as at USDA NPARL, Sidney.

Identification of all these isolates by molecular means (B-locus gene sequence) classified them as *Beauveria pseudobassiana and B. bassiana. Beauveria pseudobassiana* was by far the more common. All the isolates fall into three closely related but distinct groups. Apparently, the *Beauveria* isolates from each field are more closely related to each other than to isolates from the other fields, being, in a sense, island populations. Further identification and taxonomic differentiation by ARS, using high resolution Arbitrary Fragment Length Polymorphism, is not yet complete.

Replicated larval wheat stem sawfly bioassays were conducted by ARS using three isolates of *B. pseudobassiana* and one of *M. pemphigi* (isolated in 2013). In brief, exposure of last instar larvae from a disease-free field consisted of having healthy larvae crawl over filter paper impregnated with spores of the fungi, at densities of 1, 3, 10, 30, 100 spores /mm^2 of surface. Larvae were subsequently incubated for 5-7 days. Any dying of fungus infection were isolated and incubated at high humidity and room temperature for 5 days to elicit emergence of the fungi for identification and isolation. Conveniently, larvae infected by *Beauveria* turn a distinct red color just before death, followed by characteristic fungal outgrowth on cadavers and spore production. In all cases the infecting fungi covered their victim's bodies with characteristic mycelial growth and spores. All the fungi were very infectious and pathogenic for the WSS larvae, with two isolates causing 80% larval mortality at 3-10 conidia/mm^2 surface area and remaining isolates highly so at 30-100 conidia/mm^2.

Results

Our survey has indicated that the occurrence of *Beauveria* in wheat stem sawfly larvae is rare. From the beginning of this research, *Beauveria* presence in larvae has been identified in only 4 fields. While DNA studies by ARS are not complete, it may be that the origin of the *Beauveria* is from the soil in the affected fields. ARS isolated *Beauveria* from the soil attached to collected stubble and is currently determining their taxonomic identity. In retrospect, our sampling procedure, generally targeting fields with high levels of sawfly infestation with the goal of efficient collection, may have biased the observations. The *Beauveria* was found in fields with few larvae, and when present had a very high prevalence. It is possible that *Beauveria* has hitherto been an invisible mortality factor repressing sawfly populations in specific fields.

The bioassays conducted by ARS indicate considerable pathogenicity of the tested fungi. An implication of the bioassay data is that the *Beauveria*, if indeed endophytic in wheat as implied by ARS from their other MWBC-grant-funded experimentation, would not have to greatly grown out and sporulated in the interior of a wheat stem to infect a copresent sawfly larva. Larval mortalities from exposure to 1-10 conidia/mm^2 of surface area, esp. within 5 days of exposure, are exceedingly low in the experience of the ARS Co-PI.

ARS is bioassaying additional *Beauveria* isolates as supplies of diapausing sawfly larvae become available and as the additional fungus strains are identified as unique from the others. ARS is also subjecting the *Beauveria* isolated from stubble in *Beauveria*-positive and negative fields to determine if there is a relationship between observed fungus prevalence and genetic identity of the fungus strains.

Acknowledgments:

This work was supported by Montana Wheat and Barley Committee. Steve Rehner, USDA ARS Beltsville MD verified the taxonomic identification and B-locus-based clade structure of the *Beauveria*.

Figure 1. 2014-15 Montana collection sites. (top) Collections by WTARC; (bottom) collections made by ARS

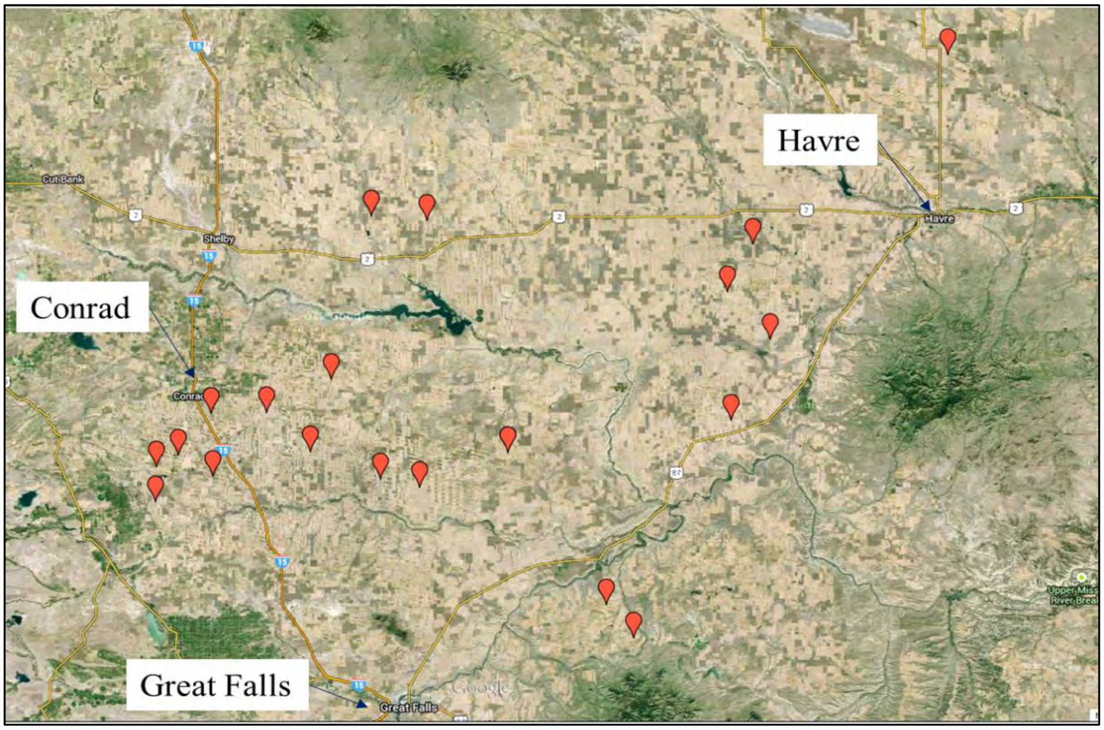
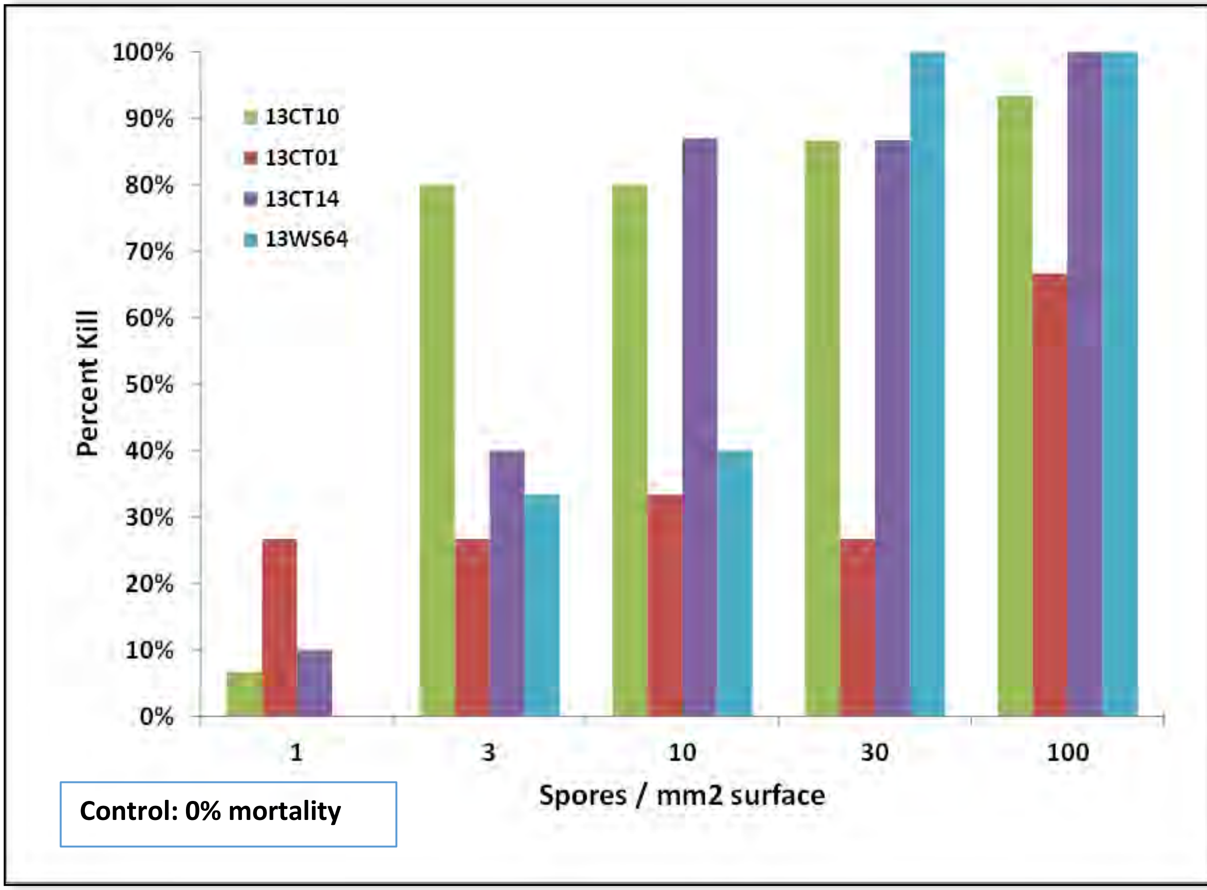


Figure 2. (left) Sawfly larvae infected by *Beauveria* showing the characteristic coloration of infection; (center) emergence of *Beauveria* from cadavers with continued incubation at high humidity; (right) sporulation of *Beauveria* upon maturation of the fungus on cadavers.

Figure 3. In vitro efficacy of three *Beauveria pseudobassiana* (13CT01, 10, 14) and one *Metarhizium pemphigi* (13WS64) for sawfly larvae. Data are mean larval mortalities 5 days after larval exposure to filter paper impregnated with 1, 3, 10, 30, or 100 conidia/mm^2 surface area. All killed larvae developed the characteristic outgrowth and sporulation of the fungus to which they were exposed.



Evaluations of six species of entomopathogenic nematodes and four carrier solutions for use in the management of wheat stem sawfly larvae, *Cephus cintus* (Hymenoptera: Cephidae)

Principle Investigators: Dr. Gadi VP Reddy and Dr. David K. Weaver

Cooperators: Dr. Scott L. Portman and Amber Ferda

Montana State University, Western Triangle Agricultural Research Center, Conrad MT, 59425

Background: Three species of entomopathogenic nematodes (EPNs) have been shown to possess the ability to infect and kill the larvae of wheat stem sawfly (*Cephus cintus*). However, the biology of these three species of nematodes (generally prefer warm moist climates) may not be suitable for use in the State of Montana where the climate is cooler and dry. Species that are active at temperatures <15 ^{o}C (avg. fall temperature in NW Montana) and more tolerant to dryer conditions could be more effective at controlling sawfly. In addition, sawfly larvae are insulated inside the hollowed out wheat stems and therefore not readily exposed to soil dwelling natural enemies such as EPNs. One mode of entry from EPNs into the wheat stem might be through the plug that sawfly larvae construct to block the opening of the girdled wheat stem. However, the plug is very hydrophobic; therefore, water does not soak into the plug easily. The exact composition of the plug is unknown but it is thought to be constructed of larval frass and plant material. Wetting agents such as ionic solutions, detergents or surfactants may function better at soaking into the plug, thus acting as a carrier solution for EPNs.

Objectives:

1) Test six different species of EPNs for their ability to penetrate into the stem and kill the sawfly larva.
2) Test four different solutions for their ability to penetrate the plug and function as a carrier solution for EPNs.

Materials and Methods:

In September and October, 2015, wheat stem stubble containing sawfly larvae was collected from several field sites in Pondera County, NW Montana. Wheat stubble was stored in clean 475 ml deli cups at 8^{o}C. Just before treatment, stubble was inserted individually into deli cups containing approximately 2.5 cm of autoclaved soil (Fig. 1). Each deli cup contained 15-20 individual wheat stems.

<u>Figure-1:</u> Deli cups with wheat stubble harboring sawfly larvae. Deli cups are filled with ≈2.5 cm of autoclaved soil. Roots were trimmed back and wheat stems were pushed into the soil until the soil covered the remaining roots.

Solutions of four different wetting agents (0.1% Triton-X, 0.1% Tween 80, 0.3% Alypso, 5.0% Urea, and distilled water) were prepared in the lab and stored at 8ºC. Alypso® is a commercially available soil surfactant (Precision Laboratories, Waukegan, IL) and was prepared according the manufacturer's instructions (0.3%). Trition-X and Tween 80 (Sigma-Aldrich, St. Louis MO) are mild detergents commonly used in washing buffers or cell lysis buffers by molecular biologists. Solutions of both Triton-X and Tween 80 were prepared according to concentrations found in molecular biology protocols (0.1%). Urea (Sigma-Aldrich, St. Louis MO), a highly ionic compound, was tested at different concentrations for EPN survival (1%, 5%, 10%). EPNs were able to tolerate both 1% and 5% urea. The 5% concentration was chosen as a treatment because the 5% solution soaked into the plug material faster than 1% solution. Distilled water was used as a control.

Six species of commercially available EPNs (*Steinernema carpocapse, S. feltiae, S. glaseri, S. krussei, S. riobrave*, and *Heterorhabditis bacteriophora*) were ordered from suppliers and stored at 8ºC. EPNs were allowed to equilibrate to room temperature (22ºC) before being added to 3ml of each wetting solution. Wetting solutions containing EPNs were first mixed thoroughly and sucked up into a disposable pipette. Solutions were applied to the wheat stems by placing a single droplet on top of the stem's plug. After solution application, treated stems were incubated at 20ºC in a growth chamber for 7 days. After 7 days, the larvae were extracted from the stems and assayed for nematode infection. Larvae that appeared healthy larvae were placed in small 60 ml deli cups and observed for latent signs of nematode infection.

Results and Discussion:

Initial experiments indicated that only three of the six species of EPNs produced significant sawfly mortality (>30%): *H. bacteriophora*, *S. riobrave,* and *S. feltiae* (Table 1). Thus the three underperforming species (*S. carpocapse, S. glaseri, and S. krausei*) were eliminated from subsequent trials.

Table 1 Values represent percent mortality rates of sawfly larvae (*Cephus cinctus*) obtained from infested wheat stubble treated with six species of entomopathogenic nematodes, combined with five different carrier solutions.

% Mortality *Cephus cintus* larvae (N=20)

Test Solution	Steinernema feltiae	Steinernema riobrave	Heterorhabditis bacteriophora	Steinernema carpocapse	Steinernema glaseri	Steinernema krausei
H2O	31.3	11.1	26.3	0.0	0.0	16.7
Alypso	22.2	44.4	5.9	6.3	15.4	12.5
Triton-X	22.2	47.1	61.1	0.0	0.0	11.8
Tween 80	23.5	52.9	22.2	0.0	0.0	5.6
Urea	10.5	20.0	41.2	0.0	5.9	6.7

To obtain sufficient sample sizes, the experiment was replicated four times. For each replication, mortality rates for all treatment combinations (solutions × nematodes) were calculated. Mortality rates were treated as independent observations in the data analysis. On average, Triton-X combined with *H. bacteriophora*, and *S. riobrave* produced the highest mortality rates (64.7% and 42.1% respectively). Two-way analysis of variance (ANOVA) was used compare differences in mortality rates among the treatments. The ANOVA model included “nematode species”, “treatment solution”, and “nematode × treatment” interaction term as predictor variables. Post-hoc multiple comparison procedure (Dunnett’s Test) was used to determine if there were any differences in mortality rates for carrier solutions vs. controls (distilled H_2O). Analysis (ANOVA P=0.048, R^2 =0.49) showed significant effects from “treatment solution” (P=0.039) but not “nematode species” (P=0.457). The interaction term was marginally insignificant (P=0.063); however, post-hoc analysis of the interaction term indicated that Triton-X combined with either *H. bacteriophora*, or *S. riobrave* produced significantly higher mortality than the control solution (P=0.006 and P=0.023, respectively; Fig. 2).

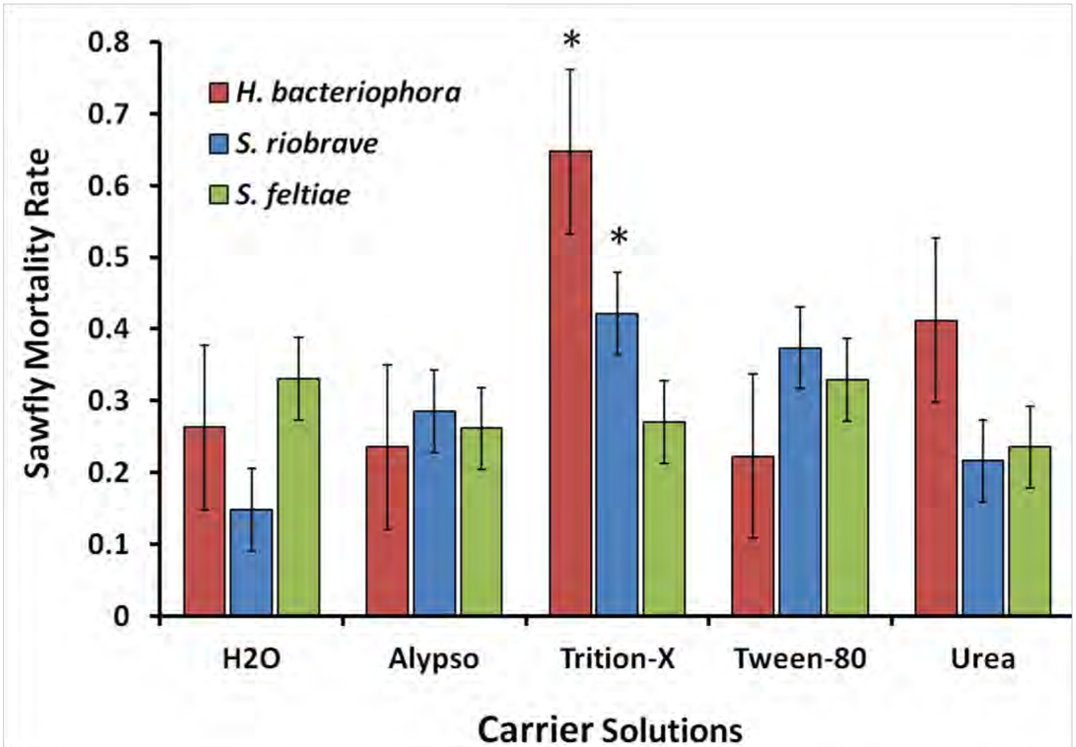


Figure-2: Bars represent mortality rates of sawfly larvae (*Cephus cinctus*), obtained from infested wheat stubble, treated with three species of nematodes, combined with five different carrier solutions. Asterisks show significant differences ($P<0.05$) in mortality compared to distilled water treatment (control).

Overall these results suggest that Trition-X might function as carrier solution that would allow EPNs to enter infested wheat stems and kill the sawfly larvae inside, particularly when they are combined with *H. bacteriophora*, or *S. riobrave.* The results using *S. riobrave* are encouraging because this species is relatively tolerant of cold and dry conditions -similar to conditions found in NW Montana in the fall (post harvest). One limitation of this study is that these results were obtained under very controlled laboratory conditions and cannot be extrapolated to effects obtained under field conditions. However, more experiments are planned for 2016 to test these treatments under field conditions. In the interim, more replications can be obtained and new solutions can be tested in the laboratory.

Acknowledgements

Funding for this research is provided by Montana Wheat and Barley Committee.

Effect of Thimet against wheat stem sawfly, *Cephus cinctus*

Principal Investigator: Dr. Gadi V. P. Reddy

Cooperators: John H. Miller, Amber Ferda, Julie Prewett

Introduction

The wheat stem sawfly (*Cephus Cinctus*) (Hymenoptera: Cephidae) is distributed across Montana, North Dakota, South Dakota, Wyoming, Idaho, Colorado, Alberta, Manitoba and Saskatchewan. This pest was first reported in Canada in the late 1800's and has been increasing its range since that time (Knodel et. al. 2010). It was originally a wheatgrass dweller, but began its migration to small grains. It has become a serious pest for Montana, with estimated damages of $30 million a year on wheat production. The larval stage of the insect is the most damaging (Figure 1). The eggs are deposited inside the wheat stem, it grows to a larva, girdles the stem and plugs the top and remains in diapause until the following spring (Fullbright et. al. 2011).

1. Effect of Thimet on the survival of wheat stem sawfly on winter and spring wheat.
2. Effect of Thimet on the survival of parasitoid of wheat stem sawfly.

Materials and methods

Field experiments were carried out to study the effects of Thimet 20-G against the *C cinctus* on the winter wheat variety, Yellowstone and spring wheat varieties, Duclair (solid stem) and, Vida, (hollow stem). Winter wheat application rates were applied as layby (between rows) treatments of 2.8, 3.9, and 5.5 kg/ha at Feeke's growth stage 5. Six treatment rates were used for spring wheat. There were treatments applied at planting and as layby treatments when the spring wheat was at Feeke's growth stage 2.2 (Table-1).

Thimet 20G was applied using a plot drill with Accupoint disk openers with individual cones for each opener. Statistics were done using a natural log transformation due to zero larvae in some wheat samples.

Wheat samples were collected prior to harvesting. Each sample was collected in one foot sections, twice, for a total of two feet. This was done for five locations. The samples were processed individually. Each individual stem was cut in half with a scalpel. The insects inside the stems were sorted into the following categories: live wheat stem sawfly and live parasitoid. They were counted and recorded.

Results

The winter wheat had live sawflies and live parasitoids and overall had many more larvae in the samples. Thimet 5.0 kg/ha significantly reduced population than other doses used (Figure-2). There were no live wheat stem sawflies in the spring wheat samples (Figure-3), but there were live parasitoids.

The wheat plant samples were collected just before harvest it is very difficult to identify dead sawflies as they may be in late stages of decomposition. Overall, there were not as many larvae of any kind in the spring wheat as there was in the winter wheat.

The yield, test weight, and protein data are not reported in this poster as there were no significant differences due to treatment with Thimet 20G®. Part of that could be weather related as we had a fairly warm and quite dry summer, especially in June.

Table 1. Thimet® 20G rates applied to winter and spring wheat at planting and layby (between rows) with planting, treatment, harvest and sampling dates.

Treatment	Rate Kg/ha[1]	Location	Planting Date[2]	Harvest Date	Sampling Date	Treatment Date
Winter Wheat Treatments						
Treatment 1	Untreated	Devon	10/6/14	7/23/15	7/23/15	5/19/15
Treatment 2	2.8	Choteau	9/30/14	8/13/15	8/13/15	5/21/15
Treatment 3	3.9	Knees	10/1/14	8/6/15	8/6/15	5/21/15
Treatment 4	5.6					
Spring Wheat Treatments						
Treatment 1	Untreated	Inabnit	5/5/15	8/27/15	8/27/15	5/21/15, 6/8/15
Treatment 2	2.8	Killion	5/5/15	8/6/15	8/6/15	5/21/15, 6/8/15
Treatment 3	2.8 plus 2.8					
Treatment 4	0 plus 2.8					
Treatment 5	5.6					
Treatment 6	0 plus 5.6					

[1] For spring wheat treatments there is a planting date with treatments and some treatments are plus another treatment applied as a layby treatment. All winter wheat treatments are done as layby.

[2] Winter wheat variety was Yellowstone and Spring wheat varieties were Duclair and Vida.

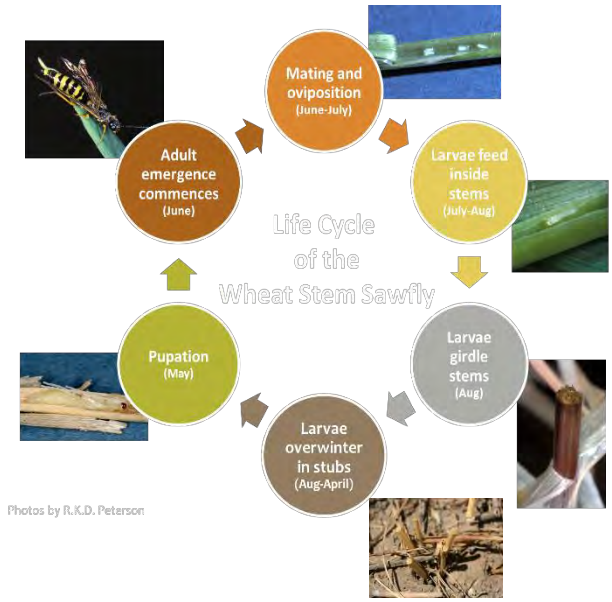


Figure-1. Life cycle of the wheat stem sawfly.

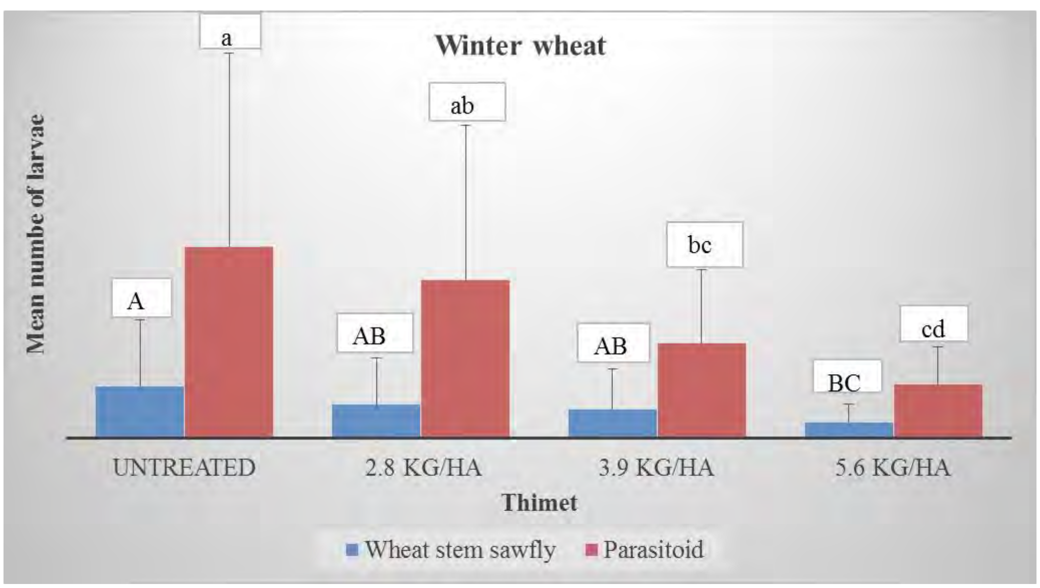


Figure-2: Effect of Thimet on wheat stem sawfly and its parasitoid on winter wheat.

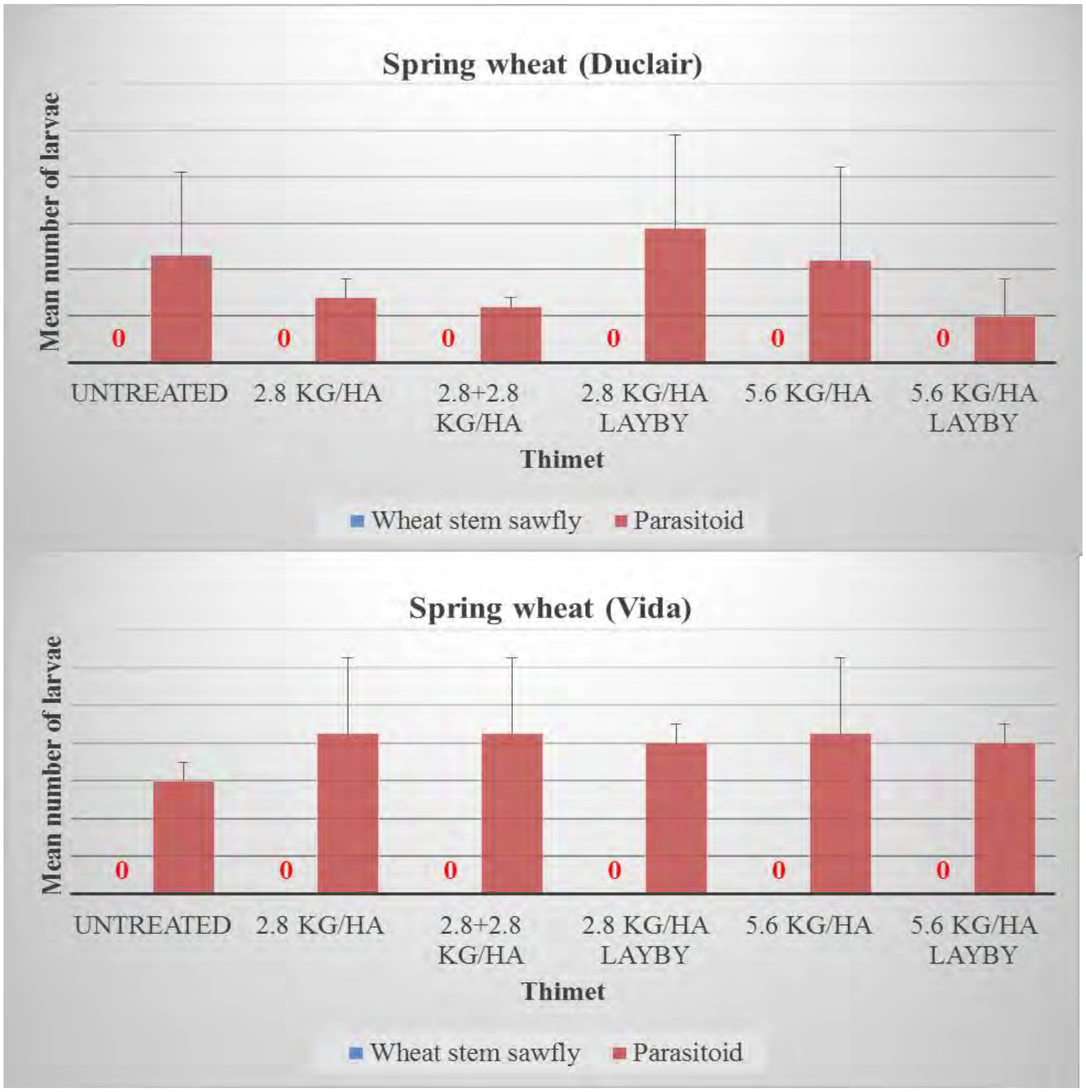


Figure-3: Effect of Thimet on wheat stem sawfly and its parasitoid on spring wheat.

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Acknowledgements

Funding for this research is provided by Montana Wheat and Barley Committee and AMVAC Chemical Corporation.

Status of *Sitodiplosis mosellana* (Diptera: Cecidomyiidae) and its parasitoid, *Macroglenes penetrans* (Hymenoptera: (Pteromalidae), in Montana

Principal Investigator: Dr. Gadi V. P. Reddy.

Cooperators: Dr. Brian M. Thompson and Daniel E. Picard

Western Triangle Agricultural Research Center, Montana State University,

9546 Old Shelby Rd, P.O Box 656, Conrad, MT 59425

Introduction

The orange wheat blossom midge, *Sitodiplosis mosellana* (Gehin) (Diptera: Cecidomyiidae), is a widespread pest of wheat of Palearctic origin that was introduced into North America in the early 1800s. This pest continues to expand to new areas of North America. The orange wheat blossom midge was first detected in northern and central Montana in 2000, near North Dakota where the midge had been detected earlier. Damage to the wheat crop in this region remained low, with only periodic minor outbreaks. Subsequently, an outbreak occurred in western Montana on spring wheat in the Flathead Valley. Initial estimates of wheat losses were over $1.5 million in Flathead County alone. Crop losses due to orange wheat blossom midge are often 30-80%, but can be100% if populations are extremely high. In North Dakota during 1990s, wheat growers lost an estimated $30 million in gross revenue due to *S. mosellana*. According to the published literature, losses in Canada exceeded US$38.65 million in Manitoba and US$77.30 million in Saskatchewan in 1995. In contrast, in eastern Montana where the midge's parasitoid was found to be present along with the pest, significant losses were not reported.

In eastern Montana, adults of *S. mosellana* begin emerging from the soil between June and July. There is one generation per year and midges overwinter as mature larvae in the soil. Eggs are laid in developing wheat heads and larvae feed on the developing seeds, causing significant damage in spring wheat North America. Larval feeding on the emerging kernel causes shriveling and reduces the value of the crop. Wheat is vulnerable to attack by *S. mosellana* from the boot stage until anthesis is complete. Yield loss and broken kernels resulting from midge feeding reduce the grade of the harvested grain, lowering its value. The concealed feeding niche of the larvae under the wheat glume and the short flight period of the adults make this pest difficult to control with insecticides.

Natural enemies, where they are established, are important regulators of *S. mosellana* populations. Many hymenopteran natural enemies are reported to attack *S. mosellana* in either its native or introduced range. The main parasitoids of *S. mosellana* eggs and larvae in the wheat head are *Macroglenes penetrans* (Kirby) (Hymenoptera: Pteromalidae), *Platygaster* sp., (Hymenoptera, Platygastridae) and *Euxestonotus error* (Fitch) (Hymenoptera, Platygastridae). All these parasitoids was introduced to North America shortly after the arrival of *S. mosellana* and are still a valuable tool in maintaining the population level below the threshold level. In addition, native Ground beetles (Coleoptera: Carabidae) are known to feed on midge larvae on the soil surface just before they enter winter diapause refuge in the soil in the fall and again in the spring before pupation and adult emergence. While specialist and generalist natural enemies both have potential to reduce wheat midge populations, their efficacy can be variable, either to due local environmental factors or, for the introduced natural enemies, the history of their spread, either tracking or not, the spread of the midge to new areas.

Macroglenes penetrans is the most important natural enemy of *S. mosellana*. It was introduced from Europe to Canada as part of a classical biological control program against wheat midge. In Canada, *M. penetrans* plays an important role in controlling *S. mosellana* populations, parasitizing up to 80% of the midge population yearly. In Montana, efforts to achieve biological control of wheat midge began in 2008 using *M. penetrans* introduced from North Dakota to Kalispell, around Flathead, Montana (B. Stougaard, Personal communication). From 2008 to 2014, no evidence of establishment of the parasitoid in Kalispell was found and a second attempt was made, using a second population of the parasitoid from Alberta. Approximately 700 *M. penetrans* were released in each of Pondera and Flathead Counties (Kalispell) in July of 2014. The total of 1400 *M. penetrans* in both of these some general region in western Montana.

In the wheat plant, larval *S. mosellana* feed on the developing wheat seed in a protected environment under the glume of the wheat seed. This concealed feeding niche protects the midge larvae from both parasitoids and pesticides, making timing of spraying critical for success. The ability of parasitoids to actively target their host, to synchronize their emergence with that of *S. mosellana* and to respond to changes in host populations makes them an attractive alternative to chemical control. The parasitoid *M. penetrans* is well synchronized with wheat midge larvae and able to reach them at their feeding sites. It is estimated to control anywhere from 40-80% of the *S. mosellana* population. While potentially able to limit damage by wheat head midge, efficacy of the parasitoid *M. penetrans* may fail either because of poor synchrony of adult parasitoids in a given area with the necessary host stage or because the pest has dispersed geographically into regions not yet occupied by the parasitoid. Host parasitization is dictated by the ability of the parasitoid to find prey at both long and short distances.

The pest, *S. mosellana*, is a weak flyer that primarily locates susceptible wheat at short range via plant volatiles. The movement and establishment of the wheat midge into new areas is therefore driven by movement of air masses during brief weather events. Recently, wheat midge has colonized wheat growing regions of western and central Montana (in 2006 and 2012, respectively) for the first time. This eruption of the pest in new wheat-growing regions has led many to speculate that the pest has left behind natural control factors like its parasitoid, *M. penetrans*. However, additional factors also affect *S. mosellana* population dynamics. Precipitation, either through rainfall or irrigation, plays an important role in midge emergence from the soil, as does the total available temperature. Differences in emergence and the timing of emergence under irrigated versus rain-fed conditions have not yet been evaluated. Moisture does, however, interact with insect emergence from the soil and from wheat heads before entering the soil and winter diapause. Larval emergence from wheat heads usually coincides with a summer rainfall, presumably because it loosens the soil, facilitating larval entry into the soil.

Conventional pesticide management of wheat midge recommends treatment if there is one adult midge for every 4–5 wheat heads during heading. Several insecticides have been found to be effective and can be applied to wheat at heading for *S. mosellana* control. Currently, the most common method of control is an application of chlorpyrifos (Lorsban™) or lambda-cyhalothrin

(Warrior®), timed to kill adult *S. mosellana* during their peak emergence. Peak emergence typically occurs over only a few days and each adult has a short life span. Thus, timing is very important but is difficult to accurately determine using pheromone traps. Furthermore, prolonged emergence in irrigated fields may expose new shoots after the 2-5 day activity of the pesticide has passed.

The incorporation of parasitism by *M. penetrans* into an integrated pest management program may allow for greater control while lowering the need for pesticide applications, which can harm non-target beneficial insects in the crop like the wheat stem sawfly parasitoids *Bracon cephi* (Gahan) and *Bracon lissogaster* Mues. (Hymenoptera: Braconidae), which have the same flight season as *S. mosellana*. Carabid ground beetle predators of *S. mosellana* are another important group of wheat midge natural enemies found in Montana wheat fields that may be harmed by pesticide applications. Late insecticide applications can actually prove detrimental to pest control by reducing certain populations of these parasitoids.

The present study was undertaken to determine the prevalence and dispersal rate of *S. mosellana* and its dominant parasitoid *M. penetrans* in the central Montana. This study examined the pest population and the prevalence of its natural enemy *M. penetrans* in central Montana, the area most recently colonized by *S. mosellana*. The study was undertaken by using three approaches, adults in pheromone traps, larvae in wheat heads, and larvae + cocoons in soil in winter. The objectives were (1) To see if wheat head midges are more abundant in dryland vs irrigated wheat; (2) To see if parasitoids of wheat head midge are more abundant in dryland vs irrigated wheat; and (3) To see if different measurements of wheat head midge abundance are correlated or not.

Materials and Methods

Study Area

Surveys for this study were carried out in central Montana, in the area around Valier, a wheat producing region known as the "Golden Triangle." *Sitodiplosis mosellana* was first documented in the study region in 2012. Work here was done in 2014 and 2015. Since 2012, wheat fields in the area have had persistent populations of *S. mosellana*. Wheat in the area is produced either as dryland or irrigated wheat, in rotation with canola, peas, or barley. The dominant crops in the region are spring and winter wheat. However, *S. mosellana* is pest on spring wheat in Montana. Surveys were conducted from May 10th – July 31st 2015 in spring wheat to span the flight season of *S. mosellana* and *M. penetrans*. The 33 sites were selected and marked those on the map in Fig. 1. In each of the 8 areas, pre-existing growers' fields that vary in size were chosen and established in the ~230 sq km wheat-producing area surrounding Valier, Montana (Fig. 1). Midge abundance in each field was estimated in four different ways: (1) pheromone traps for adult midges (in 2014), (2) sweep net sampling for adult parasitoids, (3) counts in wheat seed head for midge larvae, and (4) counts in soil cores for midge larvae or cocoons and associated parasitoids. Both dryland and irrigated spring wheat fields were sampled in roughly equal numbers.

Pheromone trapping of adult midges, 2015

Midge populations were surveyed in 2015 using delta traps baited with a pheromone lure (2,7-nonanediyl dibutyrate) (Great Lakes IPM, Inc., Vestaburg, MI 48891) with sticky card inserts

(Scentry®) at all of the 34 study sites (Table 1) Delta traps were painted green to reduce non-target catch and positioned at the height of the wheat canopy. Each trap was placed 20 m from the field edge. The trap height was adjusted weekly to match the height of the wheat canopy. The midge pheromone used attracts only male *S. mosellana*. Therefore, total midge population was calculated using documented sex ratios and average flight potential for male midges. Because sex ratios for *S. mosellana* are typically 1:1 across most populations, and because both male and female *S. mosellana* typically fly less than 500 m, we estimated local minimum female numbers near each trap from male trap catch by assuming this sex ratio and a flight distance of 400 m..

Wheat head infestation rates

Wheat heads were sampled before the current year *S. mosellana* larvae began dropping to the soil (July 31st – August 4th 2015). We sampled 34 locations for the presence of *S. mosellana* in soil within and in the vicinity of the Western Triangle Agricultural Research Center (Table 1). Estimates per wheat head were based on examining 200 wheat heads that were randomly selected and marked off the fields in a grid at each of the 34 sites and placed in mesh linen bags. These wheat heads were taken to the laboratory and dried under low humidity at room temperature before individually threshing wheat heads by hand to extract larvae *S. mosellana*. The average number of wheat heads per square meter was measured in each study site by randomly placing a square meter quadrat in three haphazard locations in each field and counting the total number of wheat stems post-harvest. The percentage of wheat infested out of the 200 randomly sampled wheat heads calculated and multiplied by our estimate of stems/m^2 to estimate larvae in wheat heads/m^2.

Densities of Wheat head midge overwintering stages in soil

Overwintering *S. mosellana* populations in soil (larvae+cocoons) were sampled in the fall of 2014 (n = 12) and spring of 2015 (n = 22) using a 5.7 cm dia bulb planter, coring to a depth of 7.6. Soil samples were selected along with transect starting 30 m from the edge the field, taking 10 samples per transect, with samples spaced 10 or more m apart. Each field was sampled only once, with only one transect. Soil samples were held at 6˚C until *S. mosellana* larvae and cocoons were separated from inorganic material using a soil washer (Flote-Tech Model A, R.J. Dausman Technical Services Inc., Rochester, Indiana, USA), where the organic material was gently broken apart from inorganic material water movement and air bubbles. Organic debris, including *S. mosellana* stages, was routed to a fine collection screen where larvae and cocoons were collected with forceps and placed in alcohol for examination and counting.

Parasitoid sweep net survey

Adult *M. penetrans* parasitoid abundance was estimated concurrently with sampling of wheat heads for *S. mosellana* larvae via sweep netting at all sample locations. Each sample consisted of 20 sweeps (180°) along a haphazardly directed line across the sample field within 400 m of the *S. mosellana* pheromone traps. Sweep net samples were taken once a day, five days per week, from wheat heading through anthesis, from June 1st - July 30th 2015. Adult parasitoids similar to *M. penetrans* were collected from field samples and were then identified in the laboratory using reference specimens and counted. Surveys were conducted at eight locations within Pondera County, MT (same locations as shown in Figure 1).

Data analysis
Abundances of wheat head midges and their parasitoid *M. penetrans* were compared in irrigated vs. dryland cropping systems using t-tests, for all of them. Sex ratios were calculated for irrigated and dryland *M. penetrans* populations. Phenology diagrams for male wheat head midges (pheromone traps) and both sexes of the parasitoid (sweep net samples) were constructed from sample data and the 10, 50 and 90 percentile points for emergence were calculated in relation to a scale of cumulative degree days (above 5 ˚C) starting January 1 of each year. Daily precipitation values were obtained for the study area using the USDA-NRCS weather station located at Western Triangle Agricultural Research Center (N 48.307404, -W111.921977 Lat. Long.). Correlations between midge populations in different locations were evaluated using linear models in the statistical package R. Data were log transformed where necessary to maintain model assumptions.

Results
Pheromone trap catch of adult midges, 2014
Summed over all 34 sites in the study area, phenology of wheat head emergence (Fig 2) showed that the first *S. mosellana* adults in 2014 were collected 16 June in the study area. By 23 June 23, 10% of *S. mosellana* had emerged (8.5 ± 1 days; mean ± SE) and 752 degree days had accumulated at or above 5˚C since 1 January. Fifty percent of *S. mosellana* had emerged by 26 June 26 (11.7 ± .5 days after first midge emergence) at 1,045 degree days. On 30 June (1,453 degree days) 90% of *S. mosellana* had emerged (25 ± 2.5 days after firstcollection). A few additional *S. mosellana* adults continued to emerge throughout July, well after the majority of the crop had progressed past susceptibility (boot – early heading). The emergence of *S. mosellana* followed a pattern of a large initial emergence peak followed by a long tail of declining trap captures throughout the season (Fig. 2A). In 2015, peak emergence occurred at all survey locations on 29 June (1,149 degree days). Late maturing wheat tillers were present throughout the flight season of *S. mosellana* in this study. The relative importance of infestation of tillers to main stems in the population dynamics of *S. mosellana* was not examined in this study.

Pheromone traps caught a total of 10,918 male *S. mosellana* from all study locations. The populations of *S. mosellana* were not significantly (P <0.05) different between irrigated and unirrigated cropping systems (1,500 ± 500 and 1,700 ± 1,100, respectively; mean ± SE) (t = -0.131, df = 2.91, P= 0.9043; Figure 3). Trapping area was estimated to be up to 1,600 m^2 (0.16 hectares) based on the flight potential of the male midge. The calculated midge population per hectare, assuming an even sex ration, was therefore 18,100 ± 5,300 midges (of both sexes) per hectare The estimated egg load for a population of this size, and thus the damage potential assuming a mean of 80 eggs/female is 724,200 ± 211,500 eggs/hectare. This number represents the maximum number of wheat seeds that could be infested per hectare assuming each egg is laid on a separate seed.

Wheat head infestation rates
Counts of *S. mosellana* larvae in wheat heads yielded 53 ± 24 midges per m^2, which amounts to 549,200 ± 260,700 *S. mosellana* larvae per hectare. The average egg load of a female *S. mosellana* is 80 eggs. Larval counts therefore suggest an average of 6,865 females per hectare. Pheromone traps instead predicted an average of 9,000 female *S. mosellana* (a 24% difference). Estimates of populations by larvae in wheat heads and by pheromone traps were not significantly

different, although they were very nearly significant (t = 2.2073, df = 9.38, P= 0.05352; Figure 4). Differences in population estimates likely stem from pheromone traps having a trapping distance greater than the 400 meters assumed for this study. Accounting for the 30% difference in trapping from larval counts equates to an effective trapping area of 0.21 hectares for the pheromone traps used in this study. There was no correlation between the number of *S. mosellana* larvae found in wheat heads per hectare and the number of *S. mosellana* adults caught in pheromone traps across all sampled fields (Figure 5).

Densities of wheat head midge overwintering stages in soil

Larvae of *S. mosellana* and cocoons represent the potential population of *S. mosellana* in the approaching season and are used to predict midge pressure in some regions (Jacquemin et al. 2014). Despite a higher concentration of *S. mosellana* in the soil of irrigated cropping systems, differences were not significantly different between irrigated and unirrigated systems (t = -1.5155, df = 18.847, P= 0.1463; Figure 6). The number of *S. mosellana* sampled from soil did not correlate with the number of adult *S. mosellana* in pheromone traps (Figure 7) nor the number of larvae in wheat heads in this study (Figure 8). Soil sampling predicts 636,100 ± 219,600 midge/hectare (mean ± SE), in contrast to the 13,600 and 18,100 midge/hectare predicted by end of season larval counts and pheromone traps (respectively).

Macroglenes penetrans survey

Macroglenes penetrans sweep net catch peaked shortly after peak capture of wheat head midges in pheromone traps.   (Figure 2B). In 2015, parasitoid peak emergence occurred on the 2 July (1,235 degree days) around Valier, MT. Meanwhile, the *M. penetrans* flight period lasted from 23 June 23 – 31 July. Ten, fifty and ninety percent population emergence occurred 3.4±1.3, 17.5±0.6 and 31.3±11.9 SE days after the first parasitoid was captured in a given field (26 June 26, 1 July, and 14 July 2015. There was no correlation between the number of *S. mosellana* adults captured in pheromone traps in a wheat field and the number of *M. penetrans* adults captured in sweep nets ($F_{1,6}$ = 0.147, P = 0.715, r^2 = 0.14).

Irrigation significantly increased the abundance of *M. penetrans* in wheat fields compared to unirrigated cropping systems (t = 2.8891, df = 4.065, P= 0.04375) (Figure 9). Irrigated fields had on average five times as many *M. penetrans* as unirrigated cropping systems (49.2 ±13 and 10.6±1.2, respectively). Meanwhile, the sex ratio of *M. penetrans* varied between sampling locations. Despite an apparent bias toward female parasitoids (female *M. penetrans* outnumbered males 2:1 overall; Figure 9A), differences were not statistically significant in this study (t = 1.4861, df = 13.248, P= 0.1607), and at individual study locations the ratio of male to female *M. penetrans* varied greatly (Figure 10B).

Acknowledgements

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Table-1: Density of *Sitodiplosis mosellana* larvae + cocoons (L+P) in soil /m^2 in winter of 2014-2015and pheromone catch of male *S. mosellana* adults in each field in 2015.

Site name	Type	L+P/m^2 mean± SD	adults/trap mean ± SD
Mageris	Unirrigated	0±0	249±7.6
Sunburst	Unirrigated	0±0	-
MFE	Irrigated	39±3.4	2,524±24.3
Sil Farm	Irrigated	78±2.8	-
Akin	Irrigated	0±0	244±3.6
Birch	Irrigated	0±0	289±6.6
Wingina	Unirrigated	0±0	519±4.3
Fretheim	Irrigated	0±0	267±4.2
Banka W	Unirrigated	39±2.6	15±4.3
GC	Unirrigated	78±6.2	101±2.8
JVD chucks	Irrigated	195±4.7	366±7.3
Banka E	Unirrigated	39±2.2	62±2.6
Crawford	Irrigated	156±6.3	1±0.5
Banka #1	Unirrigated	0±0	499±8.6
Banka #2	Unirrigated	78±4.1	40±2.1
Banka #3	Unirrigated	78±3.6	62±6.6
Banka #4	Unirrigated	117±2.8	15±2.9
Hoss	Irrigated	0±0	1±0.3
Parm	Unirrigated	39±6.3	5±2.4
Wheeler	Unirrigated	0±0	85±8.7
Moon	Irrigated	0±0	4±2.1
Valley	Irrigated	0±0	2±1.7
Section	Unirrigated	0±0	274±6.6
Hunter	Irrigated	0±0	9±2.2
Dewey	Irrigated	39±3.4	1±0.4
Turk	Irrigated	39±4.8	6±1.8
Webster	Irrigated	156±8.2	2±0.7
KB Stark	Irrigated	742±8.6	28±1.3
Dean #2	Unirrigated	0±0	39±4.1
Pondera5	Irrigated	117±4.4	2644±22.3
WTARC1	Irrigated	117±6.3	750±11.4
WTARC2	Unirrigated	0±0	249±6.5
KB #2	Irrigated	39±4.1	244±7.2
Casey	Unirrigated	39±2.7	245±9.2

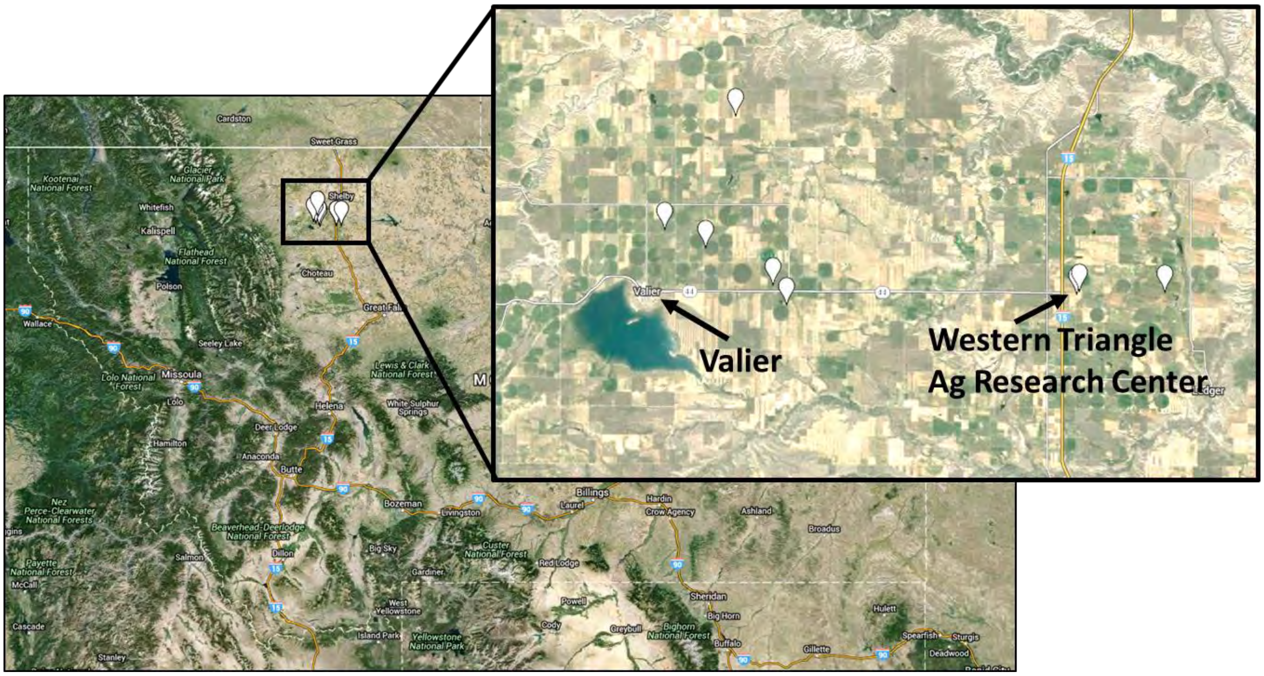


Figure-1. *Sitodiplosis mosellana* and parasitoid (*Macroglenes penetrans*) sampling locations (white markers) in Central Montana 2015.

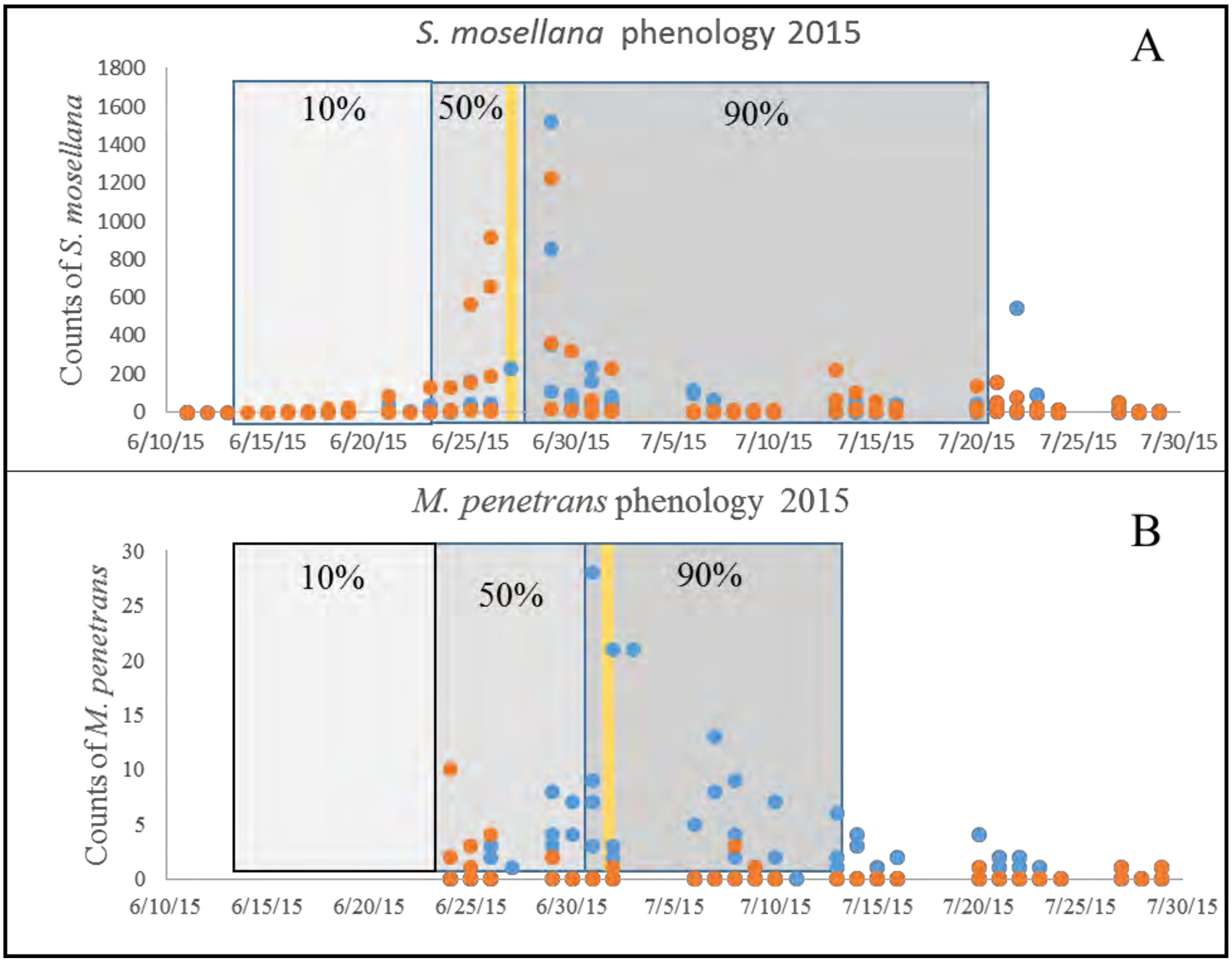


Figure-2. Flight phenology of *Sitodiplosis mosellana* (A) (male only) and *Macroglenes penetrans* (B) (both sexes) in Pondera County in 2015 in irrigated (blue) and unirrigated (orange) cropping systems. Gray areas denote the percentage of population emerged and the yellow bar denoted the peak emergence date.

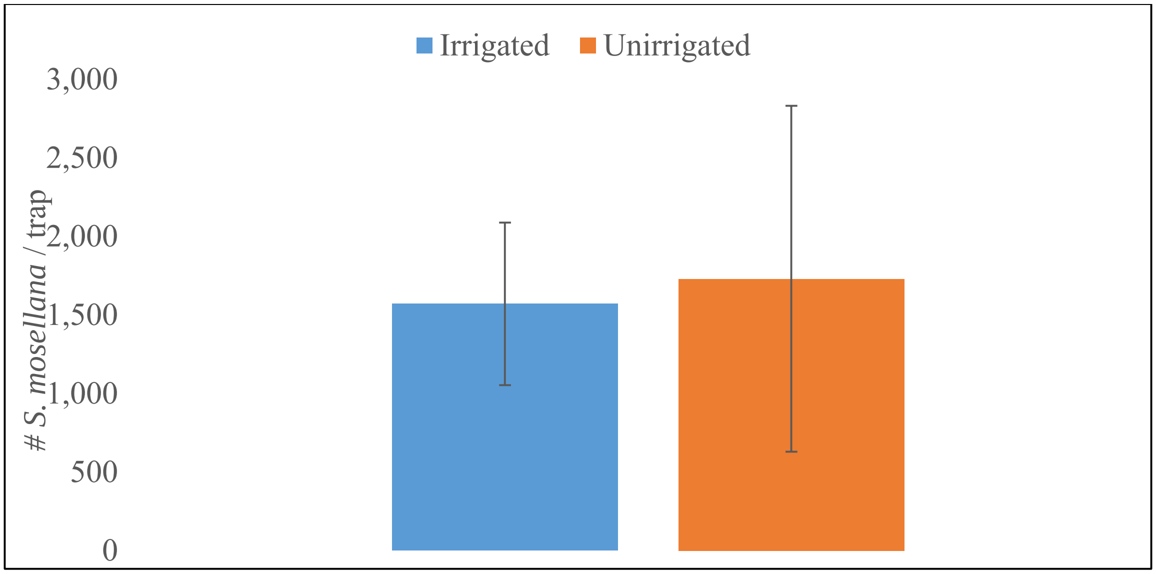


Figure-3. *Sitodiplosis mosellana* abundance in irrigated (blue) and unirrigated (orange) cropping systems (t = -0.131, = 0.9043).

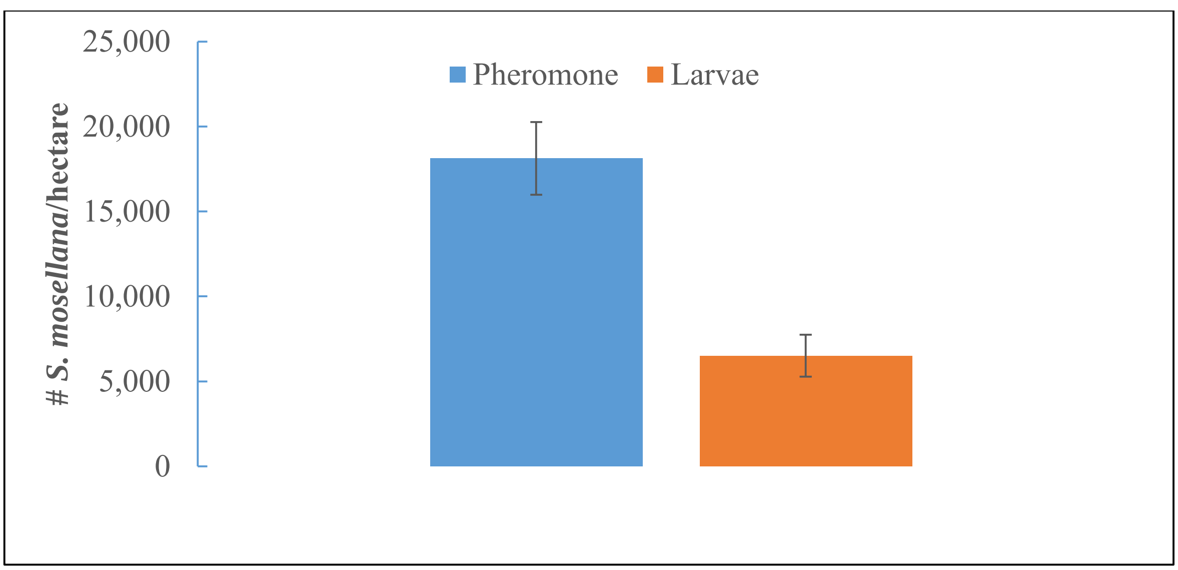


Figure-4. *Sitodiplosis mosellana* populations as predicted by pheromone baited trap and by counts of larvae in wheat heads (Larvae) were marginally significantly different by t-test (t = 2.2073, df = 9.38, *P*= 0.05352).

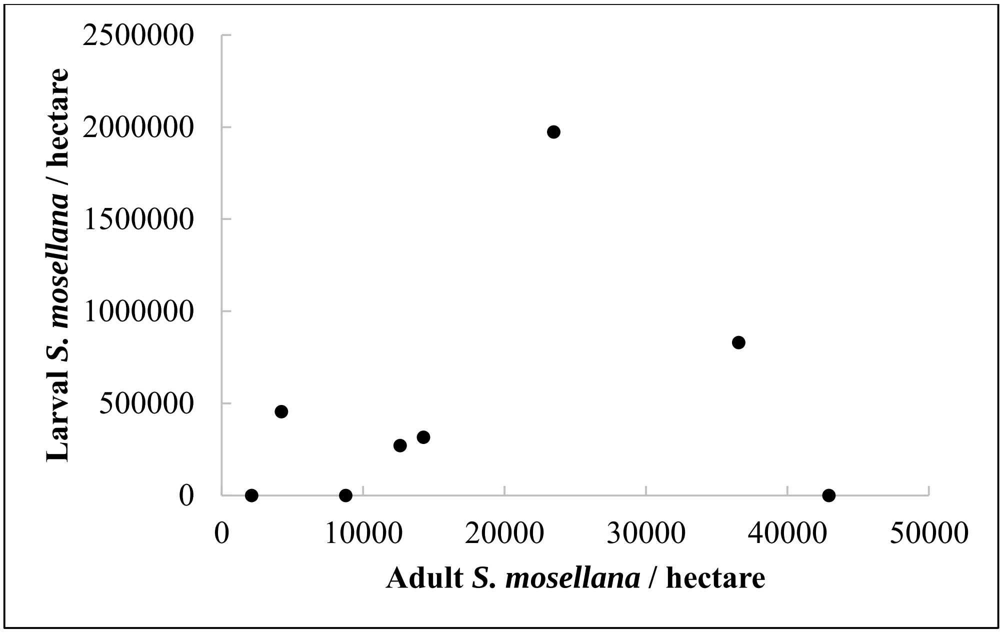


Figure-5. The number of *Sitodiplosis mosellana* larvae found in wheat heads per hectare does not correlate with the abundance of adults caught in pheromone traps in the same field in 2015.

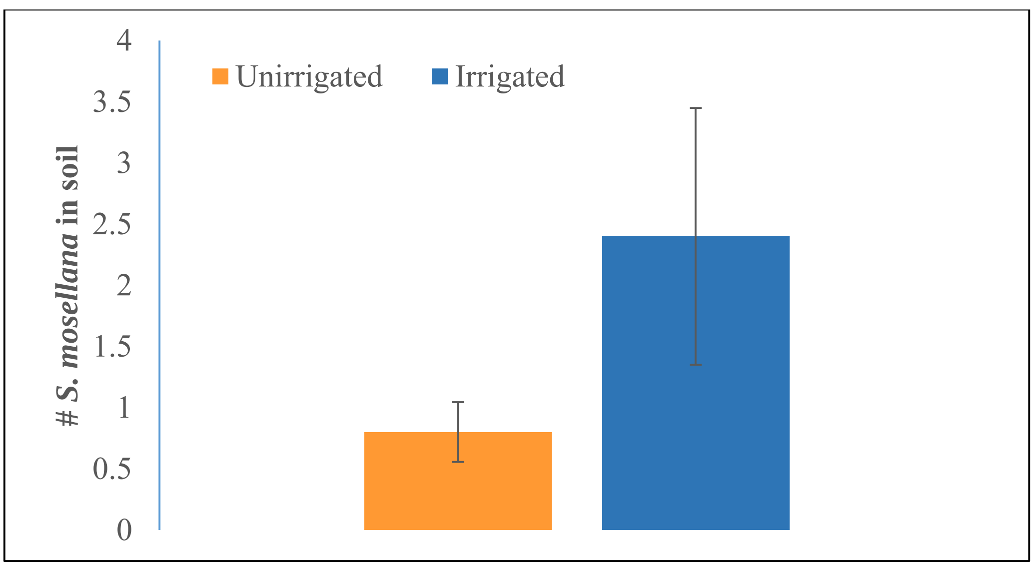


Figure-6. *Sitodiplosis mosellana* larval populations sampled from soil in 2015 in unirrigated (orange) and Irrigated (blue) cropping systems.

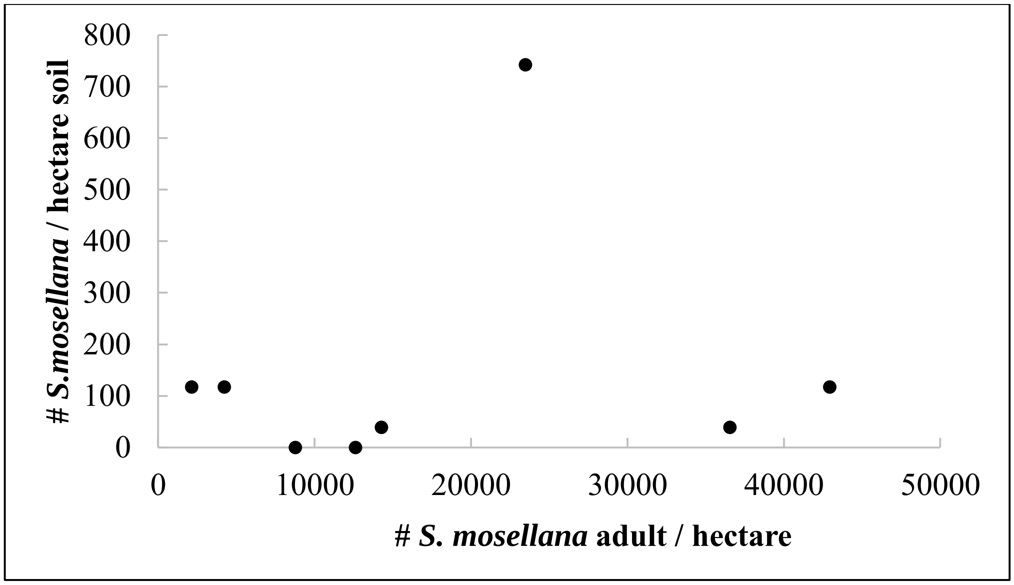


Figure-7. The number of *Sitodiplosis mosellana* per hectare in the pheromone traps was independent of the number of midges in the soil in the same field.

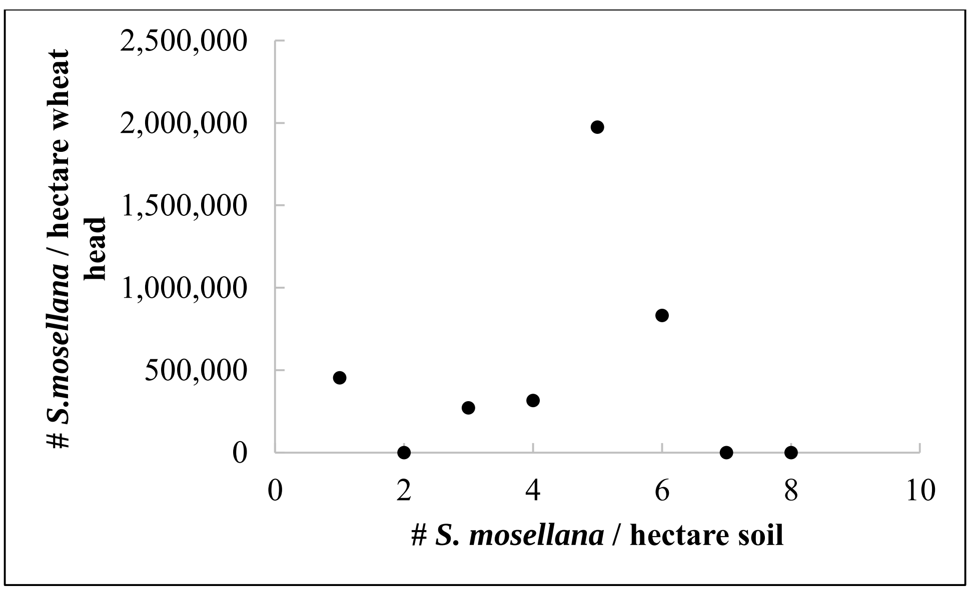


Figure-8. The number of *Sitodiplosis mosellana* estimated per hectare is independent of the number of larvae removed from wheat heads in the same fields.

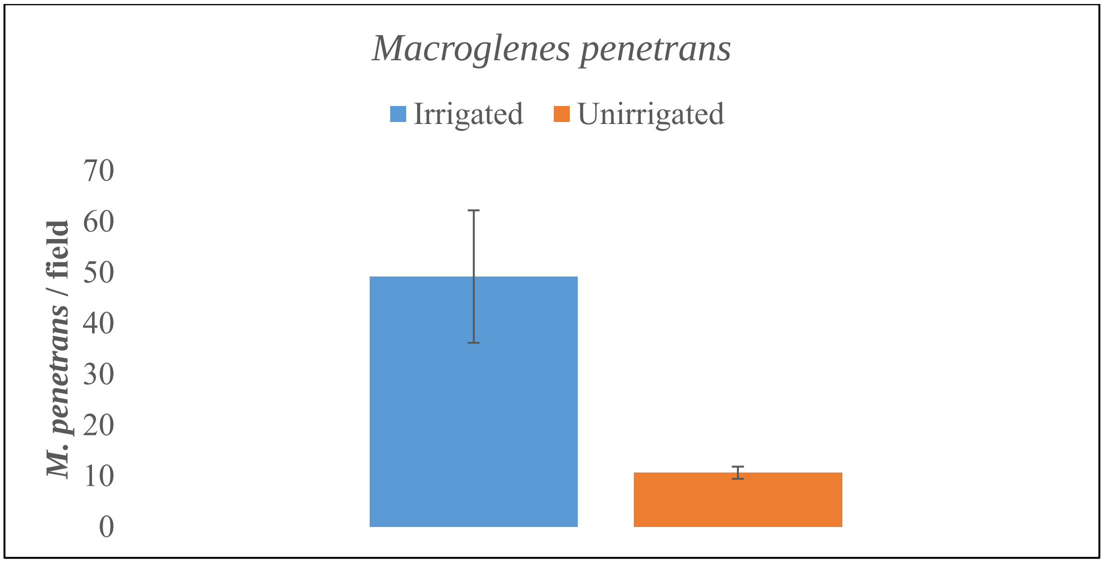
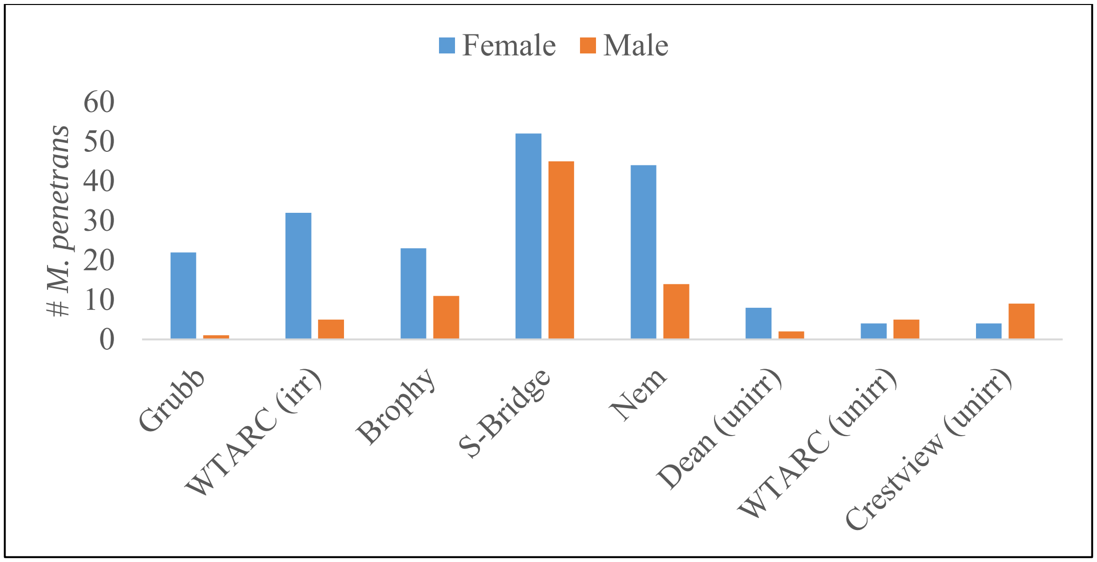


Figure-9. *Macroglenes penetrans* abundance in irrigated (blue) fields was significantly higher than in unirrigated (orange) cropping systems (t = 2.8891, df = 4.065, *P*= 0.04375). * indicates p < 0.05 significance level.



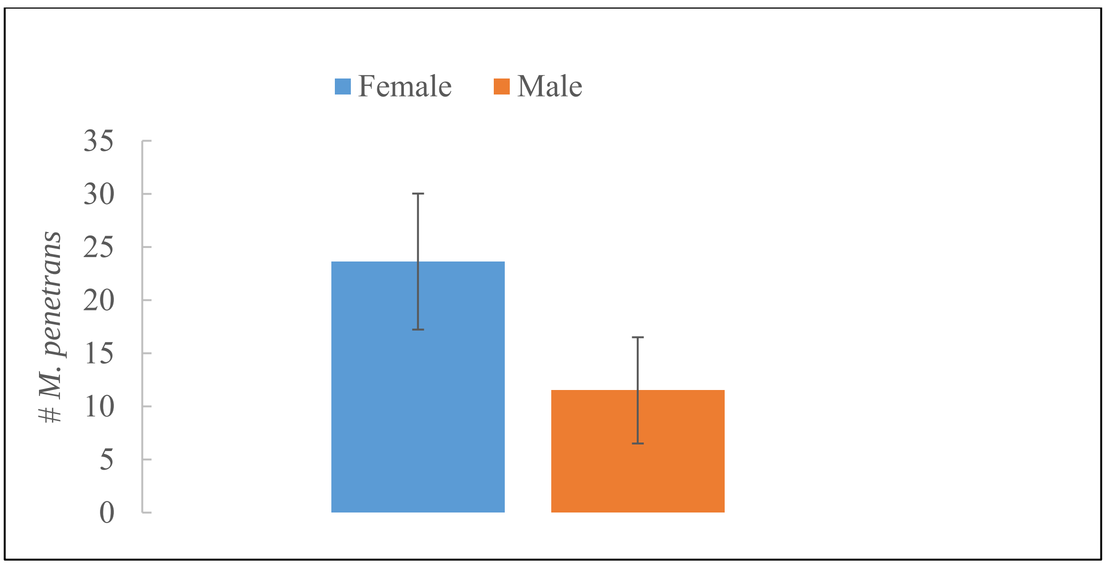


Figure-10. The sex ratio of female (blue) to male (orange) of *Sitodiplosis mosellana* in sweep net samples of wheat fields in the Valier area at each individual field (A) and combined across all fields (B). Sex ratios were often highly biased at individual locations, but were not significantly different across all fields (t = 1.4861, df = 13.248, *P*= 0.1607).

Efficacy of entomopathogenic nematodes and polymer gel against flea beetle (Coleoptera: Chrysomelidae) on canola

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Introduction

In North America, Canola (*Brassica napus* L.; Brassicales: Brassicaceae) is a major oilseed crop grown especially in the northern Great Plains of the United States and Canada. The crucifer flea beetle, *Phyllotreta cruciferae* (Goeze) (Coleoptera: Chrysomelidae), is a significant and economically an important insect pest of canola in the Northern Great Plains. Adult flea beetles emerge from overwintering sites in the spring as air temperatures warm to 14.7-20ºC. Overwintered adults initially feed on brassicaceous weeds, and as the crop emerges they move into canola fields. They immediately begin to feed on young cotyledons and leaves. Yield losses due to flea beetle damage each year, have been estimated to be tens of millions of U.S. dollars.

Figure-1: Canola crop (left) and flea beetles feeding on the canola leaves (right)

Crucifer flea beetle management is targeted at adults in early spring when the canola crop is in its seedling stage, the most vulnerable stage to flea beetle injury (Fig-1). The first line of defense against *P. cruciferae,* are chemical insecticides, as seed treatments or foliar sprays. Majority of canola acreages in the Northern Great Plains are planted to insecticide-treated seed since foliar chemical insecticides are effective against crucifer flea beetle, within a narrow window of opportunity. The reliance on chemical insecticide-based pest management increases the risk for crucifer flea beetle populations to develop resistance to these insecticides. The use of entomopathogenic nematodes applied in alternative treatment regimes or in combination with reduced rates of conventional insecticides may prevent or delay insecticide resistant development in crucifer flea beetle in canola. However, due to the concerns of insect resistance development to chemical insecticides, and impact of these chemistries on pollinators and beneficials, environmentally friendly pest management, drives the need to evaluate alternative insecticides that could be included in pest management programs for crucifer flea beetle.

Ecorational insecticides are products that are ecologically rational, with no or minimal effects on non- target organisms or the environment. Ecorational insecticides have been effective against numerous insect pests, and they may have potential in crucifer lea beetle management. Ecorational insecticides have unique modes of action compared with chemical insecticides, and can be used in insecticide resistance management and in environmental conservation. Entomopathogenic nematodes (EPNs) due to their ability to search for their hosts can serve as an alternative for used in managing soil dwelling pest, and flea beetles in *Brassica* crops. It has been reported in the literature that treatment of radish roots with *Sternenema Capocapsae* (250000-500000) reduced *Phyllotreta striolata* damage by 3 to 5 fold. The objective of our study was to evaluate reduced amounts of EPNs, their mixtures, and a polymer gel on crucifer flea beetle feeding injury to seedling canola and resulting yield.

Materials and methods

Trial Location

The trials were conducted at three field locations Cutbank (48° 50.22'N, 112° 17.746' W), Sweet Grass (48° 57.831'N, 111° 40.801' W), and at the Western Triangle Agricultural Research Center (48° 18.627'N, 111° 55.402' W in the Golden Triangle Area of Montana. Experimental plots were seeded on April 13, 2015 at Western Triangle Agricultural Research Center, April 20, 2015 at Sweet Grass, and on May 30, 2015 at Cutbank. Hy-Class canola seeds were used for the three locations. The canola crop was seeded at a rate of 12 seeds per 30 cm using a four-row plot drill with a row spacing of 30 cm apart. The herbicide RT3 (glyphosate) at the rate of 2.5 L/ha was applied before seeding for weed control. Fertilizer N, P, K, and S ratio was applied at 134.5, 25.2, 61.6, at the time of seeding. Additional application of 12.3, 25.2, and 0 kg/ha was broadcasted through the seed plot drill. The trials were conducted under dryland conditions.

Treatments

The entomopathogenic nematode treatments used were Ecomask (*Steinernema carpocapsae*), Hi (Heterorhabditis *indica*), Scanmask (*Steinernema feltiae*), Heteromask (*Heterorhabditis bacteriophora*), Ecomask + Heteromask (*Steinernema carpocapsae* + *Heterorhabditis bacteriophora*), Ecomask + Scanmask (*Steinernema carpocapsae* + *Steinernema feltiae*), Gaucho + Scanmask (imidacloprid + *Steinernema feltiae*), Barricade (Barricade polymer 4%), Barricade + Scanmask (Barricade polymer 2% + *Steinernema feltiae*), Barricade + Scanmask (Barricade polymer 1% + *Steinernema feltiae*). The source and rate of the materials are presented in Table 1.

Plot design and data collection

The plot sizes were 3.6 m ×1.2 m, with a buffer zone of 1.2 m to avoid cross contamination from spray drift. The treatments were sprayed on the plots using SOLO backpack sprayer calibrated at 87.33 gallons per acre, after arrival of flea beetles, and when canola was in the cotyledon to one-leaf stage. Untreated plots with water served as the control. Before foliar applications, each plot was rated for flea beetle feeding injury. Along a 4.6-m section of row, plants nearest to 0.3-m intervals were selected for a total of 10 plants. Residual activity of treatment applications was determined by post application ratings for flea beetle injury at 7 and 14 d after the application date for foliar insecticides. The feeding injuries and yield from the plots were evaluated for comparison of treatment effects. The injury ratings were converted into percent leaf area injury with modification OEPP/EPPO (2002). The scheme used was 1 = 0%; 2 = 2%; 3 = 5%; 4 = 10%; 5 = 25% leaf area injury. Plots were harvested on August 5, 2015 at Western Triangle Agricultural Research Center, September 14, 2015 at Sweet Grass, and on October 3, 2015 at Cutbank when 50% of the canola seeds were dark in color.

The canola crop was swathed from each whole plot at 30% seed moisture, and seed yield (kilograms per hectare) was collected from each experimental unit at 8-10% seed moisture between August and October.

Data Analysis.
Data were analyzed using multivariate analyses of covariance. Analyses of covariance were used to account for and eliminate effects of prefoliar treatment ratings on change in flea beetle feeding injury across dates after treatments. Treatment means were compared by multiple *t*-test obtained by least square means statement of GLM at the 0.05 level. Main and interaction effects of location by treatment on flea beetle feeding injury ratings and yields were determined using PROC GLM procedure (SAS Institute 2015).

Results

Percentage of leaf area injury
Crucifer flea beetle feeding leaf area injury is presented in Table 2. Across the locations, the seed treatment Gaucho 600 resulted in the lowest percent leaf area injury at 7 to 14 DPT (Table 2). At WTARC the leaf area injury ranged from 1 to 3.3% at PT (Table 2). At 7 DPT Gaucho had a significant leaf area injury of 3.1% (Table 2). Among the treatment combinations or mixtures Gaucho + Scanmask was the only treatment that resulted in a lower leaf area injury of 5.8%, and this was not significant when compared to Gaucho and water (Table 2). At 14 DPT Gaucho resulted in significantly lowest leaf area injury of 8.0%. However, this was not significant when compared to Gaucho + Scanmask treatment which resulted in a leaf area injury of 9.8%. The rest of the treatments had leaf area injury which were either not significant or were significantly higher compared to the control.

At Sweetgrass the leaf area injury varied from 2.0 to 5.3% at PT (Table 2). Treatment of canola with Gaucho 600 and Gaucho + Scanmask resulted in a significantly lower leaf area injury of 4.7 and 6.0%, respectively at 7 DPT (Table 2). Ecomask, and Baricade (2%) + Scanmask with leaf area feeding injuries of 7.4% were the only treatments with flea beetle feeding that were not significant compared to Gaucho, the seed treatment (Table 2). The rest of the treatments had leaf area injuries which were not significant compared to the water control. The leaf area injury at 14 DPT showed that Gaucho 600 (12.4%), and Gaucho + Scanmask (14.3%) had leaf area injury that were significantly lower (Table 2). Except Ecomask, Scanmask, Ecomask + Heteromask, Ecomask + Scanmask all the treatments had leaf area injury which were significant compared to the control.

The leaf area injury at Cutbank ranged from 4.3 to 8.6% at PT (Table 2). Gaucho + Scanmask, and Gaucho treatments had leaf area injuries of 4.2 and 14.3%, respectively (Table 2). Except Ecomask + Heteromask which had leaf area injury of 20.2%, the leaf area injuries among the treatments were not significant at 7 DPT. At 14 DPT Gaucho 600 was the only treatment that had a significantly lower leaf area injury of 13.2% (Table 2). Gaucho + Scanmask treatment leaf area injury of 16.5% was not significant when compared to Ecomask (19.6%), Scanmask (19.2%), Ecomask + Scanmask (19.6%) (Table 2).

Yield traits

Canola yield is presented in Table 3. The yield (F= 2.69; df = 35, 143; P < 0.0001) and location (F= 28.97; df = 2, 22; P < 0.0001) effects were significant. However, treatment (F= 1.63; df = 11, 22; P = 0.1014) and location*treatment (F = 0.84; df = 2, 22; P = 0.6704) effects were not significant. Gaucho 600 the seed treatment resulted in the highest yield of 843.2 kg/ha at WTARC (Table 3). However, this was not significant when compared to the yields from Hi (804.0 kg/ha), Heteromask (669.1 kg/ha), Ecomask + Heteromask (665.3 kg/ha), Ecomask + Scanmask (801.8 kg/ha), Barricade (4%) (758.3 kg/ha), Barricade (2%) + Scanmask (669.5 kg/ha), and Barricade (1%) + Scanmask (739.5 kg/ha).

Baricade (1%) + Scanmask treatment resulted in the highest yield of 1020.8 kg/ha at Sweetgrass (Table 3). Except with Water (588.2 kg/ha), Heteromask (560.3 kg/ha), and Barricade (2%) + Scanmask (604.5 kg/ha), the yield among the treatments were not significant (Table 3).

Baricade (1%) + Scanmask treatment resulted in the highest yield of 670.2 kg/ha at Cutbank (Table 3). This yield was however not significant when compared to Barricade (2%) + Scanmask (469.5 kg/ha), and the Water treatment (427.1 kg/ha) (Table 3). Yields were not significant among the other treatments.

Summary and Conclusion

At WTARC we observed medium flea beetle feeding pressure (200 - 300 flea beetles per trap week). At Sweetgrass we observed high flea beetle feeding pressure (200 - 300 flea beetles per trap week), whilst at Cutbank extremely high flea beetle feeding pressure was observed (> 300 300 flea beetles per trap week. The data indicates that Baricade (1%) + Scanmask can serve as alternative to the seed treatment. Moreover, Scanmask can be used to complement the seed treatment when the protection period is exceeded.

Acknowledgements

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Table 1. Materials and rates of application in each treatment

Treatment	Active Ingredient	Dose	Amount /Gallon (3.785 L) water	Source
T1: Water spray (Control)	Water	Same volume as in mix	3.785 L	-
T2: Gaucho	Imidacloprid	190 ml/ 45 kg seed		Bayer Crop Science
T3: Ecomask	*Steinernema carpocapsae*	30,000/m^2	1.3699 g	BioLogic Company Inc, Willow Hill, PA
T4: Hi	*H. Indica*	30,000/m^2	20.85 g	Southeastern Insectaries, Perry, GA
T5: Scanmask	*S. feltiae*	30,000/m^2	1.7098 g	BioLogic Company Inc, Willow Hill, PA
T6: Heteromask	*Heterorhabditis bacteriophora*	30,000/m^2	1.6995 g	BioLogic Company Inc, Willow Hill, PA
T7: Ecomask X Heteromask	*S. carpocapase &H. bacteriophora*	30,000/m^2 (15,000 each nematode	0.685 g + 0.8496 g	BioLogic Company Inc, Willow Hill, PA
T8: Ecomask X Scanmask	*S. carpocapase &S. feltiae*	30,000/m^2 (15,000 each nematode)	0.685 g + 0.8549 g	BioLogic Company Inc, Willow Hill, PA
T9: Gaucho X Scanmask	Imidacloprid *& S. feltiae*	190 ml/ 45 kg seed and 30,000/m^2 nematode	190 ml/45 kg seed (Seed treatment) + 1.7098 g product	See above
T10: Barricade (Control)	Barricade Polymer	Barricade 4% w/v (Coverage!)	151.4 ml (g)	Barricade International http://firegel.com/
T11: Barricade X Scanmask	Barricade *& S. feltiae*	Barricade 2% w/v and x 30,000/m^2 nematode	75.7 ml (g) + 1.7098 g	See above
T12: Barricade (1%) X Scanmask	Barricade 1% *& S. feltiae*	Barricade 1% w/v and 30,000/m^2 nematode	37.5 ml (g) + 1.7098 g	See above

Table 2. Crucifer flea beetle feeding leaf area injury to seedling canola treated with entomopathogenic nematodes in Montana

Treatment		WTARC[a]			Sweetgrass			Cutbank	
	PT[b]	7 DPT[c]	14 DPT[d]	PT	7 DPT	14 DPT	PT	7 DPT	14 DPT
	……Leaf area injury (%)……								
Water	2.5	5.9 abc	15.6 b	5.3	8.9 bcd	21.9 d	8.6	16.8 ab	22.3 c
Gaucho 600	2.0	3.1 a	8.0 a	2.0	4.7 a	12.4 a	4.5	14.3 a	13.2 a
Ecomask	3.3	7.6 bcd	15.9 bc	2.7	7.4 abc	21.3 cd	8.3	18.9 ab	19.6 bc
Hi	2.1	11.3 def	15.1 b	2.5	8.9 bcd	19.2 bc	5.2	15.6 ab	19.9 c
Scanmask	1.9	14.7 f	19.2 c	3.3	9.7 ab	20.9 cd	7.1	15.7 ab	19.2 bc
Heteromask	1.4	14.7 f	19.2 c	4.1	9.8 cd	18.9 bc	6.5	19.0 ab	21.3 c
Ecomask + Heteromask	1.3	12.2 ef	19.2 c	3.5	8.2 bcd	20.2 bcd	7.9	20.2 b	21.3 c
Ecomask + Scanmask	1.7	9.8 ed	15.3 b	4.2	8.1 bcd	20.6 bcd	8.2	16.0 ab	19.6 bc
Gaucho + Scanmask	1	5.8 ab	9.8 a	2.2	6.0 a	14.3 a	4.3	14.2 a	16.5 b
Barricade (4%)	1.4	9.8 cde	14.4 b	3.8	9.7 cd	18.2 b	6.6	15.5 ab	20.6 c
Barricade (2%) + Scanmask	1.7	10.0 ed	15.9 bc	3.0	7.4 abc	18.2 b	8.2	15.7 ab	20.6 c
Barricade (1%) + Scanmask	1.9	10.1 ed	16.4 bc	3.1	10.5 d	19.2 bc	6.6	17.0 ab	19.9 c

[a], WTARC, Western Triangle Agricultural Research Center.

[b], PT, pre foliar application.

[c], 7 DPT, days after foliar and granular application.

[d], 14 DPT, days after foliar and granular application.

Table 3. Canola seed yield after treatment of seedlings with entomopathogenic nematodes in Montana

Treatment	WTARC[a]	Location Sweetgrass Yield (kg/ha)	Cutbank
Water	354.8 d	588.2 b	427.1 ab
Gaucho 600	843.2 a	810.6 ab	305.1 b
Ecomask	620.0 c	778.10 ab	222.7 b
Hi	804.0 ab	645.1 ab	405.8 b
Scanmask	641.7 bc	699.4 ab	351.5 b
Heteromask	669.1 abc	560.3 b	403.9 b
Ecomask + Heteromask	665.3 abc	701.6 ab	388.6 b
Ecomask + Scanmask	801.8 ab	721.8 ab	358.0 b
Gaucho + Scanmask	650.6 bc	761.6 ab	413.0 b
Barricade (4%)	758.3 abc	720.3 ab	357.9 b
Barricade (2%) + Scanmask	699.5 abc	604.5 b	469.5 ab
Barricade (1%) + Scanmask	739.5 abc	1020.8 a	670.2 a

[a], WTARC, Western Triangle Agricultural Research Center.

Evaluation of trap crops for the management of wireworms (Coleoptera: Elateridae) on spring wheat

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Introduction

Different cereals, oilseed and legumes were evaluated as trap crop intercropped with wheat for the management of wireworms (Coleopteran: Elateridae) on spring wheat at two locations Valier and Conrad, MT from May to Mid-August, 2015. Four cereals: corn, wheat, durum and barley, two legumes: pea and lentil and one oilseed canola were the seven treatment that were intercropped with main crop wheat to reduce the damage and management of wireworms. Plant count of wheat and trap crops were taken using line intercept of 1m and wireworm number for each treatment were determined by destructive soil samples. No significance difference was observed in total number of plant count whereas there were significant difference in number of healthy plant or no damage plant count due to wireworm in treatment pea and lentil in both sites. Also, the number of wireworms differ significantly for wheat intercropped with pea and lentil in Valier but only for wheat intercropped with Pea in Conrad.

Materials and Methods

Location and experimental design

The trails were conducted on two locations: Valier and Conrad, Montana from May to August, 2015 in Golden Triangle Region of Montana. These fields have history and well known for having infested with wireworms. Valier location has sandy loan soil texture but soil of Conrad has silt clay, rich in humus. Spring wheat is the main crop grown in these locations from the past few years.

The study area is a plot of 40 m×12.6m, that was measured and divided into 42 experimental units each measuring 1.2m×4.8m. The complete randomized block design with six replications was conducted. There blocks were separated by 1m border and two plots were separated by 0.45m within a replication. Each plot has four rows having 0.3m gap between two rows; the first and third rows are always the main crop wheat and trap crops were used as intercrop in second and last row. The study has seven treatments that is seven trap crops those were intercropped in wheat. The species of trap crops used were Montech 4193 pea (T1), HyClass 955 canola (T2), Kandy Korn sweet corn (T3), Mountrail durum (T4), Metcalfe barley (T5), Greenland lentil (T6) and Duclair wheat as control (T0), respectively.

Field Preparation and Sowing

Minimum tillage was done for making the field ready for sowing. Seed driller was used for sowing. The rate of sowing was 22 seeds/m, 26 seeds/m, 26seeds/m 24 seeds /m, 7 seeds/m and 53 seeds/m for wheat, lentil, barley, durum, corn and pea respectively. In Valier, the sowing was done on May 4, 2015 while in Conrad the sowing was done on May 8, 2015. At the time of sowing, herbicide AMS having active ingredient Ammonium sulphate at the rate 2.24 kg /ha and fertilizers N, P and K ratio at 224.2,0, 22.4 kg /ha was broadcasted respectively. The sowing date was done on May 4, 2015 in Valier and May 8, 2015 in Conrad.

Data collection

The Effectiveness of Trap crop

This will be done based on number of healthy seedling/ plant count of main crop wheat for each treatment and number of wireworms found in soil sample from wheat and the following trap crops in the plots (Fig-1).

Figure-1: Soil sample processing for wireworms

Plant/Seedling count

The number of plants/seedling in each plot was measured by counting plants stand from randomly selected line intercept of 1m. In an individual plot, from the two rows of wheat three spots were selected at random and the counting was done. Similar method was followed to trap crops intercropped with wheat. While taking the count we categorize the wheat quantitatively into damaged and healthy. Healthy one was those that had no any damage in the best plant within the sampling meter. We do graded the damage as 20, 40, 60, 80 and 100% based on the wilting or yellowish appearance and plant height. Due to the cold climate there was delay in germination. The first data was taken on May 22, 2015 in Valier and on May 26 in Conrad. The following recording was done at the interval of a week in both sites. After fifth reading on both sites we increased the time period between two readings to two weeks that is 14 days. All together we took eight plant count in both sites.

Figure-2: Soil sample processing and recovery of wireworms

Wireworm sampling.

Destructive soil sampling method was applied to sample the wireworms. An instrument will be build up having dimension of 0.15*0.15*0.15m^3 that was used to take the soil sample. The samples were taken at random from each row in a plots. In row, the sampler was placed in such a way that the row was in middle and using the metal hammer, the sample was be taken. These samples was then put in plastic bag label it and brought to the Research Centre where they were processed and number of wireworms were counted and recorded. These wireworms were then kept in small plastic pots and put in the refrigerator at 8 degree Celsius. The soil sample was collected the day after the plant count was taken (Fig- 2). Total eight soil samples were collected from both sites.

Statistical Analysis
Analysis of variance (ANOVA) was used to analyze difference among treatment for total wheat plant counts and no damage or healthy plant counts. Pair difference or contrast were made for means of plant count at 95% confidence interval. Values of $P < 0.05$ were considered significant. T-test at 95% confidence interval was used to analyze the different for number of wireworms trapped among treatments.

Results

Plant count
In Valier location, there were no significant difference among total plant counts of wheat between treatments and the control ($F_{6,49}$= 1.13, P> 0.05). However, the number of healthy wheat plant counts for treatments showed almost significant difference ($F_{6,49}$ = 2.20, P= 0.058; Fig-3). The pairwise difference or contrast of treatment for total wheat plant at 95% confidence interval, we found that there were no significant difference between any one treatments with control. On the other hand, the contrasts for healthy wheat plant of treatments and control, there were

significant difference among treatment pea with control and treatment lentil with control both have P value less than 0.05. The other pairs: canola vs control, corn vs control, durum vs control, barley vs control do not showed significant difference.

In Conrad location, there were no significant difference among total plant counts of wheat between treatments and the control ($F_{6,49}$= 0.923, P> 0.05; Fig-4). However, the number of healthy wheat plant counts for treatments showed almost significant difference ($F_{6,49}$ = 3.300, P= 0.008). The pairwise difference or contrast of treatment for total wheat plant at 95% confidence interval, we found that there were no significant difference between any one treatments with control. On the other hand, the contrasts for healthy wheat plant of treatments and control, there were significant difference among treatment pea with control and treatment lentil with control both have P value less than 0.05. The other pairs: canola vs control, corn vs control, durum vs control, barley vs control do not showed significant difference.

Acknowledgements
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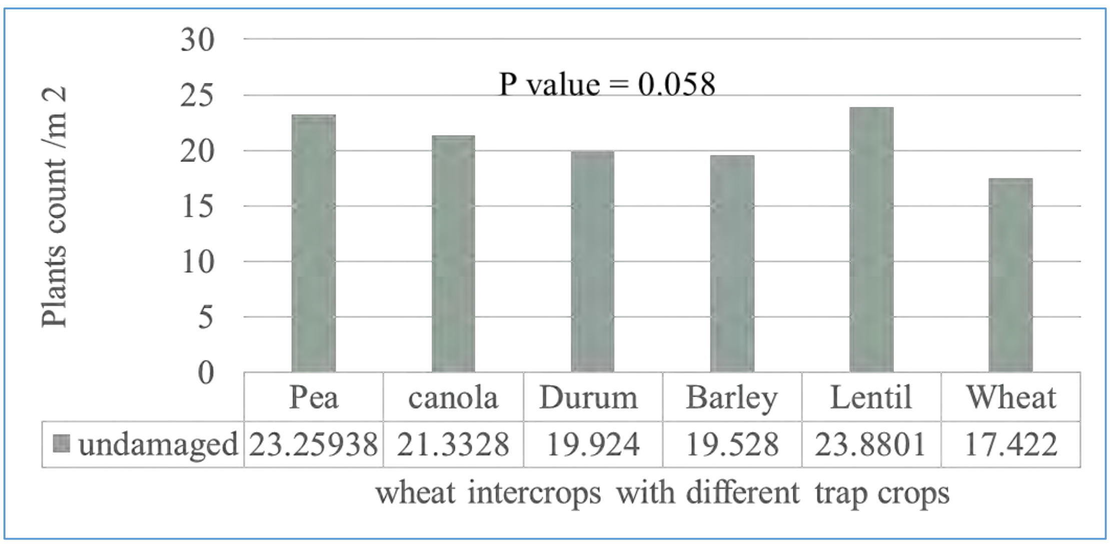

Figure-3: Number of healthy plants recorded/ m^2 in Valier.

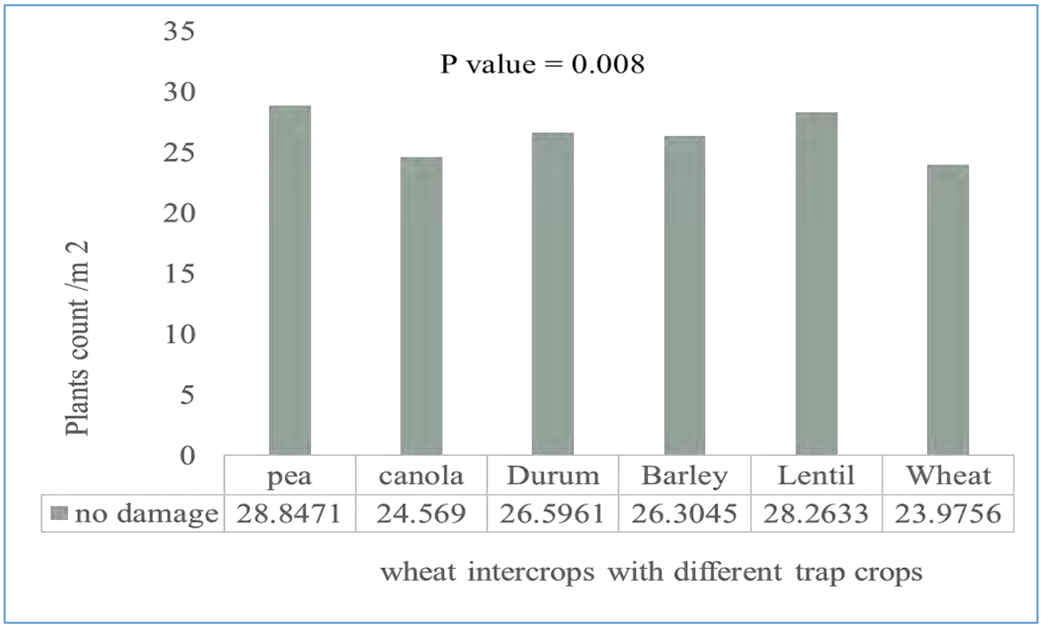

Figure-4: Number of healthy plants recorded/ m^2 in Conrad.

Wireworms:

For Valier location, the total number of wireworms found was 683. The number of wireworms found in each treatment was shown in Fig-5. The pair difference between the numbers of wireworms found in wheat row of treatment with wheat row of control showed there were significant difference among wheat pea (Wp) 0.039.

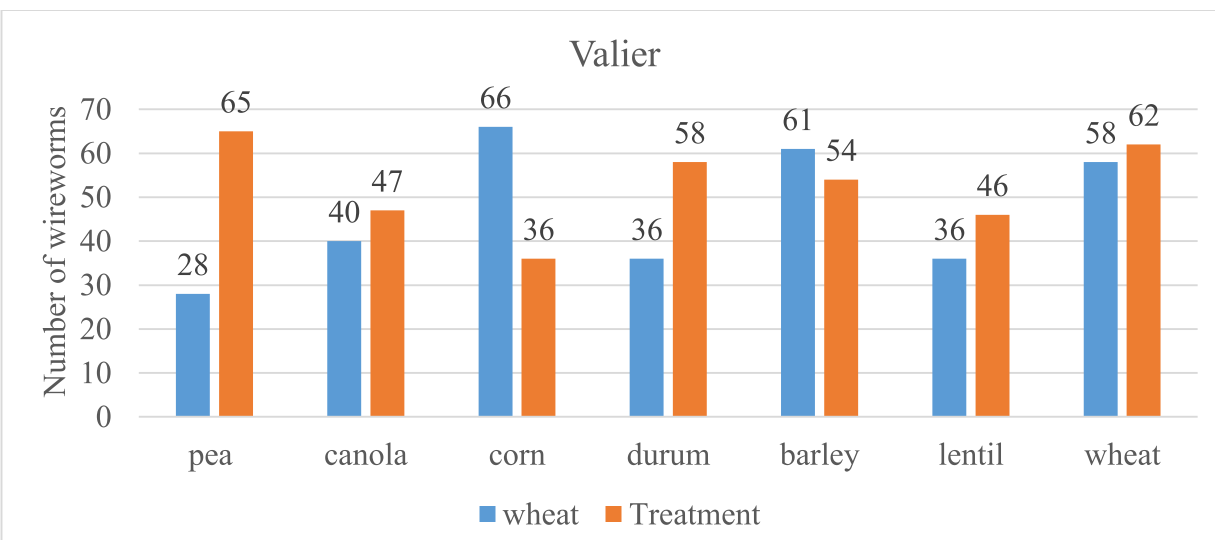

Figure-5: Number of wireworms recorded per 2.5 kg soil destructive soil sample in Valier.

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For Conrad location, the total number of wireworms found was 391. The pair difference between the numbers of wireworms found in wheat row of treatment with wheat row of control showed there were significant difference among wheat pea (Wp) with control having p value 0.013 respectively (Fig-5).

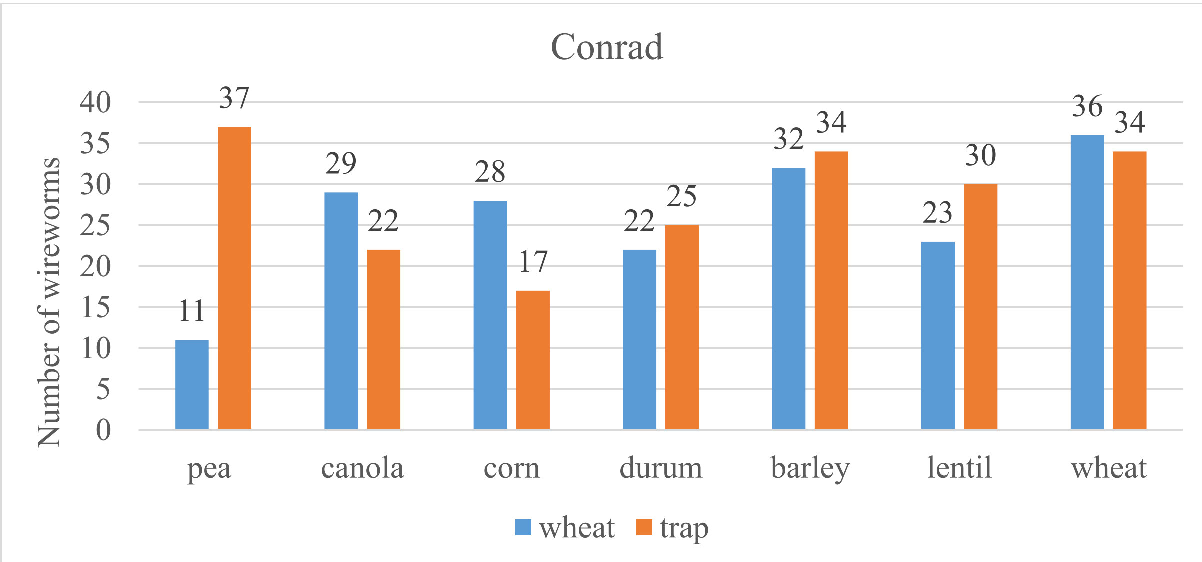

Figure-6: Number of wireworms recorded per 2.5 kg soil destructive soil sample in Conrad.

Evaluation of reduced risk insecticides for management of wireworms (Coleoptera: Elateridae) on spring wheat

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Introduction

Wireworms, the larvae of click beetles (Coleoptera: Elateridae) are significant and economic pest worldwide especially in temperate and subtropical parts of the world. Wireworms as soil dwelling pests have cryptic life cycles which makes sampling difficult, and this hinders plant damage prediction. Soil-dwelling insects are economically damaging pests in many agricultural ecosystems. Wireworms are severe pests persist in the soil as larvae for several years and are often present in agricultural fields at planting (Fig-1). Plant-eating wireworms are generalist and feeds on a large variety of crops. They cause damage to seeds, root, stems, tubers, other harvestable plant parts by feeding, chewing, or drilling into below-ground plant tissues and structures, thereby enhancing pathogens, stopping plant growth or killing plants. Moreover attacks later on stems stimulates heavy production of tillers which does not lead to heads production. This injury can cause wilting, stunting, thinning, plant maturity delays, death to seedlings, which leads to yield reduction and affects crop value. When wireworm populations are extremely high entire fields can be lost. In many fields these results in patches, allows weeds to get ahead, and make use of the available moisture, thereby preventing or lessening the tillering of adjacent uninjured plants. In many agroecosystems soil-dwelling insects are difficult to manage due to the fact that poor germination, herbicide carryover, or other pest damage can be inadvertently attributed to soil-dwelling insects. Key agricultural crops affected by wireworms include wheat, barley, rye, potatoes, corn, tobacco, most vegetables, and small fruits.

Figure-1: Wireworm larvae and adult click beetle

In view of the difficulties in estimating prevalence and damage, wireworms as soil-dwelling pests are managed often with preventive insecticides applied at planting. Historically, wireworms have been managed with inexpensive, and broad-spectrum insecticides (eg. organochlorines, organophosphates, and carbamates). Wireworms are resurging as key and important pest, in view of the fact that most of the effective insecticides for their management have either been cancelled or restricted due to environmental and health concerns. Seed treatments with neonicotinoid insecticides are used currently for managing soil dwelling pests. Neonicotinoids provide seed and foliar protection for several weeks after planting, and are used widely for many crop pests due to the low used rates and enduring residual activity. However, some of these chemicals have some effects in the agroecosystem and the environment on non-target organisms (pollinators and other beneficials). Reduced risk insecticides have been used to control insect pest damage on agricultural crops. Even though entomopathogenic nematodes and fungi have shown some promise, not much work has been done in evaluating their efficacy under field conditions for wireworm management. Therefore reduced risk insecticides that can complement or serve as alternative to the seed treatment can help in reducing the amount of chemical load in the environment. Field studies were therefore conducted to evaluate the effectiveness of reduced risk insecticides and their mixtures in managing wireworms in spring wheat.

Materials and Methods

Study sites

Prior to the initiation of the experiments we extensively sampled each farm site to determine the presence of wireworm through soil digging and bait traps. The experiments were initiated in 2015 on two commercial farms in Conrad and Valier in the 'Golden Triangle' area of Montana from April-September. Plot sizes were 3.6 m × 1.2 m, and were separated from each other by a buffer of 0.6 m to avoid cross contamination from spray drift. Each plot comprised of 4 rows, spaced 0.3 m apart. The wheat variety 'Duclair' was seeded at a rate of 22 seeds per 30 cm with a four-row plot drill at both locations. The herbicide glyphosate (RT3®, Monsanto Company, St. Louis, MO) was applied before seeding, at a rate of 2.5 L/ha for weed control, following regional farming practice. Fertilizer with an N, P, K ratio of 224.2, 0, and 22.4 kg/ha was broadcast while planting, and an additional application of 12.3, 25.2, and 0 kg/ha, respectively, of the three nutrients were placed through the seed plot drill. The trials were conducted under overhead irrigated conditions with a typical application of 5 cm of water as needed. The first irrigation was applied 30 days after treatment. The insecticides and rates used are as listed in Table 1.

Plot design and data collection

A randomized complete block design (RCBD) with four replications, 3.6 m*1.2 m treatment plots separated by 0.60 m buffer zones to cross contamination of treatment effects. The number of standing plants and seed yield in each plot were recorded to assess effectiveness of the treatments. A Hege 140 plot combine was used to thrash the wheat plots to collect grain kernels for yield assessment.

Plant stand count

Emerged wheat seedlings were counted by measuring off 1 m in the middle of the centermost 4 rows in each plot. The start and end of the 1 m lengths were marked with plastic labels and seedlings were counted within these marked areas for once per week for 4 weeks after treatment. Pre-treatment plant stand counts were also taken before spray applications.

Larval wireworm sampling

Stocking bait traps were used for assessing wireworm presence and estimating their abundance. Wireworm abundance in each plot was measured when soil temperatures were between 7-10°C using stocking bait traps. The stocking bait traps were placed in the center 1 m apart at (1.3, 2.3, and 3.3 m) along the length of the plot. About 90 g of wheat seeds were placed in nylon socks, tied shut with string, leaving a tail end of about 30 cm. The traps were immersed in water for 24 hours for the grain to start germinating before using in the field. These germinating grains in the stocking traps makes them attractive for wireworms. A hole of about 7-15 cm deep and 20-25 cm wide was dug with a shovel. The nylon stocking traps were pressed down to spread the grain mixture as wide as possible. The strings were left above the soil surface to help relocate the stocking trap later. The stocking traps were then covered with about 3-5 cm of soil. A black polythene sheet of about (12 cm×12 cm) of area were then placed on the covered holes and 4 metal fabric garden pegs used to secure them on the soil surface. Three stocking traps spaced 1 m apart were placed in the middle row of each plot. The stocking traps were placed a week (7 days) before the spray applications. One trap from each plot was removed just before spraying to serve as pre-treatment population trap count. The second and third traps were removed 14 and 28 days post treatment spray applications. Larvae caught inside the stocking traps were counted in the laboratory.

Statistical analyses

The data were analyzed using SAS 9.4 (SAS Institute, Cary, NC 2012). Data on number of standing plants and larvae were analyzed using ANCOVA (analysis of covariance) and treatment differences were tested using Fisher's Least Significant (LSD) Test). Seed yield was regressed on number of standing plants using PROC REG.

Results

Stand Protection. Plant protection as determined from stand counts taken at PT, 7 DPT, 14 DPT, 21 DPT, and 28 DPT in the various treatment plots at both locations are shown in Tables 2 and 3. In general plant stand counts decreases with time as the season progresses. At the Ledger location stand counts ranged from 20.3 to 53.2 plants per meter (Table 2). At 7 DPT Xpulse treatment resulted in the highest stand count of 25.1 (Table 2). However this was not significant when compared to the seed treatment (Gaucho 600), M1 high, and Mycotrol (Table 2). BioCeres treatment resulted in in the lowest stand count of 13.8. Among the mixtures Met52 + Gaucho 600 treatment resulted in a higher stand count of 20.8 which was significantly lower when compared to 25.1 for Xpulse or 24.4 for Gaucho 600 (Table 2). At 14 DPT Gaucho 600 treatment resulted in the highest stand protection of 22.7, and this was not significant when compared to mixtures Mycotrol + Entrust (19.3), Mycotrol + Gaucho (20.3), Met52 + Aza-Direct (19.1), and Xpulse (21.7). The treatments with single active Entrust (21.1), and M1 high (19.1) were the only treatments with stand counts that were not significant when compared to Gaucho. Water as the control had a significantly lower stand count (12.4) among the treatments (Table 2). The plant stand count at 21 DPT revealed that Gaucho had a significant higher count of 19.6 (Table 2). However, this was not significant when compared to M1 low (16.2), and M1 high (16.9), or to the mixtures Met52 + Gaucho (18.1), and Xpulse (*Beauveria bassiana* + azadirachtin) (17.6). BioCeres treatment had a significantly lower stand count of 11.0 when compared to Gaucho the seed treatment (Table 2). At 28 DPT Gaucho had the highest stand count (23.1), and this was not significant when compared to Mycotrol (20.0), or to the mixtures Met52 + Entrust (18.6), and Met52 + Gaucho (20.6) (Table 2). Met52 + Aza-Direct had a significantly lower stand count of 10.2 when compared to Gaucho the seed treatment at 28 DPT (Table 2).

Plant stand count varied from 26.8 to 54.9 for PT (pre-soil and granular application) at the Valier location (Table 3). Gaucho treatment had a high stand count (29.9), and this was however not significant when compared to the mixtures Mycotrol + Met52 (27.2), Mycotrol + Entrust (29.9), and Mycotrol + Gaucho (29.5) at 7 DPT (Table 3). Mycotrol treatment resulted in a significantly lower stand count of 16.6 when compared to the seed treatment at 7 DPT (Table 3). At 14 DPT plant stand count were significantly higher for Gaucho (29.7). Differences in plant stand counts were not significant when Gaucho (29.7) is compared with the mixtures Mycotrol + Met52 (26.8), Mycotrol + Entrust (26.8), Mycotrol + Gaucho (29.4) at 14 DPT (Table 3). Met52 + Aza-Direct (16.8), Met52 + Entrust (16.9) treatments resulted in the lowest stand counts at 14 DPT (Table 3). Gaucho treatment had the highest stand count of 19.0 at 21 DPT, and this was not significant when compared to the mixtures Mycotrol + Met52 (18.1), and Mycotrol + Gaucho (18.6), Met52 + Gaucho (18.4), and water (16.6) (Table 3). Met52 + Entrust treatment resulted in the lowest stand count of 12.1. Mycotrol + Gaucho treatment resulted in a significantly higher plant stand count of 20.1 at 28 DPT (Table 3). This was not significant when compared to stand counts of Mycotrol + Met52 (19.4) and Gaucho (19.9) (Table 3). M1 low treatment had a lower stand count of 10.5 and this was not significant when compared to Water, M1 high (13.9), Mycotrol (12.4), Met52 + Aza-Direct (11.9), Met52 + Entrust (12.4), Xpectro (13.9), and BioCeres (12.8) (Table 3).

Wireworm sampling

Ledger location. The wireworm population ranged from 0 to 4 per trap at PT (Table 4). At 14 DPT Met52 + Entrust treatment had a higher wireworm population of 5.5 per trap (Table 4). This however was not significant when compared to Entrust (4.0), M1 low (5.0), M1 high (2.3), and BioCeres (2.3) or to Mycotrol + Met 52 (2.3), Mycotrol + Entrust (3.0), Met52 + Aza-Direct (2.3), Met 52 + Gaucho (3.3), and Xpectro (2.8) (Table 4). Among the treatments Mycotrol had the lowest wireworm population of 0.3 per trap, and this was also not significant when compared to the seed treatment Gaucho (1.8) or to the water control (1.6) at 14 DPT. At 28 DPT Mycotrol had a higher wireworm of 4 per trap, which was not significant compared to M1 high (2.5), Met52 (1.5), and BioCeres (1.5), or to the mixtures Mycotrol + Met52 (1.5), Met52 + Aza-Direct (1.5), and Met52 + Entrust (2.5) (Table4). Mycotrol + Entrust had a lower trap count of 0.0, and this was not significant when compared to Gaucho and the water treatment with trap counts of 1.0.

Valier location. Wireworm population per trap varied from 1.8 to 5.3 at PT (Table 5). At 14 DPT Mycotrol + Met52 had a trap count of 1.8, which was only significant to Met52 when compared to products with one active component (Table 5). Among the mixtures this trap value of 1.8 was significant in comparison to Mycotrol + Entrust, Met52 + Aza-Direct, Met52 + Gaucho, and Xpulse which had trap counts of 0.3 at 14 DPT (Table 5). At 28 DPT the trap counts among the treatments were not significant (Table 5).

Yield traits

The yield ($F_{33,143} = 2.52$, $P = 0.0002$) and location effects ($F_{1,16} = 56.48$, $P < 0.0001$) effects were significant. However, treatment ($F_{1,16}$ = 0.76, P = 0.7230) and location*treatment ($F_{1,16}$ = 0.83, P = 0.6482) effects were not significant.

Ledger location. Xpulse treatment resulted in the highest yield (4743.7 kg/ha) (Table 6). However, this yield value of 4743.7 kg/ha was not significant when compared to Gaucho (4133.1 kg/ha), Entrust (4060.7 kg/ha), and Mycotrol (4033.1 kg/ha) (Table 6). Among the mixture treatments the yield due to Xpulse was not significant in comparison to Mycotrol + Met52 (3990.7 kg/ha), and Met52 + Gaucho (4420.4 kg/ha) (Table 5). The yields due to Xpectro (3436.2 kg/ha), Met52 (3445.9 kg/ha), and water (3498.5 kg/ha) were low and were however not significant when compared to Gaucho the seed treatment (Table 6). Protein content (%) of seeds were not significant among the treatments (Table 6).

Valier location. Yield due to Entrust (3541.3 kg/ha) was significant when compared to the seed treatment Gaucho (2336.3 kg/ka) (Table 7). The Entrust yield was also significant when compared to the mixtures Mycotrol + Met52 (2512 kg/ha), Met52 + Aza-Direct (2349.1 kg/ha), Met52 + Entrust (2448.1 kg/ha) (Table 7). Percent protein content of seeds were high in M1 low (15.06), and M1 high (15.15), and these were only significant when compared to the Mycotrol treatment with 13.96 % protein content (Table 7).

Yield and plant stand relationships
The relationship between seed yield and plant stand at Ledger, and Valier locations are presented in Tables 8, and 9, respectively.

Ledger location
Water. The regression models explained 0.24 to 57.36 % of the total response variation. A unit change in plant stand resulted in yield variation of -46.38 to 126.11 kg/ha at 0 to 28 DPT (Table 8).

Gaucho 600. At 0 to 28 DPT the models explained from 8.63 to 69.79 % of the variation in total response. The yield responses ranged from -175.33 to 58.85 kg/ha at 0 to 28 DPT (Table 8). *Entrust WP*. The regression models explained 5.49 to 74.12 % of the total yield variation. A unit change in plant stand resulted in yield variation of -349.42 to 71.44 kg/ha at 0 to 28 DPT (Table 8). *M1 low*. At 0 to 28 DPT the models explained from 6.01 to 37.02 % of the variation in total yield. The yield responses ranged from -273.05 to -77.01 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 8).

M1 high. At 0 to 28 DPT the models explained from 6.08 to 99.13 % of the variation in total yield response. The yield responses ranged from -66.42 to 21.92 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 8).

Met52. The regression models explained 1.40 to 86.16 % of the total yield variation. A unit change in plant stand resulted in yield varying from -210.74 to 86.07 kg/ha at 0 to 28 DPT (Table 8).

Mycotrol. At 0 to 28 DPT the models explained from 5.24 to 67.80 % of the variation in total yield. The yield responses ranged from -106.84 to -47.80 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 8).

Mycotrol + *Met52*. The regression models explained 0.59 to 71.52 % of the total yield response variation. A unit change in plant stand resulted in yield variation of 6.67 to 128.44 kg/ha at 0 to 28 DPT (Table 8).

Mycotrol + *Aza-Direct*. The regression models explained 10.13 to 37.30 % of the total yield variation. A unit change in plant stand resulted in yield varying from -60.15 to 804.75 kg/ha at 0 to 28 DPT (Table 8).

Mycotrol + *Entrust*. The regression models explained 0.06 to 59.51 % of the total yield variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -63.93 to 197.81 kg/ha at 0 to 28 DPT (Table 8).

Mycotrol + *Gaucho*. At 0 to 28 DPT the models explained from 0.15 to 78.69 % of the variation in total yield response. The yield responses ranged from -155.77 to 128.18 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 8).

Met52 + *Aza-Direct*. At 0 to 28 DPT the models explained from 2.13 to 69.26 % of the total yield response variation. The yield responses varied from -138.08 to 299.05 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 8).

Met52 + *Entrust*. The regression models explained 0.07 to 42.86 % of the total yield variation at 0 to 28 DPT. A unit change in plant stand resulted in yield response variation of -51.75 to 94.87 kg/ha at 0 to 28 DPT (Table 8).

Met52 + *Gaucho*. At 0 to 28 DPT the models explained from 12.54 to 39.41 % of the variation in total yield response. The yield responses ranged from -21.45 to 14.70 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 8).

Xpectro. At 0 to 28 DPT the models explained from 1.17 to 41.08 % of the variation in total yield response. The yield responses ranged from -36.31 to 119.23 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 8).

BioCeres. The regression models explained 0.01 to 65.70 % of the total yield variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -62.37 to 69.98 kg/ha at 0 to 28 DPT (Table 8).

Xpulse. The regression models explained 1.29 to 66.41 % of the total yield variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -101.70 to 150.04 kg/ha at 0 to 28 DPT (Table 8).

Valier location

Water. The regression models explained 0.02 to 92.72 % of the total yield response variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -77.69 to 88.97 kg/ha at 0 to 28 DPT (Table 9).

Gaucho. The regression models explained 0.09 to 92.39 % of the total yield response variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -253.62 to 165.15 kg/ha at 0 to 28 DPT (Table 9).

Entrust. At 0 to 28 DPT the models explained from 0.88 to 70.60 % of the variation in total yield. The yield responses ranged from -143.80 to 153.70 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 9).

M1 low. At 0 to 28 DPT the models explained from 2.87 to 94.00 % of the variation in total yield responses. The yield responses ranged from -351.49 to 281.05 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 9).

M1 high. The regression models explained 6.11 to 87.43 % of the total yield response variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -18.59 to 140.08 kg/ha at 0 to 28 DPT (Table 9).

Met52. The regression models explained 1.32 to 92.20 % of the total yield response variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -109.56 to 110.88 kg/ha at 0 to 28 DPT (Table 9).

Mycotrol. At 0 to 28 DPT the models explained from 10.91 to 98.26 % of the variation in total yield. The yield responses ranged from -169.55 to 222.47 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 9).

Mycotrol + *Met52*. At 0 to 28 DPT the models explained from 0.31 to 60.23 % of the variation in total yield responses. The yield responses ranged from -112.80 to 31.03 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 9).

Mycotrol + *Aza-Direct*. At 0 to 28 DPT the regression models explained from 0.31 to 60.23 % of the variation in total yield responses. The yield responses varied from -112.80 to 31.03 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 9).

Mycotrol + *Entrust*. The regression models explained 0.23 to 64.84 % of the total yield response variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -84.93 to 35.83 kg/ha at 0 to 28 DPT (Table 9).

Mycotrol + *Gaucho*. The regression models explained 0.05 to 77.92 % of the total yield response variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -144.16 to 142.56 kg/ha at 0 to 28 DPT (Table 9).

Met52 + *Aza-Direct*. At 0 to 28 DPT the models explained from 0.01 to 41.98.23 % of the variation in total yield responses. The yield responses ranged from -164.23 to 105.13 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 9).

Met52 + *Entrust*. At 0 to 28 DPT the regression models explained from 0.78 to 86.69 % of the total yield response variation. The yield responses varied from -587.29 to 95.74 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 9).

Met52 + *Gaucho*. The regression models explained 5.35 to 82.91 % of the total yield response variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -79.57 to 240.79 kg/ha at 0 to 28 DPT (Table 9).

Xpectro. At 0 to 28 DPT the models explained from 0.47 to 86.29 % of the variation in total yield response. The yield responses ranged from -197.44 to 124.74 kg/ha at 0 to 28 DPT for a unit change in plant stand (Table 9).

BioCeres. The regression models explained 0.27 to 42.28 % of the total yield variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -232.78 to 175.76 kg/ha at 0 to 28 DPT (Table 9).

Xpulse. The regression models explained 0.06 to 43.63 % of the total yield variation at 0 to 28 DPT. A unit change in plant stand resulted in yield variation of -6.80 to 125.86 kg/ha at 0 to 28 DPT (Table 9).

Summary and conclusion

Plant stand counts raged from 10.2 to 53.2 plants/m at PT to 28 DPT across the treatments at Ledger. At Valier stand counts varied from 10.5 to 54.9 plant/m at PT to 28 DPT across the treatments. Trap counts of wireworm population of at Ledger were 0 to 4 at PT, 0.3 to 5.5 at 14 DPT, and 0 to 4.0 at 28 DPT across the treatments. At Valier trap counts were 1.8 to 5.3 at PT, 0.3 to 1.8 at 14 DPT, and 0 to 1.5 at 28 DPT across the treatments. Xpulse, Met52 + Gaucho, Gaucho, Entrust, and Mycotrol resulted in high yields at Ledger. At Valier, Entrust treatment resulted in high yield. At Ledger the regression models explained 0.01 to 99.13 % of the total yield response variation across the treatments. For a unit change in plant stand, yield responses varied from -349.42 to 804.75 kg/ha across the treatments. At Valier the regression models explained 0.01 to 98.26 % of the total yield response variation across the treatments. For a unit change in plant stand, yield responses varied from -587.29.42 to 311.85 kg/ha across the treatments.

In general plant stand counts decreases with time as the season progresses. Xpulse treatment resulted in the highest yield at Ledger. Gaucho (seed treatment) resulted in lowest yield at Valier. The results showed that active biopesticide (*Beauveria bassiana*, *Metarhizium brunneum* or spinosad can be used to complement the seed treatment for stand protection.

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Table 1: Materials and rates of application in each treatment.

Treatment	Active ingredient	Rate (ml/L)	Source
Water	-	-	-
Gaucho 600[a]	imidacloprid	70.98/45.35 kg seed	Bayer Crop Science, Raleigh, NC
Entrust WP [b]	spinosad	0.091	Dow AgroSciences LLC, Indianapolis, IN
M1 (25g/L)	*Metarhizium brunneum*	0.09	LidoChem, NJ
Met 52 EC	*Metarhizium brunneum* F52	0.72	Novozymes Biologicals (Salem, VA)
Mycotrol ESO	*Beauveria bassiana* GHA	0.72	LAM International (Butte, MT)
Mycotrol ESO + Met 52 EC	*B. bassiana* + *M. brunneum*	0.36 + 0.36	As mentioned above
Mycotrol ESO + Aza-Direct	*B. bassiana* + azadiracthin	0.36 + 0.72	As mentioned above
Mycotrol ESO + Entrust	*B. bassiana* + spinosad	0.36 + 0.0455	As mentioned above
Mycotrol ESO + Gaucho 600[c]	*B. bassiana* + imidacloprid	0.36 + 35.49	As mentioned above
Met 52 EC + Aza-Direct	*M. brunneum* + azadiracthin	0.36 + 0.72	As mentioned above
Met 52 EC + Entrust	*M. brunneum* + spinosad	0.36 + 0.0455	As mentioned above
Met 52 EC + Gaucho 600	*M. brunneum* + imidacloprid	0.36 + 0.0785	As mentioned above
M1 (50g/L)	*Metarhizium brunneum*	0.18	LidoChem NJ
Xpectro OD	pyrethrin + *B. bassiana GHA*	2.5	LAM International (Butte, MT)
BioCeres GR[d]	*B. bassiana ANT-03*	20	Anatis Bioprotection, (St.-Jacques-le-Mineur Quebec, Canada)
XPulse OD	*B. bassiana GHA* + azadirachtin	0.72	LAM International (Butte, MT)

Table 1. contd.

[a], Gaucho 600, seed treatment application rate unit (ml/45.35 kg seed).

[b], Entrust WP, application rate unit (g/L).

[c], Gaucho 600, seed treatment application rate unit (35.49 ml/45.35 kg seed).

[d], BioCeres GR, application rate unit (20 g/m^2).

Table 2. Plant stand count of wheat seedlings treated with reduced risk insecticides: Ledger

Treatment	PT[a]	7 DPT[b]	14 DPT[c]	21 DPT[d]	28 DPT[e]
		………………………Plant stand count/m……………………..			
Water	33.4	19.6 cdef	12.4 h	15.6 bcdef	13.9 def
Gaucho 600	35.4	24.4 ab	22.7 a	19.6 a	23.1 a
Entrust WP	29.9	17.9 cdefgh	21.1 ab	15.1 bcdef	12.2 ef
M1 Low	26.8	18.4 cdefg	16.4 cdefgh	16.2 abcde	14.0 def
M1 High	33.2	21.1abcd	19.1 abcde	16.9 abcd	12.3 ef
Met 52 EC	26.9	16.5 efgh	14.4 fgh	13.5 defg	11.1 ef
Mycotrol ESO	28.7	21.9 abc	15.6 defgh	15.6 bcdef	20.0 ab
Mycotrol ESO + Met 52 EC	27.5	17.7 cdefgh	16.7 cdefg	12.8 efg	13.4 def
Mycotrol ESO + Aza-Direct	26.1	20.3 bcde	15.1 efgh	14.9 bcdef	15.3 cde
Mycotrol ESO + Entrust WP	29.1	15.4 fgh	19.3 abcd	12.9 efg	12.5 ef
Mycotrol ESO + Gaucho 600	26.1	18.1 cdefg	20.3 abc	14.4 cdefg	14.1 def
Met 52 EC + Aza-Direct	25.3	14.3 gh	19.1 abcde	12.4 fg	10.2 f
Met 52 + Entrust WP	28.1	18.4 cdefg	15.1 efgh	14.9 bcdef	18.6 abc
Met 52 EC + Gaucho 600	53.2	20.8 bcde	12.7 gh	18.1 ab	20.6 ab
Xpectro OD	25.4	17.6 defgh	16.3 cdefgh	15.0 bcdef	15.4 cde
BioCeres	20.3	13.8 h	17.4 bcdef	11.0 g	15.0 cde
Xpulse OD	31.4	25.1 a	21.7 a	17.6 abc	17.4 bcd

[a], PT, pre foliar and granular application.

[b], 7 DPT, days after foliar and granular application.

[c], 14 DPT, days after foliar and granular application.

[d], 21 DPT, days after foliar and granular application.

[e], 28 DPT, days after foliar and granular application.

Table 3. Plant stand count of wheat seedlings treated with reduced risk insecticides: Valier

Treatment	PT[a]	7 DPT[b]	14 DPT[c]	21 DPT[d]	28 DPT[e]
	……………..……….………Plant stand count/m……………………..…..…				
Water	33.3	23.4 bc	19.4 de	16.6 abcd	13.4 cde
Gaucho 600	54.9	29.9 a	29.7 a	19.0 a	19.9 a
Entrust WP	35.1	22.9 cde	24.4 bc	14.9 defg	14.9 bcd
M1 Low	27.5	19.2 defg	20.3 cde	13.4 efgh	10.5 e
M1 High	36.7	19.4 cdefg	20.8 cde	14.3 defgh	13.9 cde
Met 52 EC	30.8	23.2 bcd	22.8 bcd	15.8 bcde	15.8 bc
Mycotrol ESO	29.3	16.6 g	19.7 de	12.8 fgh	12.4 cde
Mycotrol ESO + Met 52 EC	42.6	27.2 ab	26.8 ab	18.1 abc	19.4 a
Mycotrol ESO + Aza-Direct	37.4	20.5 cdefg	23.0 bcd	15.6 cdef	15.4 bcd
Mycotrol ESO + Entrust WP	46.5	29.9 a	26.8 ab	15.9 bcde	18.2 ab
Mycotrol ESO + Gaucho 600	41.9	29.5 a	29.4 a	18.6 ab	20.1 a
Met 52 EC + Aza-Direct	27.9	18.0 gf	16.8 e	12.8 fgh	11.9 de
Met 52 + Entrust WP	29.6	18.9 gef	16.9 e	12.1 h	12.4 cde
Met 52 EC + Gaucho 600	39.8	23.3 bcd	22.9 bcd	18.4 ab	14.4 cd
Xpectro OD	28.9	21.1 cdef	20.9 cde	14.4 defgh	13.9 cde
BioCeres GR	26.8	17.2 gf	19.0 de	12.6 gh	12.8 cde
Xpulse OD	32.0	19.3 cdefg	24.3 bc	12.6 gh	14.3 cd

[a], PT, pre foliar and granular application.

[b], 7 DPT, days after foliar and granular application.

[c], 14 DPT, days after foliar and granular application.

[d], 21 DPT, days after foliar and granular application.

[e], 28 DPT, days after foliar and granular application.

Table 4. Wireworm population per trap on wheat seedling plots treated with reduced risk insecticides: Ledger

Treatment	PT[a]	14 DPT[b]	28 DPT[c]
		..Wireworm population/trap…	
Water	4	1.6 cd	1.0 a
Gaucho 600	2.5	1.8 bcd	1.0 b
Entrust WP	0.3	4.0 abc	1.0 b
M1 Low	2	5.0 ab	0.8 b
M1 High	2	2.3 abcd	2.5 ab
Met 52 EC	2	1.8 bcd	1.5 ab
Mycotrol ESO	2	0.3 d	4.0 a
Mycotrol ESO + Met 52 EC	1.8	2.3 abcd	1.5 ab
Mycotrol ESO + Aza-Direct	0.8	1.8 bcd	0.5 b
Mycotrol ESO + Entrust WP	0	3.0 abcd	0.0 b
Mycotrol ESO + Gaucho 600	1	1.5 cd	0.8 b
Met 52 EC + Aza-Direct	1	2.3 abcd	1.5 ab
Met 52 + Entrust WP	1.5	5.5 a	2.5 ab
Met 52 EC + Gaucho 600	1.5	3.3 abcd	0.8 b
Xpectro OD	1.3	2.8 abcd	1.3 b
BioCeres GR	1	2.3 abcd	1.5 ab
Xpulse OD	0.8	1.0 cd	0.5 b

[a], PT, pre foliar and granular application.

[b], 14 DPT, days after foliar and granular application.

[c], 28 DPT, days after foliar and granular application.

Table 5. Wireworm population per trap on wheat seedling plots treated with reduced risk insecticides: Valier

Treatment	PT[a]	14 DPT[b]	28 DPT[c]
	...............…Wireworm population/trap…….....		
Water	2.1	1.1 ab	1.1 a
Gaucho 600	5	0.8 ab	1.5 a
Entrust WP	5.3	0.8 ab	0.3 a
M1 Low	4.5	1.3 ab	0.5 a
M1 High	4	0.5 ab	0.8 a
Met 52 EC	1.8	0.3 b	1.0 a
Mycotrol ESO	4	0.8 ab	1.0 a
Mycotrol ESO + Met 52 EC	4	1.8 a	0.5 a
Mycotrol ESO + Aza-Direct	2.8	0.8 ab	1.3 a
Mycotrol ESO + Entrust WP	1.8	0.3 b	1.3 a
Mycotrol ESO + Gaucho 600	3.3	0.8 ab	1.0 a
Met 52 EC + Aza-Direct	4	0.3 b	1.0 a
Met 52 + Entrust WP	4.5	1.0 ab	0.0 a
Met 52 EC + Gaucho 600	4.3	0.3 b	0.3 a
Xpectro OD	2.8	0.8 ab	0.5 a
BioCeres GR	2.5	1.5 ab	1.0 a
Xpulse OD	3	0.3 b	1.3 a

[a], PT, pre foliar and granular application.

[b], 14 DPT, days after foliar and granular application.

[c], 28 DPT, days after foliar and granular application.

Table 6. Yield of wheat seedlings treated with reduced risk insecticides: Ledger

Treatment	Yield (kg/ha)	Test weight (lbs/bu)	Protein (%)
Water	3498.5 c	58.9688 ab	13.13 a
Gaucho 600	4133.1 abc	59.2905 ab	13.14 a
Entrust WP	4060.7 abc	59.3310 ab	13.11 a
M1 Low	3813.3 bc	58.9838 ab	13.22 a
M1 High	3608.4 bc	59.0884 ab	13.0 a
Met 52 EC	3445.9 c	58.7494 b	13.48 a
Mycotrol ESO	4033.1 abc	59.1936 ab	12.93 a
Mycotrol ESO + Met 52 EC	3990.7 abc	58.9535 ab	13.38 a
Mycotrol ESO + Aza-Direct	3650.5 bc	59.0843 ab	13.39 a
Mycotrol ESO + Entrust WP	3759.0 bc	59.1090 ab	13.42 a
Mycotrol + Gaucho 600	3952.6 abc	59.0438 ab	13.29 a
Met 52 EC + Aza-Direct	3703.2 bc	59.0790 ab	13.34 a
Met 52 + Entrust WP	3627.0 bc	59.1724 ab	13.28 a
Met 52 EC + Gaucho 600	4420.4 ab	59.4826 ab	12.67 a
Xpectro OD	3436.2 c	59.0438 ab	13.49 a
BioCeres GR	3659.5 bc	58.6824 b	12.78 a
Xpulse OD	4743.7 a	59.689 a	12.65 a

Table 7. Yield of wheat seedlings treated with reduced risk insecticides: Valier

Treatment	Yield (kg/ha)	Test weight (lbs/bu)	Protein (%)
Water	2832.4 ab	58.8129 bcde	14.21 ab
Gaucho 600	2336.3 b	58.7917 bcde	14.74 ab
Entrust WP	3541.3 a	59.5685 abcd	14.85 ab
M1 Low	3027.6 ab	59.3434 abcde	15.06 a
M1 High	2914.3 ab	58.6560 cde	15.15 a
Met 52 EC	3111.2 ab	59.3839 abcde	14.24 ab
Mycotrol ESO	3013.6 ab	59.71 ab	13.96 b
Mycotrol ESO + Met 52 EC	2512.9 b	58.5573 de	14.73 ab
Mycotrol ESO + Aza-Direct	2636.3 ab	58.4463 e	14.24 ab
Mycotrol ESO + Entrust WP	3162.8 ab	59.8651 a	14.62 ab
Mycotrol ESO + Gaucho 600	2920.2 ab	59.6007 abc	14.94 a
Met 52 EC + Aza-Direct	2349.1 b	59.4403 abcde	14.75 ab
Met 52 + Entrust WP	2448.1 b	59.0755 abcde	14.72 ab
Met 52 EC + Gaucho 600	3112.0 ab	58.9468 abcde	14.77 ab
Xpectro OD	2965.2 ab	59.2077 abcde	14.62 ab
BioCeres GR	3121.9 ab	59.6377 abc	14.76 ab
Xpulse OD	2651.7 ab	59.1107 abcde	14.61 ab

Table 8. Relationship between yield and plant stand of wheat seedlings treated with reduced risk insecticides: Ledger

Treatment	DPT[a]	Regression model	F	R^2	P
Water	0	Y = 4746.75 - 37.40X	0.23	0.1044	0.6768
	7	Y = 3643.27 - 7.40X	0.00	0.0024	0.9510
	14	Y = 2641.94 + 68.87X	0.14	0.0644	0.7463
	21	Y = 1528.01 +126.11X	2.69	0.5736	0.2426
	28	Y = 4142.03 - 46.38X	0.09	0.0420	0.7951
Gaucho 600	0	Y = 5688.84 - 43.98X	4.62	0.6979	0.1646
	7	Y = 5096.06 - 39.51X	0.19	0.0863	0.7062
	14	Y = 2798.06 + 58.85X	0.45	0.1841	0.5709
	21	Y = 7563.01 - 175.33X	3.50	0.6363	0.2023
	28	Y = 5436.19 - 56.50X	1.71	0.4615	0.3207
Entrust WP	0	Y = 6495.76 - 81.34X	1.23	0.3804	0.3833
	7	Y = 2855.29 + 67.20X	0.40	0.1666	0.5918
	14	Y = 5363.05 - 61.65X	0.12	0.0549	0.7657
	21	Y = 9345.71 - 349.42X	5.73	0.7412	0.1390
	28	Y = 3189.96 + 71.44X	0.16	0.0758	0.7247
M1 Low	0	Y = 6009.53 - 81.91X	0.84	0.2952	0.4567
	7	Y = 5697.23 - 102.18X	1.18	0.3702	0.3916
	14	Y = 5295.44 - 90.17X	0.13	0.0601	0.7548
	21	Y = 8233.20 - 273.05X	0.32	0.1393	0.6267
	28	Y = 4891.42 -77.01X	0.92	0.3154	0.4384
M1 High	0	Y = 3203.69 + 13.65X	0.58	0.2240	0.5267
	7	Y = 5055.60 - 66.42X	227.27	0.9913	0.0044
	14	Y = 4296.04 - 33.54X	0.68	0.2544	0.4956
	21	Y = 3286.77 + 21.92X	0.13	0.0608	0.7534
	28	Y = 4154.26 - 40.41X	15.15	0.8834	0.0601
Met 52 EC	0	Y = 1444.27 + 74.31X	12.46	0.8616	0.0717
	7	Y = 6923.02 - 210.74X	2.83	0.5856	0.2348
	14	Y = 2483.91 + 66.63X	0.07	0.0341	0.8153
	21	Y = 3092.37 + 26.18X	0.03	0.0140	0.8818
	28	Y = 2488.37 + 86.07X	1.92	0.4896	0.3003
Mycotrol ESO	0	Y = 2661.88 + 47.80X	2.17	0.5202	0.2788
	7	Y = 6376.88 - 106.84X	4.21	0.6780	0.1766
	14	Y = 4474.75 - 28.38X	0.11	0.0524	0.7711
	21	Y = 5363.21 - 85.47X	0.92	0.3160	0.4379
	28	Y = 5110.04 - 53.85X	1.82	0.4765	0.3097
Mycotrol ESO + Met 52 EC	0	Y = 3738.56 + 6.67X	0.01	0.0059	0.9234
	7	Y = 2680.45 + 70.19X	2.23	0.5267	0.2743
	14	Y = 3378.82 + 32.54X	0.37	0.1560	0.6050
	21	Y = 2276.20 + 128.44X	5.02	0.7152	0.1543
	28	Y = 3228.93 + 51.81X	1.21	0.3768	0.3862
Mycotrol ESO + Aza-Direct	0	Y = 4576.97 - 39.67X	0.52	0.2067	0.5453
	7	Y = 4758.46 - 60.15X	0.86	0.3003	0.4520
	14	Y = -8631.37 + 804.75X	1.19	0.3730	0.3893

	21	Y = 2552.65 + 66.41X	0.35	0.1496	0.6133
	28	Y = 4166.55 - 40.88X	0.23	0.1013	0.6817
Mycotrol ESO + Entrust WP	0	Y = 5847.22 - 63.93X	2.38	0.5429	0.2632
	7	Y =1500.19 + 161.62X	1.89	0.4855	0.3033
	14	Y = 165.01 + 197.81X	1.78	0.4707	0.3139
	21	Y = 3748.74 + 18.27X	0.00	0.0006	0.9749
	28	Y = 2843.87 + 91.30X	2.94	0.5951	0.2286
Mycotrol ESO + Gaucho 600	0	Y = 4062.97 - 4.24X	0.00	0.0015	0.9610
	7	Y = 1629.26 + 128.18X	1.29	0.3927	0.3733
	14	Y = 7116.72 - 155.77X	3.70	0.6488	0.1945
	21	Y = 4662.24 - 49.37X	0.27	0.1194	0.6545
	28	Y = 6046.68 - 148.92X	7.39	0.7869	0.1129
Met 52 EC + Aza-Direct	0	Y = 4538.82 - 33.01X	0.41	0.1694	0.5884
	7	Y = 5679.49 - 138.08X	4.51	0.6926	0.1678
	14	Y = 5871.32 - 113.74X	1.83	0.4778	0.3087
	21	Y = 2.54 + 299.05X	31.38	0.9401	0.0304
	28	Y = 4021.21 - 31.21X	0.04	0.0213	0.8540
Met 52 + Entrust WP	0	Y = 964.81 + 94.87X	1.50	0.4286	0.3454
	7	Y = 4465.95 - 45.50X	0.45	0.1829	0.5724
	14	Y = 3657.91 - 2.04X	0.00	0.0007	0.9733
	21	Y = 3193.56 + 29.02X	0.05	0.0241	0.8449
	28	Y = 4590.88 - 51.75X	1.13	0.3616	0.3987
Met 52 EC + Gaucho 600	0	Y = 4360.86 + 1.12X	1.30	0.3941	0.3722
	7	Y = 4230.70 + 9.14X	0.29	0.1254	0.6459
	14	Y = 4233.92 + 14.70X	0.52	0.2048	0.5475
	21	Y = 4809.21 - 21.45X	0.43	0.1760	0.5805
	28	Y = 4315.85 + 5.08X	0.30	0.1317	0.6370
Xpectro OD	0	Y = 410.84 + 119.23X	1.39	0.4108	0.3590
	7	Y = 4073.82 - 36.31X	0.17	0.0803	0.7167
	14	Y = 2663.45 + 47.37X	0.23	0.1032	0.6787
	21	Y = 3158.61 + 18.51X	0.02	0.0117	0.8919
	28	Y = 2688.07 + 48.46X	0.64	0.2438	0.5063
BioCeres GR	0	Y = 2242.47 + 69.98X	3.83	0.6570	0.1894
	7	Y = 4242.22 - 42.19X	0.24	0.1066	0.6734
	14	Y = 2479.72 + 67.90X	0.81	0.2888	0.4626
	21	Y = 4345.51 - 62.37X	0.31	0.1339	0.6341
	28	Y = 3639.30 + 1.35X	0.00	0.0001	0.9921
Xpulse OD	0	Y = 5584.56 - 26.80X	0.66	0.2475	0.5025
	7	Y = 7298.88 - 101.70X	2.06	0.5070	0.2880
	14	Y = 1489.63 + 150.04X	3.95	0.6641	0.1851
	21	Y = 6387.01 - 93.57X	0.45	0.1829	0.5724
	28	Y = 4998.79 - 14.63X	0.03	0.0129	0.8864

[a] Days post treatment.

Table 9. Relationship between yield and plant stand of wheat seedlings treated with reduced risk insecticides: Valier

Treatment	DPT[a]	Regression model	F	R^2	P
Water	0	Y = 1866.32 + 29.06X	0.75	0.2730	0.4775
	7	Y = 2862.54 - 1.29X	0.00	0.0002	0.9877
	14	Y = 1103.06 + 88.97X	25.47	0.9272	0.0371
	21	Y = 3291.02 - 27.69X	0.11	0.0502	0.7760
	28	Y = 3876.38 - 77.69X	0.29	0.1283	0.6419
Gaucho 600	0	Y = -2588.73 + 89.65X	24.27	0.9239	0.0388
	7	Y = -2597.32 + 165.15X	4.80	0.7061	0.1597
	14	Y = 2169.44 + 5.63X	0.00	0.0009	0.9694
	21	Y = 7155.45 - 253.62X	2.73	0.5771	0.2403
	28	Y = 1150.57 + 59.67X	0.28	0.1244	0.6473
Entrust WP	0	Y = 4200.27 - 18.79X	0.09	0.0408	0.7980
	7	Y = 15.86 + 153.70X	4.80	0.7060	0.1598
	14	Y = 2706.31 + 34.26X	0.10	0.0455	0.7866
	21	Y = 3165.60 + 25.15X	0.02	0.0088	0.9064
	28	Y = 5680.28 - 143.80X	0.60	0.2297	0.5207
M1 Low	0	Y = -4052.51 + 257.46X	5.41	0.7301	0.1455
	7	Y = 9771.83 - 351.49X	31.34	0.9400	0.0305
	14	Y = 3898.90 - 42.90X	0.06	0.0287	0.8306
	21	Y = 7355.54 - 322.08X	4.95	0.7122	0.1561
	28	Y = 76.59 + 281.05X	2.61	0.5658	0.2478
M1 High	0	Y = 2098.80 + 18.59X	0.62	0.2368	0.5133
	7	Y = 1735.81 + 53.94X	0.13	0.0611	0.7528
	14	Y = 1660.83 + 53.81X	0.20	0.0914	0.6976
	21	Y = 832.01 + 136.16X	0.98	0.3296	0.4259
	28	Y = 837.27 + 140.08X	13.91	0.8743	0.0650
Met 52 EC	0	Y = -298.44 + 110.88X	23.64	0.9220	0.0398
	7	Y = 1732.42 + 59.46X	0.31	0.1347	0.6330
	14	Y = 5610.50 - 109.56X	2.02	0.5027	0.2910
	21	Y = 2793.41 + 20.18X	0.03	0.0132	0.8853
	28	Y = 3642.52 - 33.60X	0.47	0.1915	0.5624
Mycotrol ESO	0	Y = 2127.89 + 30.22X	0.24	0.1091	0.6697
	7	Y = 5821.73 - 169.55X	1.46	0.4226	0.3499
	14	Y = 78.33721 + 149.09X	3.93	0.6625	0.1861
	21	Y = 163.18 + 222.47X	113.20	0.9826	0.0087
	28	Y = 983.57 +164.04X	1.14	0.3631	0.3974
Mycotrol ESO + Met 52 EC	0	Y = 2188.35 + 8.85X	0.02	0.0088	0.9064
	7	Y = 5632.46 - 112.80X	3.03	0.6023	0.2239
	14	Y = 1735.51 + 31.03X	0.19	0.0869	0.7052
	21	Y = 2338.03 + 12.56X	0.07	0.0329	0.8185
	28	Y = 2665.78 - 5.15X	0.01	0.0031	0.9447
Mycotrol ESO + Aza-Direct	0	Y = 2188.35 + 8.85X	0.02	0.0088	0.9064
	7	Y = 5632.46 - 112.80X	3.03	0.6023	0.2239
	14	Y = 1735.51 + 31.03X	0.19	0.0869	0.7052

	21	Y = 2338.03 + 12.56X	0.07	0.0329	0.8185
	28	Y = 2665.783 - 5.15X	0.01	0.0031	0.9447
Mycotrol ESO + Entrust WP	0	Y = 2707.77 + 13.51X	0.24	0.1065	0.6736
	7	Y = 3258.33 + 2.59X	0.00	0.0023	0.9518
	14	Y = 3242.62 + 3.48X	0.03	0.0150	0.8777
	21	Y = 4684.17 - 84.93X	3.69	0.6484	0.1948
	28	Y = 2684.35 + 35.83X	0.40	0.1676	0.5906
Mycotrol ESO + Gaucho 600	0	Y = 8956.77 - 144.16X	7.06	0.7792	0.1173
	7	Y = -1285.41 + 142.56X	0.42	0.1730	0.5841
	14	Y = 520.78 + 81.51X	1.77	0.4699	0.3145
	21	Y = -2868.38 + 311.85X	3.65	0.6462	0.1961
	28	Y = 2978.13 - 2.89X	0.00	0.0005	0.9782
Met 52 EC + Aza-Direct	0	Y = 2263.49 + 3.07X	0.00	0.0001	0.9923
	7	Y = 5305.16 - 164.23X	1.45	0.4198	0.3521
	14	Y = 581.60 + 105.13X	0.27	0.1184	0.6560
	21	Y = 2170.09 + 13.97X	0.00	0.0012	0.9648
	28	Y = 1856.01 + 41.52X	0.03	0.0149	0.8781
Met 52 + Entrust WP	0	Y = 7843.61 - 182.51X	13.03	0.8669	0.0689
	7	Y = 2687.27 - 12.67X	0.02	0.0078	0.9114
	14	Y = 12395 - 587.29X	0.24	0.1084	0.6708
	21	Y = 7199.62 - 393.91X	1.43	0.4165	0.3546
	28	Y = 1257.30 + 95.74X	0.62	0.2359	0.5143
Met 52 EC + Gaucho 600	0	Y = 1879.26 + 30.97X	0.65	0.2440	0.5060
	7	Y = 4967.03 - 79.57X	0.11	0.0535	0.7686
	14	Y = -2411.17 + 240.79X	9.70	0.8291	0.0894
	21	Y = 1182.57 + 104.65X	16.38	0.8912	0.0560
	28	Y = 2183.54 + 64.59X	4.34	0.6845	0.1727
Xpectro OD	0	Y = 2408.82 + 19.27X	0.30	0.1317	0.6370
	7	Y = 7123.70 - 197.44X	6.49	0.7643	0.1257
	14	Y = 1725.61 + 59.38X	0.38	0.1611	0.5987
	21	Y = 1171.98 + 124.74X	12.59	0.8629	0.0711
	28	Y = 2800.36 + 11.88X	0.01	0.0047	0.9314
BioCeres GR	0	Y = 6075.42 - 110.15X	0.25	0.1104	0.6677
	7	Y = 100.99 + 175.76	0.93	0.3178	0.4362
	14	Y = 3372.88 - 13.21X	0.01	0.0027	0.9479
	21	Y = 6046.15 - 232.78X	1.47	0.4228	0.3498
	28	Y = 2442.07 + 53.32X	0.09	0.0442	0.7898
Xpulse OD	0	Y = 2602.08 + 1.55X	0.00	0.0006	0.9753
	7	Y = 2262.80 + 20.20X	0.09	0.0441	0.7900
	14	Y = 2816.94 - 6.80X	0.01	0.0038	0.9388
	21	Y = 1062.74 + 125.86X	1.55	0.4363	0.3395
	28	Y = 2723.11 - 4.99X	0.01	0.0026	0.9492

[a] Days post treatment.

Toxic effects of biologically derived insecticides on larvae of the alfalfa weevil, *Hypera postica* (Coleoptera: Curculionidae)

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Introduction

Alfalfa weevil, *Hypera postica* (Gyllenhall) (Coleoptera: Curculionidae), is the most destructive insect pest of alfalfa hay in the intermountain west of the United States. *Hypera postica* not only decreases yield and quality of the first cutting, but can also harm subsequent cuttings. Both larvae and adults damage terminals, foliage and new crown shoots, thereby lowering crop yield and quality. However, larvae cause the most damage (Figure-1). During severe infestations, larvae can cause substantial defoliation, resulting in severe first cutting losses. Heavily infested fields may appear silver or white, as most leaves are skeletonized or consumed entirely. If large numbers of adults or larvae survive until harvest, they can damage stems and crown buds, retarding regrowth. A decrease in stem elongation occurred at a density of 30–100% of the smallest larval density. Residual effects from severe damage decrease plant vigor, resulting in lower stand density and poor yields in subsequent harvests.

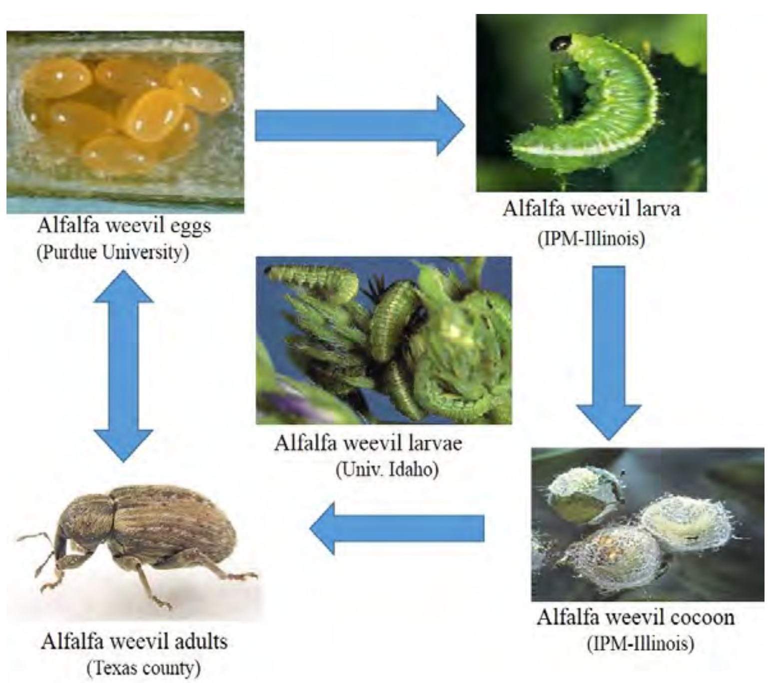

Figure-1: Life Cycle of the Alfalfa Weevil

Although *H. postica* is native to Europe it was inadvertently introduced into the western United States in the early 1900s and again, separately, into the eastern United States in the late 1940s. In Montana, alfalfa (*Medicago sativa* L., Fabaceae) is the second most important crop after small grains. Alfalfa growers in Montana first began to notice *H. postica* during spring 2013 when the weevil caused considerable damage and yield losses. In addition, alfalfa weevils caused economic damage in irrigated fields in the Yellowstone and Missouri river valleys in Montana. As a rule, insecticidal treatment are considered economical when larval populations average between 1.5 – 2.0 larvae / stem, or 20 larvae / sweep. In 2014 and 2015, an *H. postica* outbreak occurred in Valier, Montana. Even though *H. postica* does the most damage before the first cutting, considerable damage was noticed even after the first harvest.

To date, other than classical biological control, insecticide applications and early harvesting are the most common management strategies for alfalfa weevil. However, most of the chemical insecticides used to control this pest are extremely hazardous to bees and other beneficial insects like the parasitoids *Bathyplectes curculionis* (Thomson) (Hymenoptera: Ichneumonidae) and *Oomyzus incertus* Ratzburg (Hymenoptera: Eulophidae). Increasing concerns for environmental safety and insecticide resistance arising from frequent use of synthetic insecticides affect the long-term feasibility of the current strategy of alfalfa weevil management. Consequently, many alfalfa growers in north central and central Montana are looking for more environmental friendly control methods for managing this destructive pest.

Several reports have demonstrated the effectiveness of entomopathogenic fungi against many species of beetles and weevils. *Beauveria bassiana* and *Metarhizium anisopliae* sensu lato (formerly *M. anisopliae*) was been reported to infect larvae and adults of various weevil species and have been used successfully in biological control experiments against these pests. *Hypera postica* was reported to infect *B. bassiana*. In addition, it has been reported that high mortality of *H. postica* caused by *M. brunneum* in Japan.

Alfalfa is a favorable habitat for many beneficial arthropods including pollinators and natural enemies of pests (Nicholls and Altieri, 2013). A number of naturally derived insecticides have been reported to be safe to many types of non-target organisms. Here, we studied the effects of several commercially available, biologically derived insecticides against larvae of *H. postica*.

Materials and methods

Rearing of Insects

Hypera postica larvae were collected from alfalfa fields in Valier, Montana, USA, using sweep nets in July, 2015 and taken to the laboratory. Larvae were placed in collapsible cages (12 × 10 × 10 cm), fed alfalfa foliage, and held at 22 ± 2 °C, 70–80% r.h. and an approximately14:10 h L:D photoperiod. Field-collected larvae were separated by instar as described by Harcourt (1981). The instars ranged from first to fourth instars. The first instar is light yellow or tan in color with a darker head and about 1 mm long while the second instar is yellowish-brown with their head deepening to black, third and fourth instar size is up to 9 mm long, are bright green with shiny black head capsule, and have a white stripe down the halfway point of their rears. Second instars were used for all tests.

Insecticides

Insecticides tested were commercial formulations (Table 1) stored dry place at 4-5 °C until diluted them to the desired concentrations for use. Concentrations tested were 0.1, 0.5, 1.0 and 2.0 times the lowest label rate, except for Entrust, which had additional concentrations of 0.001 and 0.01 times the lowest label rate also prepared due to the high toxicity of this compound.

Toxicity tests

Toxicity tests were carried out in the laboratory from 15 July through August 2015 when test larvae from field populations were available. Materials were applied via contact at the desired concentrations (see Table 1 for rates). For each replicate, five larvae were transferred onto a disk of Whatman No. 1 filter paper (9 cm diam, Whatman® quantitative filter paper, ashless, Sigma-Aldrich, St. Louis, Missouri, USA) in a 9 cm disposable Petri dish where they were topically treated with the test material.

Each Petri dish also contained three alfalfa stems about 5 cm long, each with 6-8 leaves as larval food. Six replicate Petri dishes, containing a total of 30 larvae, were treated (using a Sprayer (Sprayco, Livonia, MI) with 1 mL of a test material (Reddy et al., 2014). Controls were treated with 1.0 mL of tap water. Following application, Petri dishes were held under the same laboratory conditions used for rearing, and larval mortality was assessed daily for nine days.

Statistical analyses

Because mortality rates for several of the tested materials (Mycotrol, Met 52, Aza-Direct, Xpulse, Xpectro and Entrust, Figs. 1-6) increased over time, treatments were analyzed with probit analysis using the program Probit-MSChart (http://140.120.197.173/ecology/Download/Probit-MSChart.rar). Control mortalities were adjusted using the Abbot method (Abbott, 1925). Mortality response (in probits) was regressed against $\log_{10}$ day.

Results

Our contact bioassays for *H. postica* found a good linear regression relationship between mortality (in probit) of *H. postica* and time ($\log_{10}$ day) after treatment with Mycotrol, Met52, Aza-Direct, Xpulse, Xpectro and Entrust (Figs. 2-6). The mortality rate (in probit) increased with $\log_{10}$ day for Mycotrol, Met52, Aza-Direct, Xpulse, Xpectro and Entrust. For Mycotrol (*Beauveria bassiana*), the mortality responses for a unit change in time (log day) varied from 9.56 to 13.53 probit units (Fig. 2). For Met 52 (*Metarhizium brunneum*), mortality rates (probit) for a unit change in $\log_{10}$ hour ($\log_{10}$ day) ranged from 9.82 to 14.66 probit units (Fig. 3). For Aza-Direct (azadirachtin), probit units varied from 5.97 7.66 for a unit change in $\log_{10}$ hour ($\log_{10}$ day) (Fig. 4). For Xpectro (*Beauveria bassiana* + pyrethrin), probit units ranged from 2.48 to 4.88 for a unit change in $\log_{10}$ hour ($\log_{10}$ day) (Fig. 5). For Xpulse (*Beauveria bassiana* + azadirachtin), probit units for a unit change in $\log_{10}$ hour ($\log_{10}$ day) varied from 4.83 to 7.55 (Fig. 6). For

Entrust, probit units ranged from 3.62 to 3.7 for a unit change in $\log_{10}$ hour ($\log_{10}$ day) (Fig. 7).

In the treatment of *H. postica* with *B. bassiana* (Mycotrol) the LT_{50} ranged from 122.7 to 164.7 hours (5.11 to 6.86 days) (Fig. 1). For *M. brunneum* (Met52) the LT_{50} ranged from 103.6 to 148.8 hours (4.32 to 6.2 days) (Fig. 2). The LT_{50} for *A. indica* (Aza-Direct) ranged from 71.9 to 111.3 hours (2.996 to 4.64 days) (Fig. 3). The LT_{50} for *B. bassiana* + pyrethrum (Xpectro) ranged from 43.6 to 73.9 hours (1.82 to 3.08 days) (Fig. 4). For (*B. bassiana* + *A. indica*) Xpulse the LT_{50} ranged from 61.4 to 94.6 hours (2.56 to 3.94 days) (Fig. 5). Finally, for Entrust (spinosad) all larvae died within 12 hours of treatment (data not shown) for the concentrations 0.1 to 2.0. However, LT_{50} for the lower concentrations (0.001 and 0.01) ranged from 18.1 to 27.8 hours (Fig. 6), making Entrust the most toxic of the products tested. Generally, LT_{50} decreased with increasing time $\log_{10}$ hour ($\log_{10}$ day) for all treatments and concentrations (Figs. 1-6).

Acknowledgments
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Table 1 Materials and application rates used for the laboratory bioassays against *Hypera postica* larvae.

Treatment	Chemical name	Trade name	Concentrations (ml/L)	Source
T1	Untreated control	-	-	-
T2	spinosad (*Saccharopolyspora spinosa*)	Entrust® a wettable powder	0.000091, 0.00091, 0.0091, 0.0455, 0.091, and 0.182	Dow Agro Science LLC, Indianapolis, IN
T3	*Metarhizium brunneum* F52	Met52® emulsifiable concentrate	0.072, 0.36, 0.72, and 1.44	Novozymes Biologicals, Salem, VA
T4	*Beauveria bassiana* GHA	Mycotrol ESO® emulsifiable concentrate	0.072, 0.36, 0.72, and 1.44	LAM International, Butte, MT
T5	Azadirachtin (extracts from *Azadirachta indica*)	Aza-Direct® emulsifiable concentrate	0.144, 0.72, 1.44, and 2.88	Gowan Company, Yuma, AZ
T6	*B. bassiana* GHA + pyrethrins	Xpectro® emulsifiable dispersible oil	0.25, 1.25, 2.5, and 5.0	LAM International, Butte, MT
T7	*B. bassiana* GHA + cold pressed Neem extract	Xpulse® emulsifiable dispersible oil	0.072, 0.36, 0.72 and 1.44	LAM International, Butte, MT

Figure-2. Probit analysis of lethal time of *Beauveria bassiana* to *Hypera postica* at different concentrations.

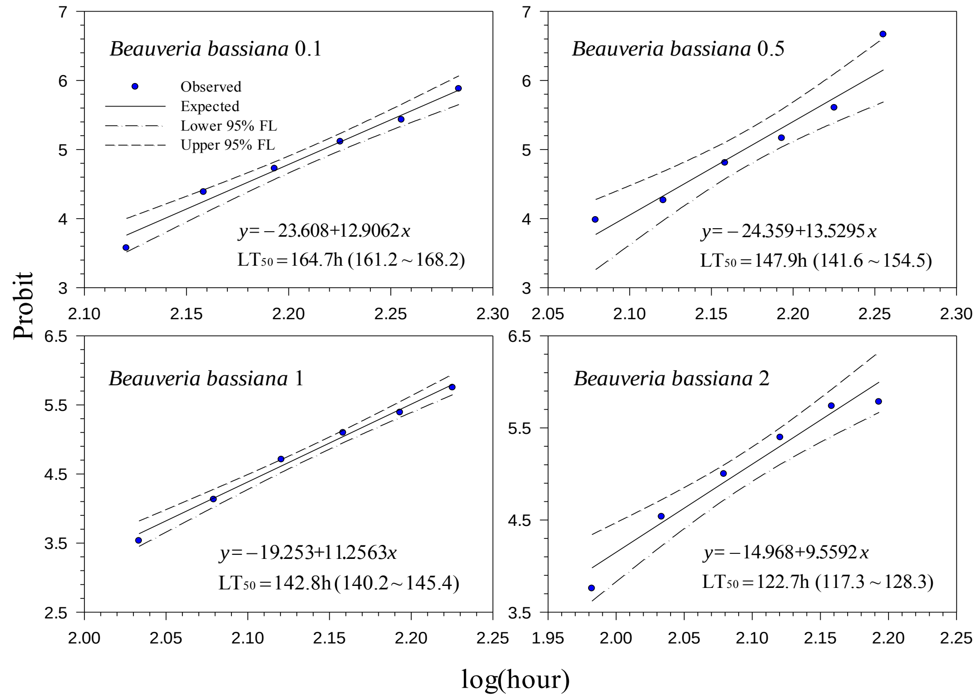


Figure-3. Probit analysis of lethal time of *Metarhizium brunneum* to *Hypera postica* at different concentrations.

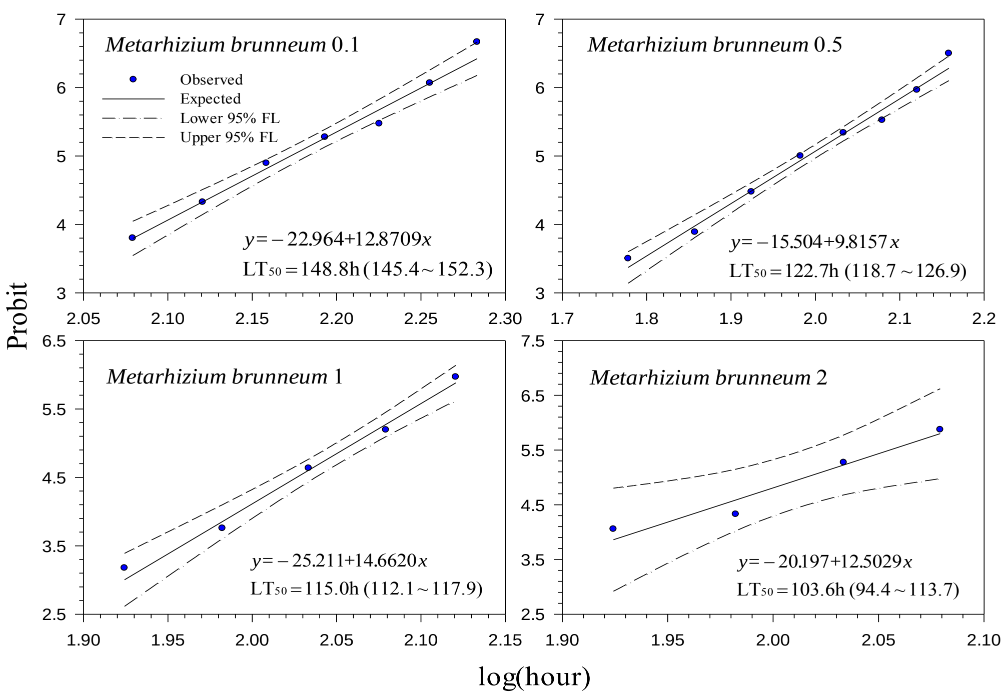


Figure-4. Probit analysis of lethal time of *Azadirachta indica* to *Hypera postica* at different concentrations.

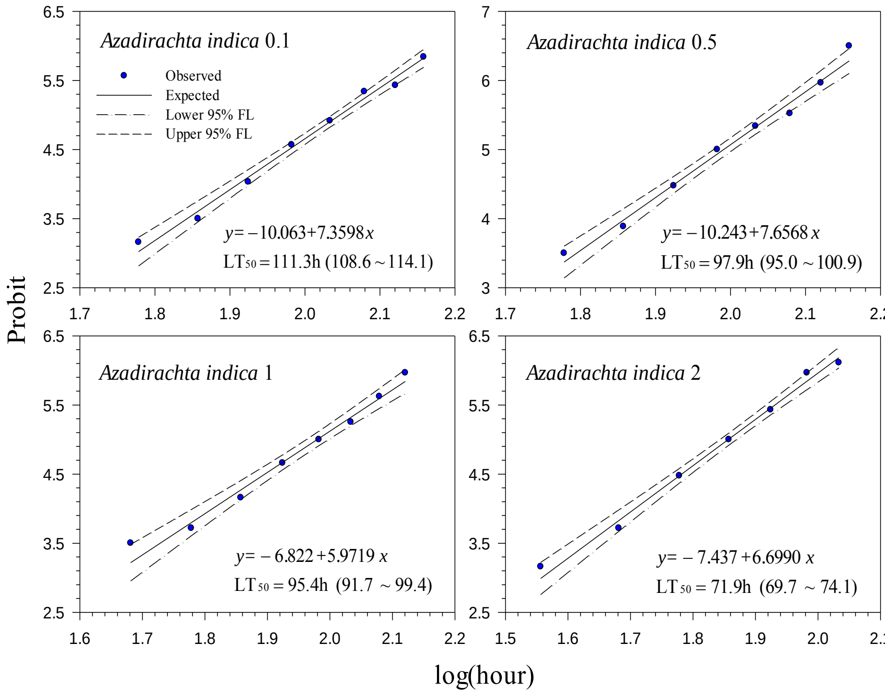


Figure-5. Probit analysis of lethal time of Xpectro® (*B. bassiana* GHA + pyrethrins) to *Hypera postica* at different concentrations.

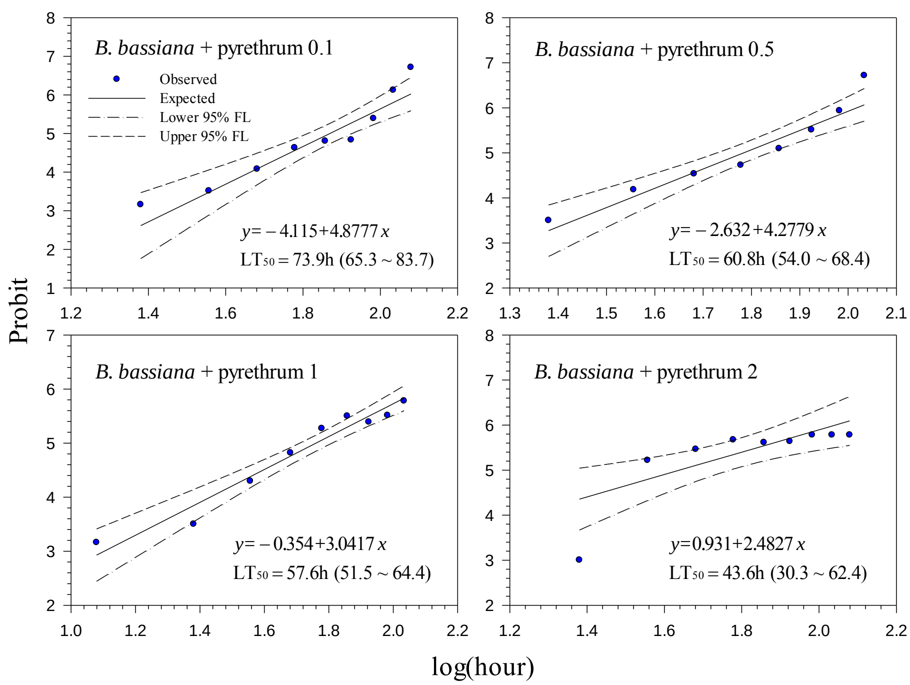


Figure-6. Probit analysis of lethal time of Xpulse® (*B. bassiana* GHA + azadirachtin) to *Hypera postica* at different concentrations

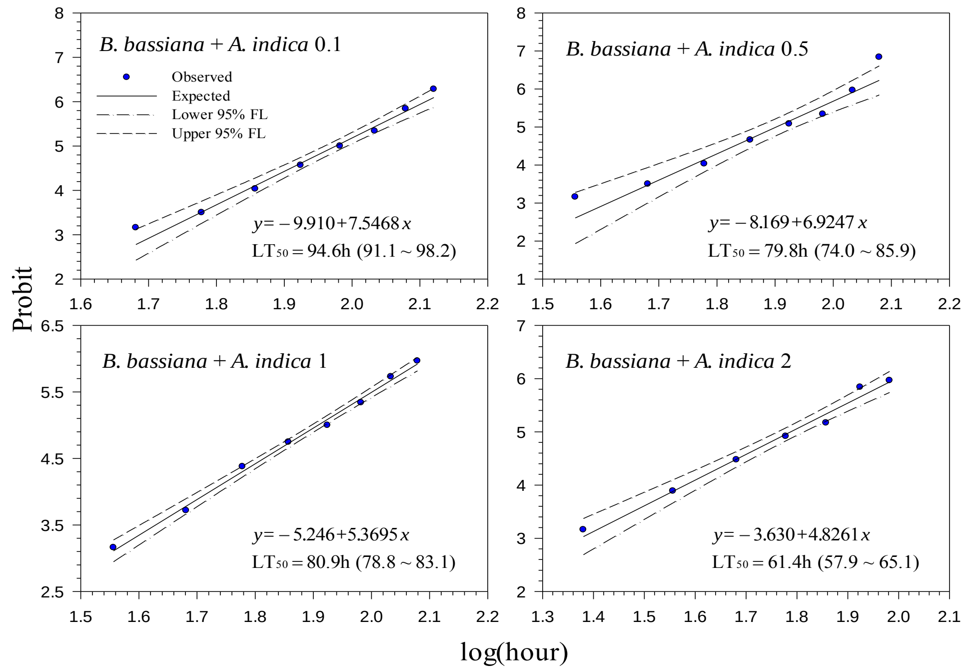
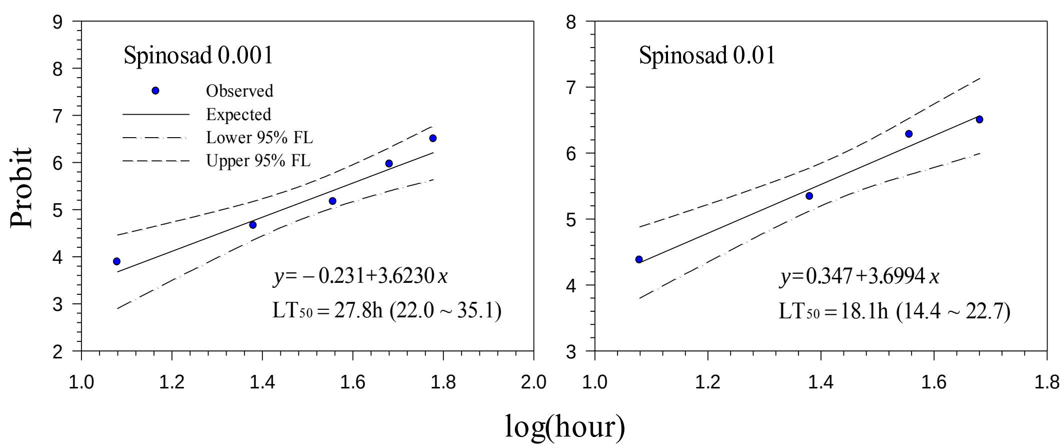


Fig. 7. Probit analysis of lethal time of Entrust® (spinosad) on to *Hypera postica* at different concentrations.



Toxicity of natural insecticides on the larvae of wheat head armyworm, *Dargida diffusa* (Lepidoptera: Noctuidae)

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Introduction

The wheat head armyworm, *Dargida* (previously *Faronta*) *diffusa* (Walker) (Lepidoptera: Noctuidae), while usually a minor pest, can sporadically cause important crop damage. This species is similar in appearance to its congener *Dargida terrapictalis* (Buckett) (Lepidoptera: Noctuidae), with which it is often confused. Both species were moved from *Faronta* to *Dargida*. *Dargida diffusa* feeds on a range of grasses and cereal crops and appears to prefer seed heads, making it a pest of cereal grains throughout the Midwest and Great Plains of North America. Although its host range and pest status are not well studied, crop damage seems to occur both in the field and during grain storage. There are currently no IPM thresholds or recommended treatments for this pest due to its sporadic late season appearance.

Darginda diffusa larvae (Fig-1) pupate and overwinter in the soil, and adults mate within a few days of emerging. Females then lay eggs on developing wheat or barley. Larvae occur on wheat heads by June. Larvae and adults are typically nocturnal. In more northern regions, *D. diffusa* has two generations per year and adults fly in late August. A 35% yield loss in spring wheat due to *D. diffusa* has been reported in Washington State. Both *D. diffusa* and *D. terrapictalis* to cause crop damage in Idaho and Oregon.

Figure-1: Larvae of wheat head armyworm (left) and adult (right)

Concern over this pest increased with the occurrence of increased percentages of insect-damaged kernels (IDK) in the 2014 in the wheat harvest in the Golden Triangle area of Montana. It has been reported that reported that *D. diffusa* responds to lures baited with a combination of the sex attractant compounds Z11-16Ac and Z11-16Ald. Such pheromone lures are being used to detect and monitor adults in wheat fields. However, the use of these lures is limited to monitoring, and control is based on use of insecticides, even though such applications may not be advisable near harvest. Sustainable insect pest management (SIPM) products are intended to be safe alternatives to conventional insecticides, and some are both effective and harmless to the environment. To date, no attempt has been made to find materials with these attributes for use against *D. diffusa*. Here we present results from a laboratory bioassay to evaluate the efficacy of several commercially available biorational products against larvae of *D. diffusa*.

Materials and methods

Insects

Larvae of *D. diffusa* were collected from wheat fields near Valier, Montana, USA, using sweep nets, in June and July, 2015. Larvae were taken to the laboratory and placed in collapsible cages (12 × 10 × 10 cm), where they were fed wheat seed heads, and held at 21 ± 2 °C, 70–80% relative humidity, and an approximately14:10 h L:D photoperiod. Field-collected larvae were separated by instar and ranged from first to four instars. For all experiments, second instars were used for laboratory bioassays.

Insecticides

Insecticides used were commercial formulations of (1) Entrust WP (spinosad 80%, Dow AgroSciences Indianapolis, IN), (2) Mycotrol ESO (*Beauveria bassiana* GHA, Lam International, Butte, MT), (3) Aza-Direct (Azadirachtin, Gowan Company, Yuma, AZ), (4) Met52 EC (*Metarhizium brunneum* F52, Novozymes Biologicals, Salem, VA), (5) Xpectro OD (*Beauveria bassiana* GHA + pyrethrins, Lam International, Butte, MT), and (6) Xpulse OD (*Beauveria bassiana* GHA + Azadirachtin , Lam International, Butte, MT). Cultures of *M. brunneum* F52 (a commercialized isolate previously identified as *M. anisopliae*) conidial powders were stored dry at 4-5 °C until formulated for use. The concentrations tested were 0.1, 0.5, 1.0 and 2.0 fold lowest label rate, while for Entrust additional concentrations of 0.001 and 0.01 fold the label rate were also prepared (Table 1).

Laboratory tests

Laboratory tests were carried out from July and August of 2015 via contact application of various concentrations of the test materials (see Table 1 for exact concentrations tested). For each replicate, five second instar larvae were transferred onto a disk of Whatman No. 1 filter paper (9 cm diam, Whatman® quantitative filter paper, ashless, Sigma-Aldrich, St. Louis, Missouri, USA) in a 9 cm disposable Petri dish. Each Petri dish received three wheat stems about 5 cm long, each with 8-10 leaves as food for the larvae. Six replicate Petri dishes, containing a total of 30 larvae (5 per dish), were treated (using a 473 ml capacity Plant & Garden Sprayer, Sprayco, Livonia, MI) with 1 mL of the relevant test material. Controls were sprayed with 1.0 mL tap water. Following application, dishes were held under the same laboratory conditions used for rearing, and larval mortality was assessed daily for nine days.

Statistical analyses

The data were analyzed with SAS 9.4. Mortality rates were corrected using Abbot's formula (Abbott, 1925; Perry et al., 1998) to adjust for control mortality. Survival rates were determined from the mortality rates. Graphs of survival rate (%) against log concentration were plotted with Sigma Plot 13.0 (SPSS Inc., Chicago, IL). Survival rates were regressed on log concentration using PROC REG. Lethal values (LC_{50}) were determined with PROC PROBIT. Differences in lethal values between treatments were determined by comparison of the 95% confidence limits. Poor fit models were accounted for by multiplying the variances by the heterogeneity factor (χ^2 /k-2), where k is the number of concentrations to account for extra binomial variations due to genetic and environmental influences that caused poor fit.

Results

Survival rates

The results of contact bioassays with tested materials against second instars of *D. diffusa,* shown in Fig. 1. Entrust caused high mortality to larvae, acting rapidly and reaching 83 to 100% mortality (0 to 17% survival rate) at day 3 across all concentrations (Fig. 2.). Mortalities were 66.7 - 100% (0 - 33.3% survival rate) for Xpectro, 42.5 - 100% (0 - 57.5% survival rate) for Xpulse, 30.8 -100% (0 - 69.2% survival rate) for Aza-Direct across all concentrations from days 4 to 9. Across all the concentrations from days 5 to 9 mortalities were 10 - 100% (0 – 90% survival rate) for Mycotrol, 30 - 100% (0 - 70% survival rate) for Met52 (Fig. 1.). Table 2, show the regression relationship between survival rates of *D. diffusa* and log concentration of tested materials (Mycotrol, Met52, Aza-Direct, Xpulse, Xpectro, and Entrust). Lethal concentrations for each test material are presented in Table 3. Generally, there was a good fit to the model assumptions. Entrust was the most effective insecticide compared to Mycotrol, Met52, Aza-Direct, Xpulse, and Xpectro, since Entrust had a steep slope of mortality over time (i.e., it killed rapidly) (Fig. 1).

For Mycotrol the models explained 22.78 - 90.17% of the total survival rate variation for wheat head armyworm for days 1 to 9 (Table 3). The regression models explained 3.67 to 99.44% of the wheat head armyworm survival in the Met52 treatment from days 1 to 9 (Table 2), and 24.29 - 99.30% of the total survival rate response variation for days 1 to 9 in the Aza-Direct treatment (Table 2). Regression models explained 24.29-98.33% of the total survival rate of Wheat head armyworm to Xpulse from days 1 to 9 (Table 2). Xpectro treatment to Wheat head armyworm resulted in total survival rate response variation of 24.29 to 97.67% at days 1 to 9 (Table 2). Entrust treatment also resulted in the models explaining survival rate of Wheat head armyworm variation from 35.02 to 61.09% at days 1 to 9 (Table 2).

For Mycotrol the slopes varied from -10.56 to 2.12 at days 1 to 9 (Table 2). For Met52 the slopes ranged from -17.70 to 2.12 at days 1 to 9 (Table 2). Aza-Direct treatment resulted in slopes ranging from -9.11 to 1.12 at days 1 to 9 (Table 2). Xpulse treatment resulted in slopes varying from -19.77 to 2.12 from days 1 to 9 (Table 2). At days 1 to 9 for Xpectro treatment the slopes varied from -5.49 to 0.67 (Table 2). From days 1 to 9 for Entrust treatment the slopes ranged from -275.06 to 16.51 (Table 2). Lethal concentrations at 5 days post treatment were determined for Entrust ($8.11*10^{-6}$ g a.i./L), Aza-Direct (0.0004042 g a.i./L), Xpulse (0.0007180 g a.i./L), Xpectro (0.00177 g a.i./L), Met52 (0.01880 g a.i./L), and Mycotrol (0.10968 g a.i./L) (Table 3). Based on the lethal concentrations Entrust was the most toxic among the treatments to *D. diffusa*.

Acknowledgments

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Table-1: Insecticide treatments and concentrations used.

Treatments	Insecticide concentration[a]						
	0X	0.001X	0.01X	0.1X	0.5X	1X	2X
Mycotrol ESO[b]	0			0.072	0.36	0.72	1.44
Met52 EC[c]	0			0.072	0.36	0.72	1.44
Aza-Direct[d]	0			0.144	0.72	1.44	2.88
Xpulse OD[e]	0			0.072	0.36	0.72	1.44
Xpectro OD[f]	0			0.25	1.25	2.5	2.5
Entrust WP[g]	0	0.000091	0.00091	0.0091	0.0455	0.091	0.182

[a] Insecticide concentration: 0X, control (water); 0.001X, 0.01X, 0.1X, 0.5X, 1X, and 2X of the lowest label application rate.

[b] Mycotrol ESO: 0.1X = 0.072 ml/L (0.007848 g a.i./L); 0.5X = 0.36 ml/L (0.03924 g a. i./L); 1X = 0.72 ml/L (0.07848 g a.i./L);

2X =1.44ml/L (0.15696 g a.i./L).

[c] Met52 EC: 0.1X = 0.072 ml/L (0.00792 g a.i./L); 0.5X = 0.36 ml/L (0.0396 g a. i./L); 1X = 0.72 ml/L (0.0792 g a.i./L);

2X =1.44ml/L (0.1584 g a.i./L).

[d] Aza-Direct: 0.1X = 0.072 ml/L (0.01728 g a.i./L); 0.5X = 0.72 ml/L (0.0864 g a.i./L); 1X = 1.44 ml/L (0.1728 g a.i./L);

2X =2.88 ml/L (0.03456 g a.i./L).

[e] Xpulse OD: 0.1X = 0.072 ml/L (0.0072432 g a.i./L); 0.5X = 0.36 ml/L (0.036216 g a.i./L); 1X = 0.72 ml/L (0.072432 g a.i./L);
2X =1.44ml/L (0.144864 g a.i./L).
[f] Xpectro OD: 0.1X = 0.25 ml/L (0.002025 g a.i./L); 0.5X = 1.25 ml/L (0.010125 g a.i./L); 1X = 2.5 ml/L (0.02025 g a.i./L);

2X = 5 ml/L (0.0405 g a.i./L).

[g] Entrust WP: 0.001X = 0.000091 ml/L (0.0000728 g a.i./L); 0.01X = 0.00091 ml/L (0.000728 g a.i./L); 0.1X = 0.0091 ml/L (0.00728

g a.i./L); 0.5X = 0.0455 ml/L (0.0364 g a.i./L); 1X = 0.091 ml/L (0.0728 g a.i./L); 2X = 0.182 ml/L (0.1456 g a.i./L).

Table-2: Relationship between survival rate of wheat head armyworm and log concentration of Aza-Direct, Entrust, Met 52, Mycotrol, Xpectro, and Xpulse.

Treatment	Day	Regression model[a]	F	R^2	P
Mycotrol ESO	1	Y = -2.27 + 2.12X	2.67	0.4711	0.2007
	2	Y = 100.00 + 0X	ND[b]	ND	ND
	3	Y = 100.00 + 0X	ND	ND	ND
	4	Y = 100.00 + 0X	ND	ND	ND
	5	Y = 100.15 - 4.93X	27.51	0.9017	0.0135
	6	Y = 95.26 - 10.15X	7.71	0.7198	0.0692
	7	Y = 91.75 - 14.18X	5.67	0.6541	0.0975
	8	Y = 85.15 - 12.63X	1.75	0.3681	0.2779
	9	Y = 82.27 -10.56X	0.88	0.2278	0.4163
Met52 EC	1	Y = -2.27 + 2.12X	2.67	0.4711	0.2007
	2	Y = 99.88 - 0.15X	0.11	0.0367	0.7575
	3	Y = 99.88 - 0.15X	0.11	0.0367	0.7575
	4	Y = 100.46 - 2.81X	30.63	0.9108	0.0116
	5	Y =100.27 - 14.41X	530.11	0.9944	0.0002
	6	Y = 93.18 - 17.70X	16.10	0.8430	0.0278
	7	Y = 87.55 - 15.34X	3.59	0.5447	0.1545
	8	Y = 82.56 - 11.89X	1.16	0.2796	0.3595
	9	Y = 81.83 - 11.24X	0.96	0.2429	0.3989
Aza-Direct	1	Y = -2.09 + 1.12X	2.50	0.4550	0.2117
	2	Y = 100.00 + 0X	ND	ND	ND
	3	Y = 100.48 - 1.81X	52.20	0.9457	0.0055
	4	Y = 100.84 - 6.41X	423.48	0.9930	0.0003
	5	Y = 94.45 - 9.11X	26.06	0.8968	0.0145
	6	Y = 87.07 - 7.20X	3.09	0.5074	0.1770
	7	Y = 81.83 - 5.62X	0.96	0.2429	0.3989
	8	Y = 81.83 - 5.62X	0.96	0.2429	0.3989
	9	Y = 81.83 - 5.62X	0.96	0.2429	0.3989
Xpulse OD	1	Y = -2.27 + 2.12X	2.67	0.4711	0.2007
	2	Y = 100.00 + 0X	ND	ND	ND
	3	Y = 100.55 - 6.47X	176.49	0.9833	0.0009
	4	Y = 98.05 - 19.77X	114.71	0.9745	0.0017
	5	Y = 90.27 - 17.50X	6.26	0.6759	0.0876
	6	Y = 83.19 - 12.33X	1.35	0.3096	0.3300
	7	Y = 81.83 - 11.24X	0.96	0.2429	0.3989
	8	Y = 81.83 - 11.24X	0.96	0.2429	0.3989
	9	Y = 81.83 - 11.24X	0.96	0.2429	0.3989
Xpectro OD	1	Y = -1.94 + 0.67X	2.39	0.4437	0.2197
	2	Y = 101.35 - 2.19X	22.18	0.8808	0.0181
	3	Y = 98.29 - 5.49X	125.61	0.9767	0.0015
	4	Y = 90.00 - 4.89X	5.75	0.6573	0.0960
	5	Y = 85.50 - 4.17X	2.23	0.4260	0.2325

	6	Y = 82.93 - 3.52X	1.28	0.2984	0.3408
	7	Y = 81.83 - 3.24X	0.96	0.2429	0.3989
	8	Y = 81.83 - 3.24X	0.96	0.2429	0.3989
	9	Y = 81.83 - 3.24X	0.96	0.2429	0.3989
Entrust WP	1	Y = -3.14 + 16.51X	7.85	0.6109	0.0379
	2	Y = 77.06 - 275.06X	4.20	0.4563	0.0958
	3	Y = 69.80 - 224.03X	2.92	0.3683	0.1484
	4	Y = 68.04 - 210.76X	2.72	0.3525	0.1599
	5	Y = 67.82 - 209.10X	2.70	0.3502	0.1616
	6	Y = 67.82 - 209.10X	2.70	0.3502	0.1616
	7	Y = 67.82 - 209.10X	2.70	0.3502	0.1616
	8	Y = 67.82 - 209.10X	2.70	0.3502	0.1616
	9	Y = 67.82 - 209.10X	2.70	0.3502	0.1616

[a] Regression model: Y = Survival rate (%); X = Concentration ($\log_{10}$).

[b] ND = No data due to insufficient variation in the data to create a density plot.

Table 3: Lethal concentrations of wheat head armyworm larvae to reduced risk insecticides

Treatment	Day	LC_{50} (g a.i./L)	C. I. (95%)	$P > \chi^2$
Mycotrol ESO[a]	5	0.10968	0.042 - 164.62	0.0834
Met52 EC[b]	5	0.01880	0.0094 - 0.029	0.0382
Aza-Direct	5	0.0004042	ND[c]	0.0100
Xpulse OD[d]	5	0.0007180	1.0733E-26 - 0.0035	0.7012
Xpectro OD	5	0.00177	0.0017 - 0.0019	1.0000
Entrust WP	5	8.11E-6[e]	1.70179E-8 - 0.000037	0.8477

[a] Weight estimate of $4.78 * 10^{-12}$ grams per spore ($2 * 10^{13}$ viable spores per quart).

[b] Contains $5.5 * 10^{9}$ colony forming units (CFU)/gram of product ($5 * 10^{10}$.viable conidia per gram of active ingredient.

[c]ND, no data as confidence interval could not be determined by statistical analysis.

[d] *Beauveria bassiana* Strain GHA (0.06%) contains not less than $1 * 10^{11}$ viable spores per quart..

[e] 8.11E-6 = $8.11 * 10^{-6}$.

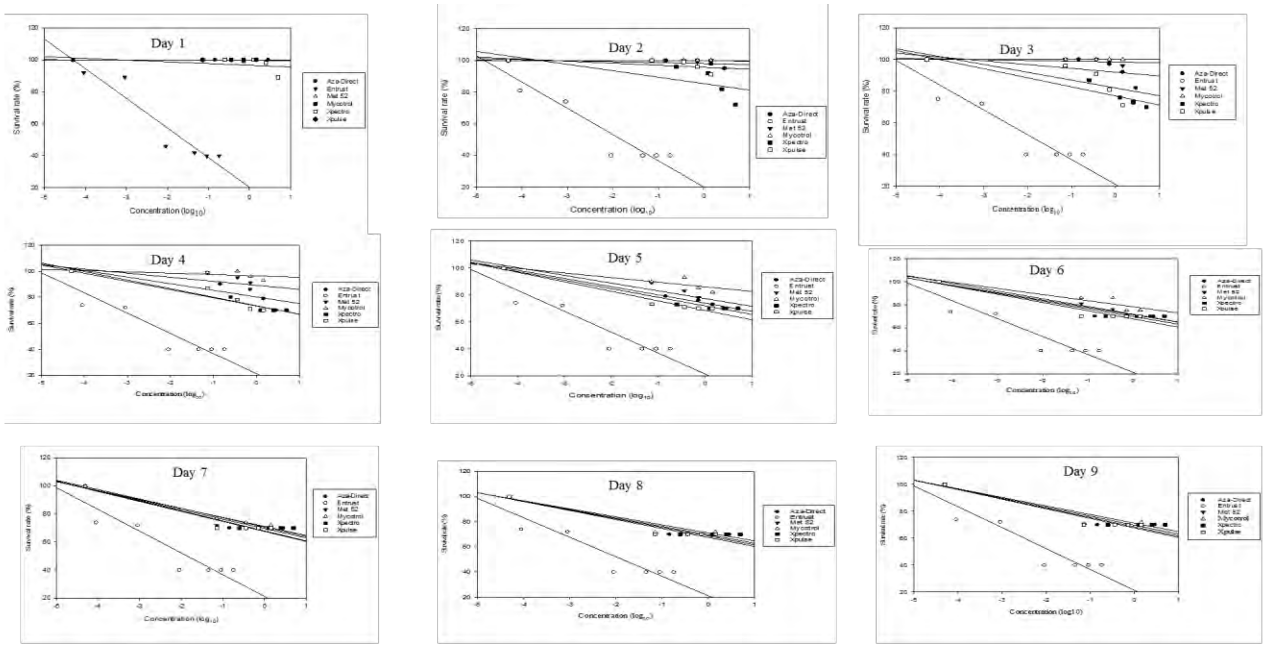

Figure-2: Survival rate of Wheat head armyworm (*Dargida diffusa*) larvae versus log concentration of Aza-Direct, Entrust, Met52, Mycotrol, Xpectro, and Xpulse at days 1 to 9.

Effect of temperature on two bio-insecticides for the control of confused flour beetle (Coleoptera: Tenebrionidae)

Principal Investigator: Dr. Gadi V. P. Reddy.

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Introduction

Globally, 10-20% of all grain produced is lost to stored product pests before it reaches the consumer. Climate plays an important role in grain storage as it interacts with the grain and the pests that consume it. Bacteria, fungi, and insects, the primary pests of stored grain, are highly responsive to changes in climate. Climate affects the growth rate, reproduction, mortality and geography of pests. The interconnectedness of climate and biology has predicted changes in distribution, phenology, and abundance of many animals, and stored grain pests are likewise expected to adapt to their changing surroundings. Changes in climate may also alter current and future control strategies for stored grain pests as changes in temperature, rainfall and crops all adjust to new climate paradigms.

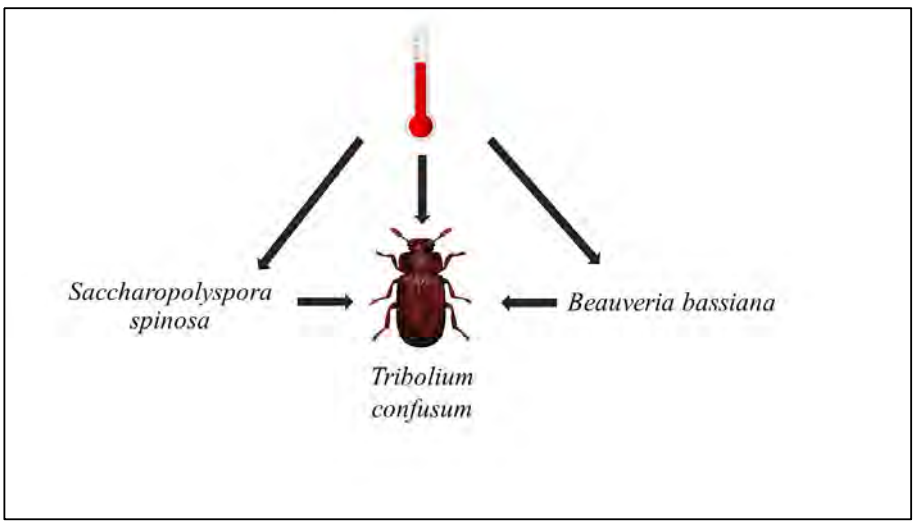

Figure-1: Interaction between temperature and bio-based insecticides on *Tribolium confusum*

At high latitudes, seasonally cold ambient air temperatures are conducive to physical control of grain pests through desiccation and freezing. Cold air is continuously pumped through the grain mass in storage using fans. A continuous supply of cold dry air desiccates and freezes flour beetle larvae and adults of the confused flour beetle, *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae). Heated or cooled air treatments allow more rapid alterations of the internal environment of the grain bin, which is usually well buffered from external temperature. Physical control using heated or cooled air is only applied when outside air temperature provides a natural source of conditioned air. Under a warming climate, forced air circulation may lose efficacy, especially at higher latitudes and higher elevations where winter temperatures are expected to moderate over the coming century.

The development of new pesticides that reduce the risk of non-target effects (e.g., development of resistance, residue problems, etc.) are badly needed in grain production. Aluminum phosphide is currently the best control measure for almost all stored product species, but is highly toxic to humans and animals, and resistance has developed within *T. confusum* populations. Alternative control strategies for the control of stores grain pests are needed. Biologically based insecticides are an alternative that is gaining traction for their adaptability and safety compared with aluminum phosphide, but the effectiveness of biologically based control measures is reliant on their ability to function under various climate regimes.

Biologically based insecticides are an attractive alternative to physical control and aluminum phosphide insecticide. Spinosad is a bioinsecticide produced from the bacterium *Saccharopolyspora spinosa* Mertz & Yao that is increasingly used against stored grain pests. It consists of metabolites that are toxic via contact or ingestion. Once inside the insect body, spinosad excites the nervous system, causing paralysis and eventually death. Spinosad ingested with the stored grain is 5–10 times more active than spinosad encountered through surface contact.

Entomopathogenic fungi such as *Beauveria bassiana,* in contrast, work primarily on surface contact. Spores of *B. bassiana* attach to the insect cuticle when the insect brushes against the spores. Binding of active sites on the infective spore with the insect cuticle initiates germination and the start of the infection process. Entomopathogenic fungi may germinate in grain storage conditions through favorable microclimates on the insect's body, where moisture levels are higher, to grow and infect. Oral, anal and respiratory orifices are moist microhabitats where fungal pathogens may enter the insect body and initiate infection. Though *B. bassiana* often displays host specialization, it can also be a generalist pathogen capable of infecting many insect species. *Beauveria bassiana* is reported to be effective for managing both *Tribolium castaneum T. confusum* (Coleoptera: Tenebrionidae).

The differing nature of these biologically based insecticides for controlling insects at differing temperatures has not been examined. Changes in temperature can affect the reproduction, development and behavior of insects and their pathogens. Growth and reproduction of many stored grain pests is optimal at 25-33˚C. We tested the effectiveness of *B. bassiana* and spinosad against *T. confusum*, which is one of major stored grain pests in the Golden Triangle grain-growing region of Montana, USA, when exposed to varying temperatures.

Materials and methods

Source and rearing of insects

Adults of *T. confusum* were purchased from Carolina Biological Supply Company, Burlington, NC (USA) and reared on a 1:1 mixture of whole-wheat Durham grain and flour grown and processed at the Western Triangle Agricultural Research Center. Laboratory cultures were maintained for one month prior to use in experimental trials at which time all life-stages were present within the colony. Rearing containers were clear plastic storage containers (30 cm long ×

9 cm wide × 5 cm depth) with < 1 mm diameter aeration holes in the lid. Colonies were held using environmental chambers (Shel Lab, Cornelius, OR, USA) at 20˚C and 50% RH under complete darkness until needed

Test arena

Tests were conducted in chambers modified from 60 mL sample vials (SecurTainer II™, Simport Scientific, QC, Canada). Container lid centers were removed and lids were screwed down over the top of sterilized vellum cloth for ventilation. Between tests, all test vials and covers were sterilized with 70% ethanol and UV light for 24 h prior to use. Each vial received 5.0 g of equal parts wheat flour and whole-wheat seeds identical to the rearing mixture. The test arena volume precluded microclimate variance, and wheat moisture was not measured during the experiment.

Larval response to temperature and insecticidal activity

Because the larvae are the most damaging life stage of *T. confusum*, this stage was chosen for all trials. Confused flour beetle in the last instar (9th) were selected from the rearing colony for use in the experiment. The larval age is determined based on the descriptions given in Park (1934). Ninth instar larvae are brown in color and 6.0 mm long, 0.69 mm broad across the head, and weigh 2.4 mg. Late instar larvae are very active feeders (Park 1934). We tested two biobased pesticide treatments: spinosad 80% (Entrust® WP; Dow Agro Sciences Indianapolis, IN, USA) and *B. bassiana* (BotaniGard® 22WP; Laverlam International, Butte, MT, USA) at 8, 16, 22, and 25 ˚C. Each temperature used in this study is typical of temperatures experienced in the local grain production area (central Montana) during grain harvest and storage. Temperatures outside this range are known to be detrimental to *T. confusum* survival. Each vial with 5 larvae (treatment × temperature combination) was replicated 5 times (for a total of 25 test larvae per pesticide × temperature combination). Biologically based insecticides were mixed with wheat grain and flour prior to adding test larvae. *Beauveria bassiana* was added at the label rate of 2×10^{13} spores per 0.45 kg of grain as dry material, so as not to alter moisture levels in grain. Spinosad was added at the label rate of one part per million (ppm) dry powder. Test vials were held in the dark at one of the four experimental temperatures and at constant relative humidity of 52% in a Panasonic MLR-352H-PE plant growth chamber. Control insects were held under identical experimental conditions minus the addition of the biobased insecticides. Larvae were extracted from the wheat-flour mixture once a week to determine mortality or survival. Trials were continued until the larvae were either all dead or pupated (12-45 d depending on temperature treatment).

Response of adults of *T. confusum* to *B. bassiana*

Adult flour beetles were held at one temperature (22˚C) in the presence of *B. bassiana* under exposed conditions and in grain. Both assays took place in containers identical to those used for larvae. The grain mixture and *B. bassiana* concentrations were also the same as in the larval experiment. “Exposed” assays consisted of placing adult beetles on sterile filter paper in SecurTainers™ without grain. *Beauveria bassiana* treatments received 2×10^{13} spores per 0.45 kg of grain or, for the exposed containers that had no grain, this same quantity of spores but in vials without grain. The spores were counted under the microscope. Beetles were held in the dark and monitored for mortality. Mortality was assessed by gently squeezing the beetles with forceps to look for movement. After 28 d, mortality was assessed for all treatment times. Ten beetles were tested in each replicate container. There were five containers for each treatment. Dead beetles were placed in petri dishes with sterile filter paper and 100 µl of sterile water, and fungal growth was monitored for the presence of *B. bassiana*.

Statistical analysis

The percentage mortality was calculated for each replicate as the number dead out of the original five placed in each replicate container. Percentages were arcsine transformed before statistical analysis to correct for the assumption of normality and percentage data. Analysis of covariance was used to determine whether or not treatments affected survival across the time period using the aov command in R for the model at each temperature. Post-hoc analysis was conducted with Tukey's HSD test for multiple comparisons. Statistical significance is reported where appropriate at a P value ≤ 0.05 with the Holm-Bonferroni adjustment for multiple comparisons.

Results

Larval response to temperature and insecticidal activity

Temperature affected the efficacy of spinosad and *B. bassiana* on survival of *T. confusum* larvae. Insects exposed to low temperature (8 ˚C) sustained high rates of mortality (about 80% for control and both treatments) (Fig. 1). Biological control treatments were not significantly different from the control treatment at any time period during the experiment ($F = 1.713$; df = 2; $P = 0.18$). Mortality in the control was statistically equivalent to those with biological control agents throughout the 45 days of treatment. During this time, very few (< 10%) larvae reached the pupal stage.

Mortality at the intermediate temperature of 16 ˚C did not differ significantly between treatments ($F = 0.658$; df = 2; $P = 0.52$). Mortality slowly increased at the same rate across treatments over of the course of exposure at this temperature (Fig.1). Most larvae (> 60%) entered pupation by the end of 15 d, at which time the study was concluded.

Tribolium confusum at 22 ˚C experienced a high rate of mortality when exposed to spinosad ($F = 62.53$; df = 2; $P < 0.001$). After 14 d, larval mortality on spinosad approached 88% (Fig. 1). Spinosad was significantly different from both *B. bassiana* and the control treatments ($P < 0.001$) as examined using Tukey's HSD test for multiple comparisons. *Beauveria bassiana* and the control were not significantly different by post-hoc Tukey test. After 14 d, the majority (> 80%) of surviving larvae had entered the pupal stage.

At the highest temperature tested (25 ˚C), mortality was significantly higher in the *B. bassiana* treatment compared to control or spinosad ($F = 24.21$, df = 2, $P < 0.001$)(Fig. 1). The *B. bassiana* treatment resulted in over 80% mortality compared to < 10% mortality observed for the control and spinosad treatments. The experiment was allowed to run until all larvae were either dead or pupated. More than 80% of surviving larvae pupated in the first two weeks of this temperature treatment. All the dead larvae killed in the *B. bassiana* treatment yielded fungal hyphae indicative of *B. bassiana* when placed in chambers with high humidity to encourage fungal growth.

Adult *t. Confusum* response to *B. bassiana*

There were significant differences in adult response (Fig. 2) to *B. bassiana* under exposed and concealed environments ($F = 5.035$; df = 3; $P = 0.002$) at 22˚C. Beetles exposed to *B. bassiana* without grain were subject to high mortality (84 ± 8%), whereas beetles in the treatment that included grain showed similar mortality to the control (about 30 ± 10%) (F = 1.312; df =1; P = 0.254). All the dead beetles displayed fungal infection.

Acknowledgements

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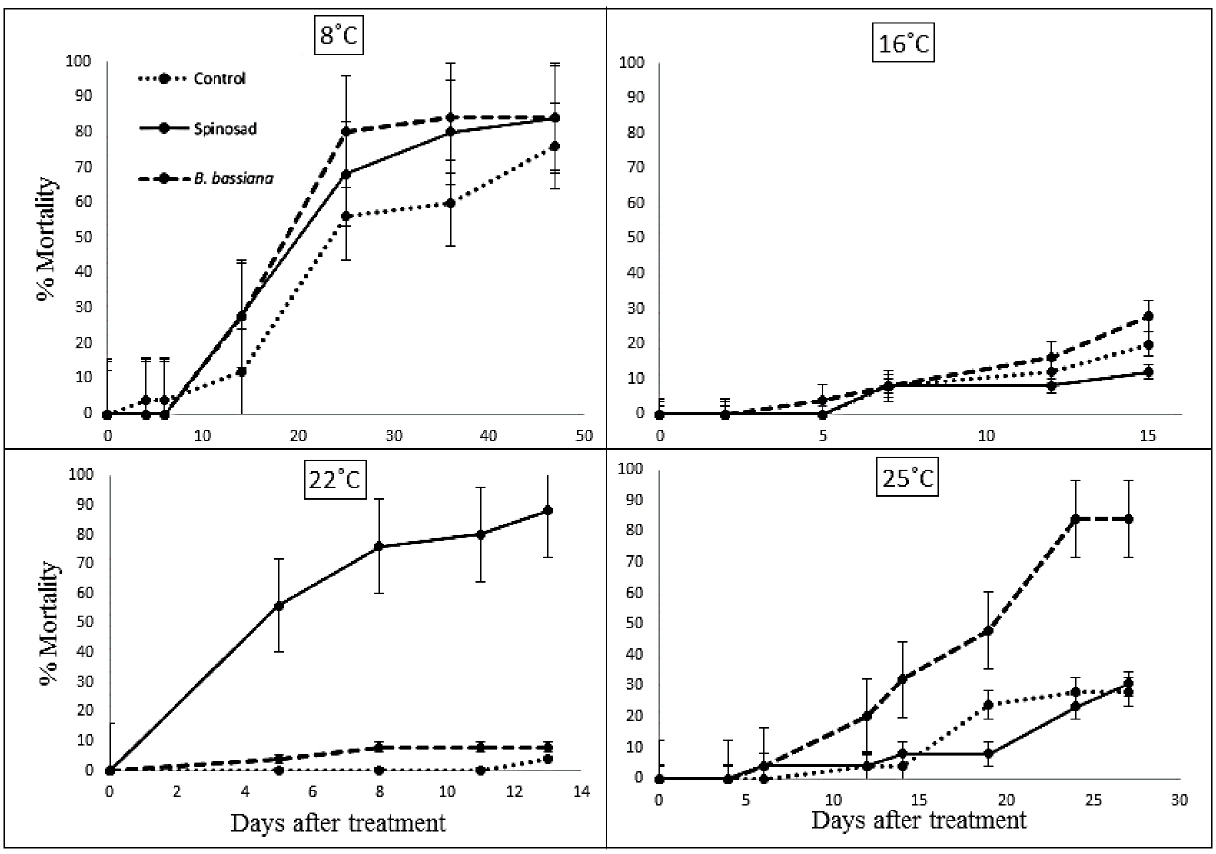

Fig. 1. Mortality of *Tribolium confusum* larvae exposed to *Beauveria bassiana* (large dash), spinosad (solid line) and control (small dash) at 8, 16, 22 and 25 °C. Vertical error bars depict the residual SE of the mean.

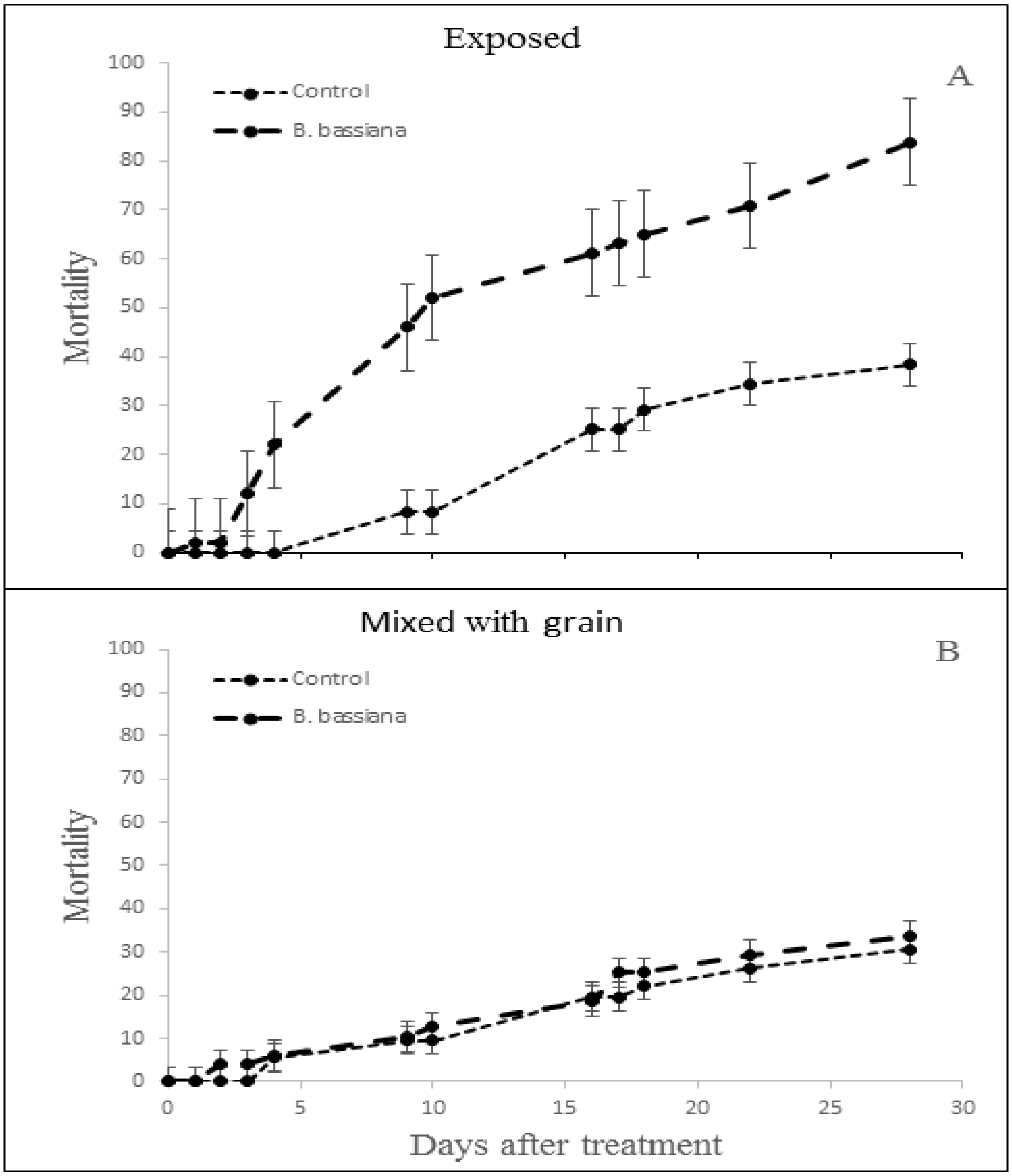

Figure-2: Mortality of *Tribolium confusum* adults with exposure to *Beauveria bassiana* (large dash line) A) on paper and B) in grain compared with controls not exposed (small dashed line). Vertical error bars depict the residual SE of the mean.

Comparative evaluations of three entomopathogenic nematodes against *Tenebrio molitor* (Coleoptera: Tenebrionidae), for use in management of wireworms (Coleoptera: Elateridae) in Montana wheat fields

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Cooperators: Dr. Scott L. Portman* and Amber Ferda

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Introduction

Wireworms, the larval stage of click beetles (Coleoptera: Elateridae), live in the soil and attack the roots of germinating wheat seedlings during the spring months. The damage caused by these insects is typically variable but can be as severe as 28% loss in spring wheat yields. Historically, wireworms have been difficult to control because these insects can burrow deep into the soil column in response environmental factors such as temperature and moisture. One possible control method for wireworms might be entomopathogenic nematodes (EPNs). These microscopic roundworms have the ability to move through the soil as they search for insect prey. However, EPNs are not well known to infect and kill wireworms because of the insect's hardened cuticle and well protected entry points such as spiracles, mouth or anus. During the winter months, wireworms are difficult to collect in the field because they burrow deep into the soil to avoid the freezing temperatures in Montana. Nevertheless, some species of Tenebrionidae, such as *Tenebrio molitor* (mealworm), have similar morphology to wireworms. Mealworms could serve as a good substitute for wireworms to test the ability of different EPNs to infect insects with hardened cuticle and well protected entry points.

Objectives:

1) Test three species of EPNs for their ability to infect and kill *Tenebrio molitor* (mealworm) larva and pupae, as a proxy for wireworms.

Materials and methods

Tenebrio molitor larvae and adults were obtained from Carolina Biological Supply Company (Burlington, NC). Larvae were separated into early and late instars and transferred to 33.7 cm × 21.8 cm × 11.9 cm (L×W×H) plastic containers and reared on a diet of oat bran. Adults were housed in a 475 ml plastic deli cup with 2.5 cm of oat bran on the bottom for egg laying. Potato slices were provided in each container as a source of moisture. Mealworm colonies were stored in a 23^{o}c incubator prior to treatment.

Just before treatment, 30 late instar larvae, 30 early instar larvae, and 30 pupae were removed from the mealworm colonies. For each EPN being tested, ten individuals from each development stage were transferred to the bottom of three clean 475 ml deli cups. Due to an insufficient number of available pupae, *S. feltiae* was not tested with *Tenebrio* pupae (Table 1). A thin layer of oat bran was added to the bottom of the deli cups housing larvae to provide them with a food source. Approximately 5 cm of autoclaved soil was added on top of the insects.

Table-1: Experimental design of the entomopathogenic nematode treatments with *Tenebrio molitor*.

H. bacteriophora	*S. riobrave*	*S. feltiae*
Early Instar	Early Instar	Early Instar
Late Instar	Late Instar	Late Instar
Pupae	Pupae	

Three species of commercially available EPNs (*Steinernema feltiae, S. riobrave*, and *Heterorhabditis bacteriophora*) were ordered from suppliers and stored at 8ºC. EPNs were allowed to equilibrate to room temperature (22ºC) before being added to 3ml of distilled water. EPN solutions were first mixed thoroughly and sucked up into a disposable pipette. EPNs were added to the deli cups containing larvae and pupae by applying 10 drops of the solution, randomly, to the surface of the soil. After EPN application, deli cups were incubated at 20ºC in a growth chamber for 5-14 days. After 5 days, dead or dying larvae and pupae were removed from the deli cups and placed individually in small 75 ml plastic portion cups for several days (2-4 days) of observation. After the observation period, dead larvae and pupae were assayed for nematode infection.

Results and discussion

The experiment was replicated two times. For each replication, mortality rates for all treatment combinations (insect development stages × nematodes) were calculated. Average mortality rates were calculated from the two replications (Fig. 1). On average, mortality rates were above 75% for all EPN treatments. Larvae (late and early) treated with *S. feltia*e exhibited the highest mortality at 100%. Interestingly pupae treated with *H. bacteriophora*, and *S. riobrave* also showed high mortality (100% and 77.8% respectively). Due the similarity in morphology between mealworms and wireworms, these results suggest that wireworms may be susceptible to infection by the three EPN species tested here.

Because only 2 independent samples were obtained for each treatment, no statistical tests could be performed on the data. More replications will be conducted in order to obtain enough data for more robust statistical analysis. In this study, the larvae were free to move through the soil at libitum, presumably coming in close proximity to the nematodes at the surface. To better understand how EPNs migrate through the soil, future work could test their ability to infect insects at different soil depths. Future work (spring 2016) also includes collecting wireworm samples from wheat fields in NW Montana and testing the infectivity of the three EPN species discussed in this report.

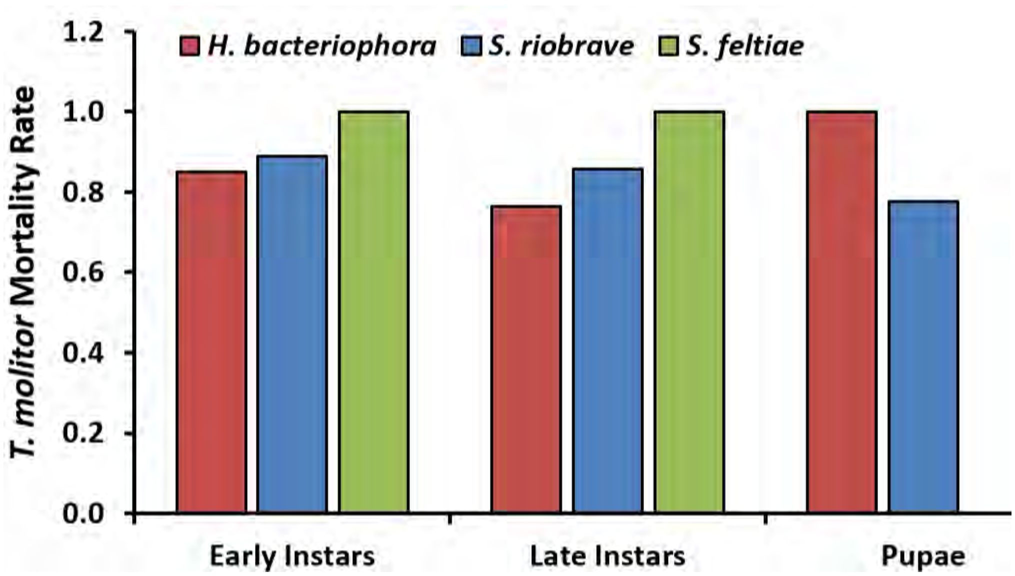

Figure 1 Bars represent average mortality rates of different development stages of mealworms (*Tenebrio molitor*), treated with three species of entomopathogenic nematodes.

Acknowledgements

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Varietal Testing Program

MONTANA STATE UNIVERSITY
College of AGRICULTURE & MONTANA AGRICULTURAL EXPERIMENT STATION

Winter wheat

Project Title: Winter wheat variety evaluations at Western Triangle Ag. Research Center

Principle Investigator: Gadi V.P. Reddy, Superintendent and Associate Professor of Entomology/Insect Ecology, Western Triangle Ag Research Center

Personnel: John H. Miller, Research Associate and Julie Prewett, Research Assistant WTARC, Conrad, MT, and Phil Bruckner and Jim Berg, MSU Plant Science Dept., Bozeman, MT.

Cooperators: Bradley Farms, north of Cut Bank, MT
Brian Aklestad, north of Devon, MT
Aaron Killion, east of Brady, MT
Inbody Farms, northeast of Choteau, MT

Objectives: There are diverse cropping environments within the area served by Western Triangle Agricultural Research Center. Each off station location has its own unique environment and soils. Producers in the various locations are interested in variety performance in the local area. To this end the objective is to evaluate winter wheat varieties under the local conditions with respect to yield, test weight, plant height, and seed protein. The environmental conditions at the off station nurseries can vary greatly from those at WTARC. The research center strives to provide growers of the western triangle area unbiased information of various winter wheat varieties.

Methods: On station plots consist of the Intrastate, Advanced and Preliminary A nurseries. Off station winter wheat nurseries consist of 25 entries replicated three times, seeded with a four row plot seeder on one foot spacing. All plots were planted on no-till chemical fallow. Plots were trimmed, measured for length, and then harvested with a Hege 140 plot combine. Winter wheat seed was cleaned prior to collecting data. Orange wheat blossom midge pheromone traps were installed at each off station plot.

Results: All winter wheat plots started the spring looking spotty, all recovered well with the exception of the plots at Choteau and Devon. On station winter wheat data are presented in tables 1 thru 4, off station plots were harvested at Choteau, Cut Bank, Devon, and the 'Knees'. Data for Choteau and Devon are not presented as the stands were very poor. The data are presented in Tables 5 thru 7.

The soils were generally dry at the surface when seeding winter wheat during the fall of 2014. The precipitation in September and October was below the 29 average, with a cooler September and a warmer October, and November was significantly much cooler than normal.

Overall, the crop year temperatures where close to the 29 year average at the research center with the exception of 2.5 inches less moisture than the 29 year average. The winter temperature was close to average, with the exception of November being 8 degrees cooler than usual. March was 7 degrees warmer than the normal. Also June was 4.6 degrees warmer compared to the 29 year average.

Soil temperatures at the station under chemical fallow stubble stayed under 40 degrees at a depth of eight inches until mid April. May was cool with slightly above average precipitation. Early in June we received 0.95 inches, then it warmed up and remained dry for about 30 days, during that time the winter wheat was running out of water as it was heading. With July having normal amounts of rain, but not enough to completely fill all the kernels in the heads.

Grain yields for the Intrastate nursery were about 12 bu/ac less than the six year average and test weights were down about a pound per bushel with respect to the six year average. Seed protein was 1.2 percent higher this year as compared to the six year average. The top yielding varieties were Denali, LCS Mint, and SY Wolf at 95.9, 95.2, and 90.8 bu/ac with each also having a test weight over 60 lbs/bu (Table 1).

Grain yields and test weights at the ‘Knees’ were 8 bu/ac higher and 1 lb/bu lower than the four year average. Seed protein at the ‘Knees’ was almost two percent lower than the four year average. There is no long term table for Cut Bank as the plot has been destroyed by hail and one spray accident the last three of 5 years. The plots in Devon and Choteau had very poor stands and the data was not conclusive to give adequate information for this year.

Top yielders at the ‘Knees’ include Montana State University experimental line MT1138, SY Wolf, Montana State University experimental line MTS1224 at 78.1, 72.5, and 71.6 bu/ac. At Cut Bank, the top yielding wheat’s were WB3768, Montana State University experimental line MT1257 and new Montana State University release Northern (2015) with yields of 65.1, 64.0,and 63.6 bu/ac.

No insect incidence (wheat stem sawfly or wireworms) was noticed in any of the winter wheat varieties. This is because of the high number of parasitoids of the wheat stem sawfly are present at the research center. Insignificant amount of adult of orange wheat blossom midge were found at the off station locations.

Summary: The data from the off station plots is supported by the local producers and advisory committee as well as the seed industry. It is planned to continue the off station variety plots at the same locations as the environmental conditions at each location is unique to the western triangle area. No insect incidence or damage was noticed in any of the varieties.

These data should be used for comparative purposes rather than using absolute numbers. Statistics are used to indicate that treatment or variety differences are really different and are not different due to chance or error. The least significant difference (LSD) and coefficient of variability (CV) values are useful in comparing treatment or variety differences. The LSD value represents the smallest difference between two treatments at a given probably level. The LSD at p=0.05 or 5 % probability level is usually the statistic reported, and it means that the odds are 19 to 1 that treatment differences by the amount of the LSD are truly different. The CV value measures the variability of the experiment or variety trial, and a CV greater than 15 % indicates a high degree of variability and less accuracy.

Funding Summary: Office of Special Projects will provide expenditure information. No other grants support this project.

MWBC FY2016 Grant Submission Plans: A similar project will be proposed for FY 2016. The continuation of on and off-station variety trials help elucidate researchers and farmers which varieties are better suited for that particular region in Montana.

Table 1. 2015 Intrastate winter wheat variety nursery, Western Triangle Ag. Research Center, Conrad, MT.

Variety or ID	Source	Solid Stem score*	Yield bu/ac	Test weight lb/bu	Heading date Julian	Plant height Inches	Protein %
Denali	Colorado,2011	-	95.9	61.5	155.2	36.0	11.9
LCS Mint	Limagrain 2012	-	95.2	62.0	153.0	34.4	12.4
SY Wolf	Syngenta(AgriPro),2010	-	90.8	61.8	154.7	32.0	12.9
MT1348	PI572290/BigSky	-	89.9	59.6	155.4	34.7	12.7
Keldin	WestBred, 2011	-	89.8	60.3	157.1	33.1	13.5
MT1361	-	-	89.5	59.2	158.9	32.9	12.7
Freeman	Nebraska, 2013	-	89.3	59.6	150.7	33.5	12.6
MT1286	-	-	89.0	61.2	158.1	35.8	12.9
MTCL1131	-	-	89.0	59.5	158.5	35.1	12.4
Northern	Montana, 2015	-	87.9	59.3	158.1	35.0	12.9
MT1332	-	-	87.3	59.9	158.6	36.6	12.5
MT1356	-	-	87.2	59.6	158.7	34.9	12.8
Brawl CL Plus	Colorado, 2011	-	85.7	62.9	150.5	34.1	13.4
SY Monument	Syngenta(AgriPro),2014	-	83.9	58.5	155.7	33.8	12.7
Cowboy	Wyomimng/Colorado, 2012	-	83.6	59.5	154.9	32.5	12.3
T158	Trio Research/Limagrain, 2009	-	83.4	62.6	150.3	32.2	13.2
Yellowstone	Montana, 2005	-	83.1	60.0	158.6	34.4	12.7
SY Clearstone 2CL	Montana/Syngenta, 2012	-	83.0	57.2	158.1	34.2	12.6
06BC796#68	Syngenta(AgriPro)	-	82.4	62.6	152.8	30.7	13.3
CDC Falcon	Sask/Krichauff	7.1	82.3	59.9	157.9	34.7	12.7
LCH 10-13	Limagrain	-	81.8	63.3	154.3	35.8	13.9
MTS1224	-	17.1	80.7	57.5	159.4	31.3	13.3
MT1265	-	-	80.4	58.7	158.2	36.3	13.4
Colter	Montana, 2013	-	79.6	58.2	158.5	31.1	13.5
Broadview	Alberta, 2009(meridian seeds)	-	77.5	58.8	158.0	33.4	13.5
Ledger	WestBred, 2004	8.5	77.4	61.3	155.1	34.0	12.6
MT1138	-	-	76.8	58.7	157.1	34.8	13.3
WB4614	WestBred, 2013	-	75.5	60.5	156.4	32.3	13.6
MT1078	-	-	75.2	55.3	158.2	33.4	13.1
WB3768	Montana/WestBred, 2013	-	74.9	59.6	159.8	35.7	13.8
MTS1305	-	20.7	74.8	60.6	155.5	32.3	13.1
Jerry	North Dakota, 2001	-	74.6	58.5	157.8	38.4	13.0
Byrd	Colorado, 2011	-	74.4	58.7	153.4	33.7	12.4
MTCL1329	-	-	73.9	62.1	155.2	31.2	12.7

Table 1 continued on next page

Table 1 continued								
Variety and Class	Source	Solid Stem score*	Yield bu/ac	Test weight lb/bu	Heading Date Julian	Plant height inches	Protein %
Decade	Montana/North Dakota, 2010	-	72.9	59.8	155.8	32.9	13.5
MTCS1204	-	-	72.7	60.3	155.8	33.3	13.2
MT1354	-	-	72.6	57.9	158.5	35.0	13.7
MT1117	-	-	72.2	58.4	158.6	35.0	14.4
MTF1232	-	-	68.4	58.4	159.4	43.8	14.5
Genou	Montana, 2004	17.2	67.4	59.8	156.8	38.6	14.0
WB4623CLP	WestBred, 2014	-	67.1	59.9	157.3	30.7	14.0
Bearpaw	Montana, 2011	21.3	66.9	58.9	155.6	31.9	13.7
WB4059CLP	WestBred, 2013	-	65.4	61.7	152.5	32.0	13.9
MTS0826-63	-	22.4	64.8	57.9	159.9	34.7	14.9
Judee	Montana, 2011	20.1	63.1	58.6	155.2	33.7	14.4
Rampart	Montana, 1996	20.8	59.5	59.7	157.8	36.2	14.5
Warhorse	Montana, 2013	22.5	58.2	57.4	157.8	31.4	14.0
WB Quake	WestBred, 2011	19.9	54.3	58.6	158.4	32.2	14.0
Mean		19.0	78.2	59.7	156.4	34.1	13.3
LSD (0.05)		2.9	16.6	1.9	1.5	2.2	1.1
C. V. (%)		8.8	12.2	1.8	0.5	4.0	4.9
P-value (Varieties)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	

Planted: 9/29/14 on chemical fallow and harvested on 7/24/15.
Fertilizer, actual pounds/ac of N-P-K: 11-22-0 applied with seed and 40-0-20 broadcast at planting. 130 lbs/ac N as urea was broadcast on 3/3/2015.
Herbicide, Huskie at 11.0 oz/ac and Axial XL at 16.4 oz/ac applied on 5/14/2015.
* Solid stem score of 19 or higher is generally required for reliable sawfly resistance.
CL = Clearfield System

Table 2. Six-year means, 2010 – 2015, Winter wheat varieties, Western Triangle Ag. Research Center, Conrad, MT.

Variety	Source	Solid stem* score	6-Year Means Yield bu/ac	Test Wt.	Height inches	Head date	Protein %	Winter survival class
Northern			100.8	60.3	34.3	171.5	12.0	
SY Wolf	Syngenta	-	100.5	61.8	30.9	167.2	11.9	-
Yellowstone	MSU	-	100.4	60.3	34.7	171.2	11.6	4
Colter	MSU	-	97.3	59.6	34.1	171.7	12.1	-
SY Clearstone 2CL	SY/MSU	-	96.2	59.1	35.2	170.8	11.8	-
CDC Falcon	CDC/WestBred	7.1	92.9	60.6	31.9	169.2	11.7	4
Decade	MSU/ND	-	90.6	60.6	33.1	167.1	12.4	-
Judee	MSU	20.1	88.0	62.1	33.2	168.0	12.0	-
Ledger	WestBred	8.5	86.4	61.3	32.6	168.6	11.5	2
Bearpaw	MSU	21.3	86.2	60.5	32.3	168.7	12.3	-
Warhorse	MSU	22.5	85.3	60.0	32.8	170.3	12.4	-
Jerry	N. Dakota	-	83.8	59.9	38.2	170.3	12.2	5
Genou	MSU	17.2	83.6	61.0	37.0	170.1	12.5	2
WB-Quake	WestBred	19.9	83.2	60.6	33.4	170.6	12.2	-
Rampart	MSU	20.8	77.9	60.6	36.5	169.9	13.3	2
Mean		19.0	90.2	60.6	34.0	169.7	12.1	

* Solid stem score of 19 or higher is generally required for reliable sawfly resistance.
HW = Hard White; CL = Clearfield herbicide system.
Winter hardiness: 5 = high, 1 = low.

Table 3. 2015 Advanced Yield Nursery, Western Triangle Ag. Research Center, Conrad, MT.

ID or Variety	White	Yield bu/ac	Test weight lb/bu	Heading Date Julian	Plant height inches	Protein %
MT1465		77.8	60.3	155.9	29.9	12.8
MTW1490	w	75.5	59.5	158.0	32.7	13.0
MTW1479	w	73.8	59.2	158.2	31.3	12.8
MTS1412	w	73.2	61.5	155.8	32.1	13.6
MT1460		72.8	59.0	157.4	33.3	13.5
MT1478		70.6	59.2	155.6	32.5	13.5
MT1471		68.5	60.4	155.9	33.1	14.6
MT1446		68.3	59.6	157.6	32.0	13.1
MT1489		67.4	58.1	158.5	31.2	13.3
MT1459		67.4	59.4	157.4	33.1	13.3
MTS1413	w	67.1	58.9	156.0	29.8	12.7
MTF1432		66.9	57.6	159.4	36.6	13.1
MT1443		66.8	58.5	158.2	32.5	14.0
Judee		66.4	61.2	154.2	32.4	13.4
MT1467		66.4	62.1	152.9	31.7	14.3
MT1445		66.1	59.1	157.6	32.3	13.7
MT1448		66.0	56.2	158.3	30.8	13.1
Genou		65.9	58.5	156.6	35.9	13.3
MTW1491	w	65.5	58.5	158.7	34.0	13.9
MTS1444		65.5	59.4	156.7	33.5	13.4
Jagalene		65.3	62.3	155.2	31.2	13.7
MTF1435		65.1	59.5	157.7	39.4	13.3
MT1473		64.7	59.0	154.2	32.0	14.6
MTS1407		64.7	58.5	158.4	29.3	14.0
MT1488		64.4	57.7	158.8	31.2	13.8
Yellowstone		64.1	58.6	156.9	33.2	13.4
MT1449		64.0	58.3	156.4	30.0	14.0
MT1483		63.9	56.3	158.3	33.3	13.2
Decade		63.2	59.1	155.0	31.1	14.0
MTS1409		60.5	59.7	154.8	31.4	13.6
MTS1402		59.6	57.0	155.9	31.8	13.3
MTS1422		59.5	59.6	155.4	29.5	13.9
MT1451		59.1	59.6	156.2	31.6	13.8

Table 3 Continued on next page

Table 3 Continued

ID Or Variety	Yield bu/ac	Test weight lb/bu	Heading Date Julian	Plant height inches	Protein %
MT1472	58.2	58.6	156.7	30.7	14.7
MTS1410	57.2	56.6	155.6	30.8	13.7
MT1404	54.0	58.2	156.5	29.1	14.2
Mean	65.7	59.0	156.7	32.1	13.6
LSD (0.05)	ns	1.9	1.6	2.0	0.8
C.V. (%)	10.5	1.8	0.6	3.7	3.4
P-value (Varieties)	0.0874	<0.0001	<0.0001	<0.0001	0.0002

Planted: September 29, 2014 on chemical fallow barley stubble and harvested on July 29, 2015.
Fertilizer, actual pounds/ac of N-P-K: 11-22-0 applied with seed and 40-0-20 broadcast at planting. 160 lbs/ac N as urea was broadcast on 3/3/2015.
Herbicide: Preplant sprayed with Huskie at 11 oz/ac and Axial XL at 16.4 oz/ac. applied on 5/14/2015.

Table 4. 2015 Preliminary A Variety Nursery, Western Triangle Ag. Research Center, Conrad, MT.

Variety	Yield bu/ac	Test weight lb/bu	Heading date Julian	Plant height inches	Protein %
Jagalene	96.0	63.3	155.5	34.0	12.2
MT1539	92.9	58.7	155.0	34.6	13.1
MT1511	91.7	61.0	156.8	45.5	12.2
MT1512	89.0	61.0	154.4	31.4	12.4
MT1558	87.3	60.2	158.1	34.6	12.8
MT1552	86.8	59.2	156.7	36.3	12.6
MT1542	86.5	57.9	157.6	34.7	12.9
MTW1560	84.9	59.4	158.2	34.0	12.9
MT1514	84.1	60.5	157.1	33.5	12.9
MT1548	83.8	58.5	152.2	36.5	12.5
CDC Falcon	83.3	59.3	156.0	31.5	12.9
MTCL1501	82.9	58.7	158.5	33.3	12.7
MT1551	82.9	58.6	156.8	33.7	13.7
MTW1522	82.5	61.5	156.8	32.8	13.2
MTW1556	81.3	60.1	154.0	34.5	13.5
MT1505	80.8	59.7	157.0	34.6	13.4
MTCL1503	80.7	58.9	157.4	32.1	13.7
MT1545	80.4	57.7	158.9	34.5	12.4
MT1521	80.3	60.9	157.6	32.1	13.3
MTW1525	79.8	60.8	157.3	32.3	13.1
MT1519	79.7	58.9	156.8	32.7	13.0
MT1540	78.7	59.4	157.4	32.6	13.4
MT1529	78.6	57.8	156.8	34.5	12.8
MT1506	78.1	57.7	156.5	33.3	13.4
MT1554	77.7	56.0	154.0	33.3	13.7
MT1541	77.7	60.6	157.6	34.5	12.5
MTF1559	76.0	54.2	156.5	37.6	13.4
MT1527	75.9	57.7	158.1	29.8	13.8
MTW1513	75.7	59.7	157.5	35.6	13.4
MT1537	75.6	55.6	158.1	32.9	14.0
MTW1544	75.5	59.3	157.4	32.7	14.0
MTW1516	74.5	59.0	156.6	32.2	13.1
MT1534	74.1	60.0	157.0	33.4	13.5
Yellowstone	73.8	58.6	158.8	33.7	13.2

Table 4 Continued on next page

Table 4 Continued

Variety	Yield (bu/ac)	Test Weight (lbs/bu)	Heading Date Julian	Plant Height inches	Protein (%)
MT1549	73.7	58.8	158.4	32.3	14.1
MT1515	73.4	55.0	157.2	32.2	13.2
MT1530	73.3	58.5	157.3	29.9	13.5
MT1536	72.5	58.5	154.8	32.3	12.2
MT1507	72.4	59.5	158.5	33.6	12.7
MTCL1502	72.3	59.5	157.5	31.7	12.8
MT1550	72.0	57.0	153.9	33.3	13.9
MT1535	71.6	57.2	156.0	30.9	14.5
MT1547	71.3	58.5	156.9	32.3	14.3
MT1518	71.1	58.5	158.6	31.3	13.6
MT1533	70.5	57.5	156.7	30.9	13.5
MTW1543	69.7	58.1	157.3	31.5	14.2
MT1504	68.8	56.5	156.9	32.9	13.7
MT1526	67.8	57.3	154.9	33.3	13.9
MT1508	67.8	56.0	153.9	31.1	13.5
MT1531	67.5	55.8	157.3	30.7	14.2
MT1532	67.0	54.3	157.1	30.6	14.2
MT1546	66.9	57.8	158.3	31.5	13.8
MT1538	66.6	55.0	156.2	33.1	13.8
MT1528	65.5	56.3	157.6	31.9	14.4
MT1553	65.1	58.6	155.3	33.9	13.4
MT1510	65.1	55.7	154.3	30.6	13.4
MT1523	65.0	58.1	156.7	32.0	14.4
MT1509	64.7	56.4	154.0	30.6	13.6
MT1557	62.8	53.1	158.7	32.0	14.4
MT1555	61.4	56.9	155.5	31.8	13.8
MTW1520	59.4	55.0	158.1	31.3	13.4
Decade	54.5	58.2	155.9	31.3	14.9
MTW1524	53.7	53.0	156.4	31.0	15.2
MT1517	36.1	54.6	156.8	30.9	15.0
Mean	74.3	57.3	156.7	32.7	13.4
LSD (0.05)	ns	3.8	2.5	2.9	ns
C. V. (%)	14.9	3.1	0.8	4.2	6.0
P-value (Varieties)	<0.0741	<0.0006	<0.0001	<0.0005	<0.1706

Planted: September 29, 2014 on chemical fallow and harvested on July 29, 2015.
Fertilizer, actual pounds/ac of N-P-K: 11-22-0 applied with seed and 40-0-20 broadcast at planting. 160 lbs/ac N as urea was broadcast on 3/3/2015.
Herbicide, Huskie at 11.0 oz/ac and Axial XL at 16.4 oz/ac applied on 5/14/2015.

Table 5. Off-station Winter Wheat variety trial located north of Cut Bank, MT. Glacier county. Western Triangle Ag. Research Center, 2015.

Variety	Yield bu/ac	Test Wt lb/bu	Height inches	Protein %
WB3768	65.1	60.5	30.4	12.5
MT1257	64.0	59.8	30.3	12.4
Northern	63.6	60.8	28.0	12.8
MT1265	63.1	60.8	29.3	12.5
Yellowstone	63.5	59.7	30.0	12.5
MT1296	61.4	61.1	29.0	12.1
SY Wolf	59.5	60.5	27.3	12.6
Genou	58.7	58.8	32.0	12.7
Colter	58.2	59.9	28.0	12.5
MTS0826-63	57.9	59.4	28.0	12.7
MT1117	57.2	60.8	30.7	12.6
Bearpaw	57.3	58.4	28.3	12.4
MT1138	56.0	59.6	29.7	12.2
Jerry	55.9	59.1	29.0	12.2
Decade	55.7	59.7	27.3	12.8
MTS1224	55.6	60.2	25.3	12.3
MT1078	54.3	59.1	26.3	11.8
Broadview	54.1	58.4	26.0	11.6
CDC Falcon	53.6	58.3	27.7	12.6
Judee	52.9	61.2	26.0	12.6
SY Clearstone 2CL	50.0	60.0	29.0	12.9
MTCS1204	47.6	60.1	30.7	12.5
WB-Quake	47.4	59.9	27.7	12.1
Rampart	40.7	59.8	26.3	13.2
Warhorse	34.1	60.1	27.3	12.7
Mean	55.5	59.9	28.4	12.5
LSD (.05)	10.9	0.9	3.4	ns
C.V.(%)	9.9	0.9	7.1	3.8
P-Value	<0.0001	<0.0001	0.0167	0.2462

Cooperator and Location: Bradley Farms, northern Glacier county.
Planted 10/7/2014 on chem-fallow. Harvested 8/24/2015.
Fertilizer, actual lbs/a: 11-22.5-0 with seed at planting, topdressed with 163-0-20 on 3/9/2015. Sprayed with Huskie at 11 oz/ac and Axial XL at 16.4 oz/ac on 6/4/2015.
Precipitation: 4.20 inches
** = Solid stem sawfly-resistant (solid stem score of 19 or higher). * = Less preferred by sawfly (behavioral preference) in small plots. Conducted by MSU Western Triangle Ag. Research Center.

Table 6. Off-station Winter Wheat variety trial located near the Knees. Chouteau County. Western Triangle Ag. Research Center, 2015.

Variety or ID	Yield bu/ac	Test Wt. lb/bu	Height inches	Lodging %	Protein %
MT1138	77.1	58.6	34.3	17.7	10.5
MTS1224	73.2	58.7	32.7	6.7	11.5
Colter	72.1	59.1	36.3	15.3	10.4
SY Wolf	71.7	60.8	32.3	6.7	10.1
MT1257	71.1	58.2	34.3	19.5	11.0
MT1078	70.1	57.1	33.0	9.7	11.1
Northern	70.0	59.3	32.3	23.6	11.4
Decade	69.5	59.2	33.7	4.8	10.2
SY Clearstone	69.5	57.8	35.7	23.1	10.5
WB3768	69.5	59.4	37.0	14.8	10.9
MTS0826-63	69.4	59.6	36.7	16.0	11.3
Yellowstone	68.8	58.6	33.7	23.2	11.0
Warhorse	68.7	59.3	31.3	9.1	11.1
MTCS1204	67.3	60.4	33.3	14.5	11.6
MT1117	65.8	59.8	34.0	11.6	10.7
Broadview	65.5	58.7	33.3	18.2	10.6
MT1286	65.4	59.6	34.3	19.6	11.0
Bearpaw	63.6	58.7	33.3	16.1	11.2
MT1265	62.4	58.5	35.0	18.3	10.6
Judee	59.7	60.0	30.3	13.8	11.6
CDC Falcon	59.0	58.0	31.7	19.7	11.4
Genou	58.0	59.9	36.3	23.4	10.4
Jerry	55.7	58.5	35.7	32.4	11.0
WB Quake	55.0	58.9	31.3	10.8	12.1
Rampart	52.8	60.1	35.0	13.1	11.8
Mean	66.6	59.1	33.9	16.1	11.0
LSD (.05)	10.5	0.7	2.7	11.2	ns
C.V. (%)	8.9	0.7	4.8	39.8	5.9
P-Value	0.0012	<0.0001	0.0002	0.0026	0.1078

Cooperator and Location: Aaron Killion, western Chouteau County.
Planted 10/1/ 2014 on chem-fallow. Harvested 8/6/15.
Fertilizer, actual lbs/ac: 11-22-0 with seed at planting, 40-0-20 broadcast while planting. Spring topdressing took place on 3/5/2015 with 65-0-0. For fertilizer rates a yield goal of 70 bu/ac was used.
Pre-plant sprayed with Olympus @ 0.6 oz/ac on 10/1/2014. Precipitation: 1.75
Conducted by MSU Western Triangle Ag. Research Center.

Table 7. Five-year means, Winter Wheat varieties, Knees area, western Chouteau County. 2011-2015.

Variety Or ID	**	5-Year Mean Yield bu/a	Test weight lbs/bu	Height inches	Protein %
Northern (0978)		68.9	60.1	30.4	12.9
Yellowstone		65.7	59.4	31.9	12.9
Colter (MT08172)		64.9	59.9	31.7	12.5
SY Clearstone 2CL		64.2	58.8	33.2	12.8
Decade		62.6	60.7	30.6	12.9
Warhorse (MTS0808)	**	62.4	60.5	29.2	12.6
CDC Falcon		58.4	60.3	28.1	13.0
Judee (MTS0713)		57.5	61.0	28.4	13.3
WB-Quake	**	56.7	60.3	29.4	12.9
Jerry	**	53.4	59.3	32.8	13.0
Bearpaw (MTS0721)	**	53.1	60.0	29.5	13.0
Rampart	**	50.9	60.5	31.7	13.4
Genou	**	49.9	60.5	32.3	13.0
Mean		58.6	60.1	30.7	12.9

** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
Cooperator and Location: Aaron Killion, western Chouteau County.
Conducted by MSU Western Triangle Ag. Research Center.

Winter Wheat Variety Notes & Comments

Western Triangle Agricultural Research Center, Conrad, MT

Winterhardiness ratings: 5 = very good; 1 = poor.
Coleoptile length: Long = 3.4" or more; Short = 3" or less.
Stem solidness scores of 19 or higher are generally required for reliable sawfly resistance.

Accipiter (Sask. DH0018196): First tested in 2008. High yield in 2008. 4" taller than Falcon. Similar to Falcon for test weight, head date and protein. Parentage = Raptor x Falcon.

Bauermeister (WA7939, 2005): Winterhardiness = 2. Medium height, med-strong straw. Medium coleoptile. Very late maturity. Very low test weight.

Bearpaw (MSU, 2011): Awned, white-glumed, solid-stem (stem solidness score = 21.8), semi-dwarf hard red winter wheat. Maturiety similar to CDC Falcon, and a day earlier than Genou and Rampart. About 3.5 inches shorter than Genou and Rampart, with yields similar to CDC Falcon and higher than Genou and Rampart. Susceptible to strip and leaf rust. Resistant to prevalent races of stem rust and UG99.

Big Sky (MT9432, 2001): Nuwest/Tiber cross, hard red kernels, white chaff. Good winterhardiness (4). Strong, stiff straw, very good lodging resistance, height equal to Tiber. Medium coleoptile. Medium maturity, heading 1-2 days later than Rocky, but 2 days earlier than Tiber and Morgan. Yield about equal to Rocky, and 2-3 bu higher than Tiber. High test weight and protein. Post-harvest seed dormancy is high, like Tiber. Septoria and tan spot resistance is good. A good alternative to Tiber.

Bond (CO 2004): Winterhardiness = 2. Clearfield system IMI resistant. Stiff straw, medium height & coleoptile, early maturity. Above average yield. Average test weight. Resistant to biotype 1 Russian wheat aphid. Low protein and poor quality.

Buteo (CDC, WPB, Sask., 2006): Winterhardiness = 4. Standard height, medium coleoptile. Medium-late maturity. Below average yield. Above average test wt. Average protein.

Bynum (MSU & WPB, 2005): Clearfield system single-gene resistance to imazamox or 'Beyond' herbicide. Winterhardiness = 2. Medium strong straw, medium height, long coleoptile. Stem solidness = 20 (compared to 22 for Rampart), which typically provides a reliable level of sawfly tolerance. Similar in yield and other characteristics to Rampart. Sawfly resistant, low yield, high protein, and excellent baking quality.

Carter (WestBred, 2007): Winterhardiness = 3. Semidwarf height, stiff straw, short coleoptile. Stem solidness score = 15. Medium early heading. Average yield. Above average test weight. Average protein. Moderate resistance to stripe rust.

Colter (MSU, 2013): White chaffed, hard red winter wheat. A high yielding winter wheat, similar to Yellowstone. Colter has a test weight of 0.5 lb higher than Yellowstone, heading two days later than Yellowstone. Colter has good stem rust resistance when related to Yellowstone. It is resistant to prevalent races of stripe rust, but susceptible to leaf rust.

Darrell (S. Dak., 2006): Medium height and coleoptile. Medium-early heading. High yield. Average test weight and protein.

Decade (MSU/NDSU, 2009): White chaffed, hard red winter wheat, with winter hardiness almost equal to Jerry. High yield potential, medium to high test weight, early maturity, and medium to high grain protein.

Falcon (CDC, WPB, Sask. 1999): Good winter-hardiness (4). Semi-dwarf, stiff straw, 4" shorter than Rocky. Short coleoptile. The first true winter hardy semi-dwarf available for irrigated conditions in Montana. Heading 1 day later than Rocky, 2 days earlier than Neeley & Tiber. Above average yield and test weight on dryland, good performance for irrigated or high rainfall conditions. Protein similar to Rocky. Not for stripe rust areas.

Genou (MSU, 2004): Sawfly resistant. Stem solidness not quite as solid as Rampart; and may be more sensitive to environmental factors than that of Rampart. Solid stem comparison: (max rating = 25): Rampart = 22, Genou = 19. Winterhardiness higher than Vanguard and Rampart, equal to Rocky. Medium stiff straw. Height similar to Vanguard, and 2” shorter than Rocky. Medium coleoptile. Maturity 1-2 days later than Rocky. Yield 7% higher than Vanguard & Rampart, 5% less than Rocky. Average test weight and protein.

Hawken (AgriPro, 2007): Semidwarf height, short coleoptile. Early maturity. Yield is below average. Above average test weight and protein.

Hatcher (CO 2004): Winterhardiness = 2. Strong straw, semidwarf height, medium coleoptile. Early maturity. Low protein. Resistant to biotype 1 Russian wheat aphid and Great Plains biotype Hessian fly. Very low quality.
Jagalene (AgriPro, 2002): Winterhardiness = 2. Semidwarf, stiff straw, medium coleoptile. Early maturity, 1 day earlier than Rocky. Shatter resistant. Average yield. Very high test weight. Avg protein, but higher than Rocky. Good milling quality. Good disease resistance package (stem & stripe rust, tan spot and Septoria).

Jerry (ND, 2001): Winterhardiness high (5). Medium-stiff, med-tall straw, medium coleoptile. Medium-late maturity. Yield is below average, except in winterkill areas where it’s above average. Below-average test weight. Average protein. Has one of the worst sawfly stem-cutting ratings. Shatter susceptible.

Judee (MSU, 2011): Awned, white-glumed, solid-stem (stem solidness score = 20.1), semi-dwarf hard red winter wheat with good straw strength. Maturiety similar to CDC Falcon, and a half day earlier than Genou and Rampart. About 2.5 inches shorter than Genou and Rampart, with yields similar to CDC Falcon and higher than Genou and Rampart. Winter hardiness is medium to low. Susceptible to prevalent races stem and leaf rust, but is resistant to stripe rust.

Ledger (WestBred, 2005): Winterhardiness = 2. Semidwarf height & stiff straw, 4” less than Rocky. Medium coleoptile. Stem solidness = 10, variable & sensitive to cloudy conditions; not a reliable level of sawfly tolerance. Early heading. Above avg yield & test wt. Avg protein and acceptable quality. Moderate stripe rust resistance.

Morgan (Sask & WPB, 1996): High winterhardiness (5). Standard height. Medium stiff straw. Very short coleoptile. Three days later to head and slightly later maturity than Rocky; heading similar to Neeley. Below average yield. Test wt 1-lb less than Rocky or Tiber. Protein slightly higher than Rocky, similar to Neeley. Milling and baking acceptable. Recommended for areas needing high levels of winterhardiness.

MT08172 (MSU): Awned, white-glumed, high-yielding hard red winter wheat. Similar to Yellowstone for most agronomic traits with the exception of test weight, MT08172 is about 0.5 lb/bu higher. Better stem rust resistant than Yellowstone, moderately resistant to prevalent races of stem rust including UG99. Also, moderately resistant to stripe rust, but susceptible to leaf rust. Medium to late maturity, 2.5 days later than CDC Falcon and 4 days later than Jagalene. Similar in height to Yellowstone.

Neeley (Idaho, 1980): Winterhardiness medium (3). Medium short straw. Medium coleoptile. Medium-late maturity. Susceptible to stem rust. High yielder in good years, but does poor if stressed for moisture. Below average test weight. Good shatter resistance. Protein & quality are erratic, ranging from low to high. Not for stripe rust areas.

Norris (MSU & WPB, 2005): Clearfield system single-gene resistance to imazamox or ‘Beyond’ herbicide (which controls cheatgrass, goatgrass and wild oats). Winterhardiness = 3. Stiff straw, medium height, medium coleoptile. Early maturity. Above average yield and test weight. Average protein, good quality. Replaces MT1159CL.

Northern (MSU, 2015): Hard red winter wheat developed the Montana Agricultural Experiment Station and available to growers in fall 2015. Northern is a medium-late maturing, medium-short statured wheat, with white chaff. Northern has average yield (similar to Yellowstone and Colter), average test weight, and average protein. Northern is resistant to both stem and stripe rust. Northern is a low PPO variety with average milling and average baking properties. PVP, Title V will be applied for.

Promontory (Utah, 1990): Red head. Winter hardiness poor (2 or less). Medium-short, medium-strong straw. Short coleoptile. Medium maturity. Excellent stripe rust & dwarf smut resistance; Stem rust susceptible. Average yield and above average test weight. Protein medium low. Has severe sawfly stem cutting ratings.

Pryor (WPB, 2002): Winterhardiness 3 = Neeley. Short stiff straw, 4" shorter than Neeley. Short coleoptile. Medium late maturity similar to Neeley & Tiber, 2 days later than Rocky. Above average yield. Average test weight and protein, good quality. Intended mainly for Central Montana as a replacement for Neeley. Not for stripe rust areas.

Rampart (MSU, 1996): Sawfly resistant (sister line to Vanguard). Solid stem rating = 22. Red chaff, upright head. Winterhardiness is marginal (2-). Should not be grown in areas where high levels of winterhardiness are needed, unless protected by stubble. Height 1 inch shorter than Neeley, med-stiff straw. Very long coleoptile. Matures 1 day later than Rocky, 2 days earlier than Neeley. Some resistance to stem rust, and some tolerance to wheat streak mv. Medium shatter resistance. Yield is below average, but is above average under heavy sawfly conditions. Does not seem as prone to shatter as Vanguard. Good test weight, protein and quality. See Genou.

Ripper (Colorado, 2006): Semidwarf height, medium coleoptile. Early maturity. Above average yield and test weight. Average protein.

Rocky (Agripro, 1978): A selection from Centurk for soil borne mosaic resistance. Winterhardiness = 2. Medium weak straw, medium height. Medium coleoptile. Early maturity. High yield. Very susceptible to yellow berry expression under low nitrogen conditions. Medium protein. See Jagalene and Ledger for shorter-straw alternatives.

SY Clearstone 2CL (MSU/Syngenta): SY Clearstone is a 2-gene Clearfield hard red winter wheat. SY Clearstone 2CL has yields similar to Yellowstone, and about 10 bu/a more than AP 503 CL2. SY Clearstone 2CL has average test weight and protein. SY Clearstone 2CL is resistant to stripe rust and moderate resistance to stem rust.

SY Wolf: Hard red winter wheat developed by Syngenta (AgriPro) Seeds in 2010. SY-Wolf is a medium maturing, short statured wheat with white glumes. SY-Wolf has above average yield and test weight and average protein. Winter-hardiness was average in 2011 at Sidney. SY-Wolf is moderately susceptible to moderately resistant (MS/MR) to stripe rust, but resistant to stem rust. Boomer has average milling and below average baking properties. PVP, Title V has been issued (Certificate #201100390).

Tiber (MSU, 1988): Dark Red head, (blackish-red in years of favorable moisture). Winterhardiness = 3. Medium height with good lodging resistance. Stiff straw, which may cause it to thresh a little harder than weaker-strawed varieties. Med-long coleoptile. Very resistant to sprouting, causing some dormancy. Medium maturity. Susceptible to stem rust. Very resistant to shatter. Below average yield. Protein above average. Good milling and baking quality. Fdn seed being discontinued. See Big Sky for alternative.

Vanguard (MSU, 1995): Sawfly resistant. Good stem solidness. White chaff, nodding head. Winterhardiness marginal (2-). Straw slightly stiffer and 1 inch shorter than Rocky, but moderately susceptible to lodging under high-yield conditions. Long coleoptile. Medium head date, 1 day later than Rocky, 3 days earlier than Neeley. Good wheat streak mv tolerance. Susceptible to stem & stripe rust. Below average yield; but under heavy sawfly infestation, yield is above average. Medium shatter resistance. Good test weight. Protein high; quality adequate. Not a satisfactory variety for non-sawfly areas, and should not be grown where high levels of winterhardiness are needed unless protected by stubble. See Genou.

Wahoo (Nebr & Wyo, 2000): Winterhardiness = 3. Semidwarf, 2" shorter than Rocky, stiff straw. Short coleoptile. Very early maturity. High yield. Average test weight & protein, marginally poor quality.

Warhorse (MSU, 2013): Solid-stemmed hard red winter wheat with improved yield potential over Genou and Rampart. Warhorse is a white-glumed, semi-dwarf winter wheat with medium maturity. Warhorse does well where sawfly is a problem, it has stem solidness score similar to Rampart and Bearpaw. Warhorse has average test weight, and protein, but below average winter hardiness. Warhorse is resistant to prevalent races of stripe and stem rust. It is susceptible to leaf rust.

WB Quake (WestBred/Monsanto): WB Quake has a stem solidness score similar to Judee and Genou, but less than Warhorse and Rampart. WB Quake is equal to Genou for seed protein percent and test weight. Winter hardiness of WB Quake is similar to Yellowstone, and slightly more hardy than Genou. WB Quake has good resistance to local races of stripe rust.

Willow Creek (MSU 2005): Beardless forage winter wheat for hay. HRW class. Winterhardiness = 5. Very tall straw, lodging susceptible. Long coleoptile. Very late maturity. High forage yield. Tends to be safer than barley for nitrates, because earlier seasonal development escapes heat stress better. Low grain yield and test weight. High protein.

Yellowstone (MSU, 2005): Winterhardiness = 4. Medium height similar to Neeley, and taller than Falcon, and Pryor. Straw strength is excellent. Medium-short coleoptile length. Medium maturity. Broadly adapted state-wide, but is stem-rust susceptible (thus, not for District 6, eastern Montana). Moderate resistance to stripe rust. Very high-yielding, and 3% higher than Falcon. Below average test weight. Protein is medium. Excellent baking quality and good Asian noodle quality.

Hard White Winter Wheat

Protein of hard white wheat for bread baking needs to be higher than required for noodle markets. Some varieties are dual-purpose and can be used for both bread and noodles. Although not a concern for bread baking quality, varieties with low levels of polyphenol oxidase (PPO) are desirable for Chinese noodles, since high PPO levels are associated with noodle discoloration. Low PPO provides good noodle brightness and color stability. Some hard white varieties sprout more readily than hard reds, especially those developed from Australian germ-plasm. The pure white trait is difficult to maintain, as pollen from red wheats may pollinate a white variety, causing a mixture of red kernels. It is very important to clean the combine, storage bins and other grain handling equipment prior to harvest to avoid mixing hard white wheat with other wheat. Seeding equipment and seedbed must also be free of red wheat. It is important to have a market strategy in place before growing a hard white variety.

Alice (S. Dak., 2006): Hard white. Short straw, short coleoptile. Early heading. Above average yield, test weight and protein.

Golden Spike (UT, Gen Mills, 1998): Hard white, low PPO. Winterhardiness 3. Height similar to Rocky, med-stiff straw. Medium coleoptile. Medium maturity. Below average yield. Low test weight & protein.

Hyalite (MSU & WPB, 2005): Hard White, low PPO with good noodle brightness and color stability. Clearfield system single-gene resistance to imazamox or 'Beyond' herbicide. Winterhardiness = 3. Standard height, but stiff straw. Short coleoptile. Early maturity. Average yield and test weight. Red kernel occurrence is 0.7% (high, but still acceptable). Dual-purpose quality similar to NuWest & NuSky. Above average protein, good milling & baking quality. Stem rust resistant. Stripe rust susceptible.

MDM WA7936 (Wash., 2006): Hard white. Winterhardiness = 2. Medium stiff straw. Medium coleoptile. Very late maturity. Yield similar to NuWest. Low test weight.

NuDakota (AgriPro, 2005): Hard white. Winterhardiness = 2. Semidwarf height, stiff straw. Early heading. Average yield, test weight and protein. Medium PPO.

Nuwest (MSU, 1994): Hard white, low PPO. Dual purpose, noodle and bread. Winterhardiness = 4. One inch shorter than Rocky. Stiff straw. Very short coleoptile. Two days later than Rocky. Resistant to stem rust but susceptible to stripe rust, dwarf bunt, and WSMV. Susceptible to sawfly, RWA, and Hessian fly. Average yield and well adapted to Montana. Medium test weight and protein. Good resistance to preharvest sprouting – (In 1993, everything sprouted - red or white). Contains 1 red kernal/1000. Protein medium to high. Good quality.

NuSky (MSU, 2001): Hard white, low PPO. (Sister line to the hard red var BigSky). Good dual purpose quality for noodles & bread. Winterhardiness 4. Height and straw strength similar to Nuwest & Rocky, med-stiff. Short coleoptile. Heading similar to Nuwest, Tiber & Neeley; and 3 days later than Rocky. Shatter resistant. Average yield.

Test weight similar to Nuwest. Medium to high protein. Quality similar to Nuwest. High level of post-harvest dormancy (similar to Tiber), and thus does not have the sprouting problems common to some of the other hard white wheats. NuSky is a public release.

WB3768 (MSU/WestBred/Monsanto): WB3768 is a white chaffed hard white winter wheat that is a low PPO wheat that has favorable Asian noodle color stability and noodle score. WB3768 is similar to Yellowstone with the exception of higher test weight and a later heading date and maturity. It is slightly taller than Yellowstone.

Wendy (SD, 2004): Hard white. Winterhardiness = 3. Semidwarf height, Short coleoptile. Early heading. Average yield. Above-average test weight and protein. Medium PPO.

Spring wheat and durum variety evaluations

Title: Spring wheat and durum variety evaluations at Western Triangle Ag. Research Center

Principle Investigator: Gadi V.P. Reddy, Superintendent, Western Triangle Ag Research Center

Personnel: John H. Miller, Research Associate and Julie Prewett, Research Assistant WTARC, Conrad, MT, and Luther Talbert and Hwa-Young Heo, MSU Plant Science Dept., Bozeman, MT.

Cooperators: Bradley Farms, north of Cut Bank, MT
Brian Aklestad, north of Devon, MT
Aaron Killion, east of Brady, MT
Inbody Farms, northeast of Choteau, MT

Objectives: There are diverse cropping environments within the area served by Western Triangle Agricultural Research Center. Each off station location has its own unique environment and soils. Producers in the various locations are interested in variety performance in the local area. To this end the objective is to evaluate winter wheat varieties under the local conditions with respect to yield, test weight, plant height, and seed protein. The environmental conditions at the off station nurseries can vary greatly from those at WTARC. The research center strives to provide growers of the western triangle area unbiased information of various spring wheat varieties.

Methods: On station nursery is the Advance Yield Trial (AYT) with 64 entries replicated three times. Off station spring wheat nurseries consist of 20 entries replicated three times, seeded with a four row plot seeder on one foot spacing. All plots were planted on no-till chemical fallow. Plots were trimmed, measured for length, and then harvested with a Hege 140 plot combine. Winter wheat seed was cleaned prior to collecting data. Orange wheat blossom midge pheromone traps were also installed at each off station plot.

Results: Results are tabulated in Tables 1 thru 15. Results are tabulated in Table 1 for the advanced spring wheat nursery and Table 2 is five year averages for selected varieties in the advanced spring wheat nursery. Table 3 is for the off station irrigated spring wheat nursery, with multi-year data presented in Table 4. Tables 5 thru 12 are for the off station locations, with Table 13 representing the data from the SM1 nursery and Tables 14 and 15 containing durum data.

Overall, the crop year temperature where close to the 29 year average at the research center with the exception of 2.5 inches less moisture than the 29 year average. The winter temperature was close to average, with the exception of November being 8 degrees cooler than usual. With March being 7 degrees warmer than the normal. Also June was 4.6 degrees warmer compared to the 29 year average.

Soil temperatures at the station under chemical fallow stubble stayed under 40 degrees at a depth of eight inches until mid April. May was cool with slightly above average precipitation. Early in June we received 0.95 inches, then it warmed up and remained dry for about 30 days, during that time the spring wheat was running out of water as it was heading. July had normal amounts of rain.

The AYT yields ranged from 44.5 to 67.7 bu/ac, with an average of 53.9 bu/ac and 15.4 % seed protein. The 5 year yield and protein average for named varieties in the AYT is 72.5 bu/ac and 13.5 % seed protein. Although, test weight was slightly lower than the 5 year average.

Top yielding varieties at Choteau were WPSP2-VIDA1, Montana State University lines, MT1316, MT1338, and WB Gunnison. The top three yielding varieties at Choteau were 64.9, 60.4, and 59.6 bu/ac, respectively (Table 5). Reeder, WPSP2-VIDA1, and Duclair were the high yielding varieties at Devon, 29.0, 27.8, and 27.6 bu/ac (Table 9). The 'Knees' high yielders at 40.6, 37.8, and 37.6 bu/ac, were Montana State University line MT1316, Duclair, Vida. The best yielding varieties, at the Cut Bank location were Montana State University line MT1316, WPSP2-VIDA1, and WB Gunninson. Yields at Cut Bank were 48.3, 47.7, and 47.3 bu/ac (Table7) The top yielders in the irrigated trial were Duclair, at 86.0 bu/ac, WB Gunnison 85.5 bu/ac and Choteau at 79.0 bu/ac (Table 3).

Yields in the irrigated off-station spring wheat trial ranged from 86.0 bu/ac to 52.7 bu/ac. When compared to the five year averages, the irrigated off-station spring wheat nursery had lower yields, with average test weight, and slightly higher grain protein by 1.8% (Tables 3 and 4). At Devon the 2015 yield was down 9.3 bu/ac from the four year average; with 2.7% higher grain protein and average test weight (Tables 9 and 10). The 'Knees' location had lower yields, higher grain protein and lower test weight when compared to the four year mean (Tables 11 and 12). Yields at Cut Bank ranged from 48.3 to 24.2 bu/ac, with lower grain protein for the year, with slightly higher test weights (Tables 7 and 8).

The SM1 nursery has wheat that contains the gene to make it resistant to the Orange Wheat Blossom Midge. Data are presented in Table 13.

The durum nursery had an average yield of 41.0 bu/ac. The six year average is 67.4 bu/ac. Average test weight for the 2015 growing season was 58.6 lbs/bu, down about 2 lbs/bu from the six year average. Seed protein was about 2.5 % higher for 2015 than the six year average.

No insect incidence (wheat stem sawfly or wireworms) was noticed in any of the winter wheat varieties. This is because of the high number of parasitoids of the wheat stem sawfly are present at the research center. Insignificant amount of adult of orange wheat blossom midge were found at the off station locations.

Summary: The data from the off station plots is supported by the local producers and advisory committee as well as the seed industry. It is planned to continue the off station variety plots at the same locations as the environmental conditions at each location is unique to the western triangle area. No insect incidence or damage was noticed in any of the varieties.

These data should be used for comparative purposes rather than using absolute numbers. Statistics are used to indicate that treatment or variety differences are really different and are not different due to chance or error. The least significant difference (LSD) and coefficient of variability (CV) values are useful in comparing treatment or variety differences. The LSD value represents the smallest difference between two treatments at a given probably level. The LSD at p=0.05 or 5 % probability level is usually the statistic reported, and it means that the odds are 19 to 1 that treatment differences by the amount of the LSD are truly different. The CV value measures the variability of the experiment or variety trial, and a CV greater than 15 % indicates a high degree of variability and less accuracy.

Funding Summary: Office of Special Projects will provide expenditure information. No other grants support this project.

MWBC FY2016 Grant Submission Plans: A similar project will be proposed for FY 2016. The continuation of on and off-station variety trials help to elucidate researchers and farmers which varieties are better suited for that particular region in Montana.

Table 1. 2015 Spring wheat advanced yield nursery, Western Triangle Ag. Research Center, Conrad, MT.

ID or Variety	Yield bu/ac	Test weight lb/bu	Heading Date Julian	Plant height inches	Protein %
MT 1453	67.7	60.0	165.7	32.7	14.6
MT 1427	65.3	59.1	167.3	31.7	14.7
WB 9507	62.6	60.0	169.0	32.7	14.1
LNR0311	60.1	62.4	168.0	32.0	13.9
SY Tyra	65.0	61.3	170.7	27.0	14.2
MT 1338	63.2	61.2	166.3	32.3	15.6
MT 1219	61.5	60.1	196.7	29.0	15.4
LCS Breakaway	58.7	61.0	167.3	31.7	15.8
MT 1426	58.5	28.7	164.3	31.7	14.9
MT 1448	58.3	61.1	169.0	30.0	14.7
McNeal	58.3	59.2	175.3	32.0	15.5
MT 1451	57.0	60.9	169.7	29.7	15.0
MT 1421	56.9	60.4	170.0	31.7	14.7
MT 1401	56.6	61.0	167.3	31.7	15.3
Egan	56.5	59.0	170.7	30.3	16.7
MT 1434	56.3	60.2	168.3	33.3	15.3
Vida	56.1	58.7	171.0	29.7	15.6
WP SP2-VIDA1	56.0	62.0	172.0	28.0	14.2
MT 1406	55.8	60.6	169.3	31.7	15.7
Reeder	55.3	60.6	169.7	31.3	15.7
MT 1412	55.3	59.9	168.3	30.0	15.1
MT 1413	55.3	59.0	167.3	32.0	15.3
MT 1337	54.9	59.0	166.7	31.7	15.6
MT 1454	54.4	59.2	169.7	30.7	15.3
MT 1455	54.3	58.6	198.7	29.0	16.3
MT 1424	54.1	59.9	170.0	32.7	15.7
LNR0493(LCS PRO)	54.1	59.7	169.3	35.7	15.7
MT 1436	53.9	59.5	170.3	30.0	15.4
WP SP2-VIDA2	53.1	61.1	171.0	29.7	15.1
MT 1447	52.6	60.9	169.0	32.0	15.2
WPSP2-CHOTEAU	52.6	59.5	170.0	30.3	15.4
SY Valda	52.4	61.4	169.7	28.0	15.3
SY Rowyn	52.2	60.8	168.3	28.0	14.8

Table 1 Continued on next page

Table 1 Continued

ID or Variety	Yield bu/ac	Test weight lb/bu	Heading Date Julian	Plant height inches	Protein %
MT 1415	53.9	61.7	172.3	29.7	15.7
MT 1408	53.8	60.7	170.0	33.3	14.6
MT 1319	53.4	59.4	166.3	31.7	15.8
Corbin	51.9	59.9	167.7	30.0	14.9
WB Gunnison	51.8	60.6	169.0	28.0	14.5
MT 1348	51.4	59.2	167.0	30.7	16.6
MT 1439	51.4	59.9	169.7	31.3	15.7
MT 1418	51.3	58.7	172.0	28.0	15.4
WB 9668	51.0	60.8	166.3	26.3	16.4
MT 1414	51.0	58.0	170.7	32.7	14.9
WB 9377	50.9	60.6	171.5	25.0	15.4
MT 1429	50.8	59.7	168.7	31.3	15.9
MT 1320	49.1	60.9	168.0	33.7	15.7
MT 1425	49.0	61.7	170.0	30.3	15.6
Fortuna	49.0	60.4	170.7	36.3	15.1
Choteau	48.4	60.1	170.7	28.3	15.6
WB9879CLP	47.2	59.5	171.0	28.0	15.9
Thacher	46.9	58.9	174.3	37.3	15.0
SY Soren	50.4	59.3	170.3	28.7	16.3
Brennan	50.1	63.5	167.7	29.0	15.5
MT 1417	49.9	61.6	169.0	31.3	15.5
Duclair	49.5	57.0	167.3	30.7	16.0
SY Ingmar	46.1	60.2	173.0	29.3	16.3
MT 1422	45.9	60.8	173.3	30.7	14.7
MT 1432	45.2	58.3	169.3	28.3	15.5
MT 1404	46.6	61.0	172.7	30.0	15.2
MT 1349	44.5	56.9	170.0	29.0	16.7
Mean	53.9	60.0	169.4	30.6	15.4
LSD (0.05)	-	1.8	1.8	2.5	0.9
C.V. (%)	15.5	1.9	0.7	5.1	3.6
P-value (Varieties)	ns	<0.001	<0.001	<0.001	<0.001

Planted: 4/9/2015 on conventional fallow and harvested on 8/10/2015.
Fertilizer: actual pounds/ac. of N-P-K: 11-22-0 applied with seed and a 180-0-20 blend of urea and potash was broadcast at planting. Fertilizer rates are based on a yield goal of 60 bu/ac.
Herbicide: The plot area was pre-plant sprayed with 32 oz/ac RT3 on 4/8/2015.
Precipitation for growing season: 4.55 inches.

Table 2. 5-year Means, Advanced spring wheat varieties, Conrad, MT, 2015.

Variety	Yield bu/ac	Test Wt lb/bu	Head date	Height inches	Protein %
Reeder	76.1	61.2	181.1	34.3	13.5
Sy Soren	75.7	61.2	181.2	31.2	13.8
Vida	75.2	60.2	182.0	33.7	13.8
McNeal	75.1	60.3	182.4	33.7	13.4
SY Tyra	74.8	61.1	181.8	29.1	12.2
Corbin	74.2	60.7	180.6	32.4	13.6
Duclair	74.2	59.5	179.1	32.8	13.4
WB9668	74.1	61.0	178.6	28.3	14.1
WB9879CL	70.7	60.4	181.7	31.5	13.8
Choteau	69.6	59.7	180.8	31.0	13.4
Egan	68.8	60.6	181.8	32.9	14.4
WB Gunnison	68.8	61.4	180.9	31.0	13.0
Fortuna	65.9	61.2	182.0	39.3	13.5
Means	72.5	60.7	181.1	32.4	13.5

Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 3. Off-station irrigated spring wheat variety trial located, WTARC MT. Pondera County.
Western Triangle Ag. Research Center, 2015.

Variety	Class	Yield bu/ac	Test Wt lb/bu	Height inches	Head Date	Protein %
Duclair	**	86.0	61.7	31.0	171.3	14.4
WB Gunnison	*	85.5	63.2	31.7	172.7	13.8
Choteau	**	79.0	61.8	34.0	174.0	14.6
SY Tyra	*	77.7	63.1	27.3	174.3	13.9
MT 1316	-	77.3	62.2	29.7	171.3	15.6
WB9879CLP	CL	76.9	61.9	32.0	173.7	14.8
ONeal	*	71.1	60.5	33.7	173.7	14.1
WPSP2-VIDA1	-	70.8	62.6	33.7	175.0	14.2
Corbin	*	69.9	63.2	32.0	172.7	14.0
MT 1338	-	67.7	62.7	31.7	171.0	15.3
SY Soren	-	67.0	62.4	29.0	174.0	15.8
Egan	-	66.3	61.0	32.7	174.0	17.0
Brennan	-	66.2	62.2	28.3	172.0	16.3
MT1219	-	65.7	61.7	28.3	173.7	14.8
Fortuna	**	61.1	62.0	38.7	175.0	16.0
Reeder	-	59.3	61.5	34.3	174.0	15.3
McNeal	-	57.7	61.0	32.0	174.0	16.0
Vida	*	57.6	60.9	35.0	175.3	15.6
MT1337	-	57.5	61.4	31.3	171.0	16.6
Mott	-	52.7	61.0	36.3	177.3	15.0
Mean		68.7	61.9	32.1	173.5	15.2
LSD (.05)		ns	1.1	4.0	1.1	
C.V. 1 (%) (S/mean)*100		18.3	1.1	7.5	0.4	
P-Value		0.0691	0.0001	0.0001	<0.0000	

Cooperator and Location: WTARC, Pondera County.
Planted April 22, 2015 on chemical fallow barley stubble. Harvested August 28, 2015.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and a 254-0-20 blend of urea and potash was broad cast at planting. Fertilizer rates are based on a yield goal of 80 bu/ac.
Herbicide: The plot area was pre-plant sprayed with 20 oz/ac RT3 4/22/2015.
Growing season precipitation: 5.60 inches. Irrigation: 9.9 inches
** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
* = Less preferred by sawfly (behavioral preference) in small plots.
CL= Clearfield
Conducted by MSU Western Triangle Ag. Research Center.

Table 4. 5-year means, off station irrigated spring wheat varieties, Conrad, MT,

Variety	Yield bu/ac	Test Wt lb/bu	Height inches	Head Date	Protein %
Duclair	93.2	61.7	31.7	184.2	14.2
WB Gunnison	89.6	62.8	31.7	186.1	13.7
SY Tyra	89.1	62.8	29.6	186.3	13.6
WB9879CL	87.3	61.8	33.1	185.96	12.7
Choteau	83.3	61.7	31.3	185.3	13.9
Oneal	81.2	62.3	33.8	186.3	13.6
Corbin	80.7	63.0	32.5	185.4	13.5
McNeal	77.4	62.0	33.0	186.0	12.6
Vida	76.4	61.8	33.8	186.6	13.2
Reeder	72.6	62.6	33.3	186.1	13.5
Fortuna	68.7	62.3	39.1	186.1	13.4
Means	81.8	62.3	33.0	185.8	13.4

Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 5. Off-station Spring Wheat variety trial located northeast of Choteau, MT. Teton County. Western Triangle Ag. Research Center, 2015.

Variety	Class	Yield bu/ac	Test Wt lb/bu	Height inches	Protein %
WPSP2-VIDA1	-	64.9	62.2	26.0	13.6
MT 1316	-	60.4	61.7	25.0	15.1
MT 1338	-	59.6	61.9	25.3	15.1
Duclair	**	59.5	59.6	26.0	15.2
Egan	-	59.5	60.5	26.7	16.1
McNeal	-	59.4	60.3	28.0	15.4
Corbin	*	58.6	61.4	24.7	15.1
Reeder	-	58.6	61.9	25.3	15.3
Vida	*	58.5	61.2	25.7	14.5
ONeal	*	56.1	60.8	27.0	14.9
MT1337	-	56.0	59.9	24.7	15.5
SY Soren	-	55.8	61.5	25.0	15.2
WB Gunnison	*	55.6	61.3	25.3	14.1
MT 1219	-	55.6	60.4	25.3	14.9
WB9879CLP	CL	54.8	59.9	24.7	15.5
SY Tyra	*	54.3	61.8	24.7	13.8
Choteau	**	52.7	59.9	25.0	15.5
Mott	-	52.3	61.4	27.3	15.4
Brennan	-	50.4	62.8	25.3	15.3
Fortuna	**	33.6	61.0	30.0	16.3
Mean		55.8	61.1	25.9	15.1
LSD (.05)		5.4	0.7	2.6	
C.V. (%)		5.9	0.7	6.2	
P-Value		<0.0000	<0.0000	0.0193	

Cooperator and Location: Inbody Farms, Teton County.
Planted April 24, 2015 on chemical fallow. Harvested August 25, 2015.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and a 100-0-20 blend of urea and potash was broadcast at planting. Fertilizer rates are based on a yield goal of 50 bu/ac.
Herbicide: Preplant sprayed with RT3 at 32 oz per acre on 4/24/15. Huskie at 11 oz/ac and Axial XL at 16.4 oz/ac were sprayed on 6/1/15.
Precipitation: N/A
** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
* = Less preferred by sawfly (behavioral preference) in small plots.
CL = Clearfield
Conducted by MSU Western Triangle Ag. Research Center.

Table 6. Four-year means, Spring Wheat varieties, Choteau area, Teton County. 2012-2015.

Variety	4-Year Mean			
	Yield bu/ac	Test weight	Height inches	Protein %
McNeal	46.5	57.5	29.9	15.8
WB Gunnison	46.2	58.8	27.4	14.7
Duclair	45.1	57.0	28.8	15.4
Vida	44.7	58.1	27.1	15.1
WB9879CL	44.7	57.7	26.9	15.5
ONeal	44.5	58.2	29.3	15.9
Corbin	43.7	58.9	27.3	15.7
Reeder	43.1	59.2	29.6	15.7
Choteau	41.8	57.3	26.3	15.7
SY Tyra	41.5	58.3	24.7	14.5
Fortuna	35.8	59.7	33.8	15.5
Mean	43.4	58.2	28.0	15.4

Cooperator and Location: Inbody Farm, Teton County.
Conducted by MSU Western Triangle Ag. Research Center.

Table 7. Off-station spring wheat variety trial located north of Cut Bank, MT.
Glacier county. Western Triangle Ag. Research Center, 2015.

Variety	Class	Yield bu/ac	Test Wt lb/bu	Height inches	Protein %
MT1316	-	48.3	60.4	24.7	12.1
WPSP2-VIDA1	-	47.7	61.2	27.0	12.2
WB Gunnison	*	47.3	59.5	24.7	12.8
MT1338	-	46.5	60.7	26.3	13.7
Duclair	**	46.1	60.0	25.7	12.7
SY Tyra	*	45.3	60.6	24.3	12.0
SY Soren	-	44.7	60.7	23.0	12.1
ONeal	*	43.4	61.2	26.0	12.5
Brennan	-	43.3	60.1	24.3	13.1
Vida	*	43.0	59.5	29.6	11.8
Reeder	-	42.5	60.2	24.0	12.9
Choteau	**	42.3	58.3	25.0	13.5
WB9879CLP	CL	42.0	58.4	26.3	13.7
MT1337	-	38.8	59.0	26.0	14.4
Egan	-	38.6	57.9	26.0	14.6
Corbin	*	38.4	59.4	25.0	13.1
McNeal	-	36.9	57.8	27.7	13.1
Mott	-	36.6	58.2	26.7	13.7
MT 1219	-	33.5	59.3	24.7	12.9
Fortuna	**	24.2	57.9	26.3	14.3
Mean		41.5	59.4	25.7	13.1
LSD (.05)		6.7	0.8	ns	
C.V. (%) (S/mean)*100		9.7	0.8	9.2	
P-Value		<0.0000	<0.0000	0.3154	

Cooperator and Location: Bradley Farms, northern Glacier County.
Planted April 30, 2015 on chemical fallow. Harvested September 11, 2015.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and a 75-0-20 blend of urea and potash was broadcast at planting. Fertilizer rates are based on a yield goal of 50 bu/ac.
Herbicide: The plots were sprayed with Huskie at 11 oz/ac and Axial XL at 16.4 oz/ac on 6/4/15.
Precipitation from planting to harvest: 6.25 inches.
** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
* = Less preferred by sawfly (behavioral preference) in small plots.
CL = Clearfield
Conducted by MSU Western Triangle Ag. Research Center.

Table 8. 5-year means, off station spring wheat varieties, Cut Bank, MT, Glacier county, 2010-2015

Variety	Yield bu/a	Test Wt lb/bu	Height inches	Protein %
WB Gunnison	61.7	59.4	29.4	12.9
Duclair	61.4	57.1	30.3	13.8
Choteau	59.8	57.6	29.2	13.9
Corbin	56.2	59.4	30.0	13.2
Vida	56.0	57.7	31.0	13.4
WB9879CL	55.7	57.6	29.7	14.1
Reeder	53.4	58.1	30.8	13.9
ONeal	53.4	55.9	30.5	14.0
SY Tyra	53.3	57.3	27.3	12.9
McNeal	50.1	57.1	30.6	13.5
Fortuna	43.2	59.7	35.4	13.9
Means	54.9	57.9	30.4	13.6

Location: Bradley farm, Cut Bank, MT

Table 9. Off-station spring wheat variety trial located Devon, MT. Toole county. Western Triangle Ag. Research Center, 2015.

Variety	Class	Yield bu/a	Test Wt lb/bu	Height inches	Protein %
Reeder	-	28.0	59.2	22.7	16.1
WPSP2-VIDA1	-	27.8	60.4	21.3	14.8
Duclair	**	27.6	58.8	23.3	15.9
McNeal	-	26.9	56.8	24.7	16.1
MT 1316	-	26.6	57.4	20.3	16.8
Vida	*	26.1	58.2	21.3	15.6
SY Tyra	*	25.8	60.2	20.0	15.3
WB Gunnison	*	25.8	58.2	22.3	14.6
MT 1337	-	25.6	57.8	22.3	15.4
Egan	-	25.6	56.7	22.7	17.0
Sy Soren	-	25.2	58.5	18.7	16.5
Choteau	**	24.9	58.4	22.0	16.2
Oneal	*	24.2	59.8	20.7	16.4
WB9879CLP	CL	23.8	57.9	19.7	16.6
Corbin	*	23.3	58.3	21.7	15.8
Mott	-	23.2	58.1	22.0	16.8
MT 1219	-	23.0	57.7	20.3	16.1
Brennan	-	23.0	59.4	20.7	16.2
MT1338	-	18.5	60.7	21.0	16.2
Fortuna	**	16.9	56.6	22.6	16.8
Mean		24.6	58.5	21.5	16.1
LSD (.05)		ns	0.8	2.3	
C.V.		14.8	0.8	6.4	
P-Value		0.0553	<0.0000	0.0014	

Cooperator and Location: Brian Aklestad
Planted April 27, 2015 on chemical fallow barley stubble. Harvested August 15, 2015.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and a 109-0-20 blend of urea and potash was broadcast at planting. Fertilizer rates are based on a yield goal of 35 bu/ac.
Herbicide: The plot area was pre-plant sprayed with 32 oz/ac RT3 on 4/27/2015. The plots were sprayed with Huskie at 11 oz/ac and Axial XL at 16.4 oz/ac on 6/11/2015.
Growing season precipitation: 1.25 inches rain gauge was cracked at some point during the growing season.
** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
* = Less preferred by sawfly (behavioral preference) in small plots.
CL = Clearfield
Conducted by MSU Western Triangle Ag. Research Center.

Table 10. Five-year means, Spring Wheat varieties, Devon area, Eastern Toole County, 2010-2015.

Variety	5-Year Mean			
	Yield bu/ac	Test weight	Height inches	Protein %
Vida	38.2	58.4	25.3	14.0
WB Gunnison	36.9	58.4	24.4	14.6
Duclair	36.7	56.6	25.7	14.7
Reeder	35.7	58.7	26.1	15.0
ONeal	34.5	59.8	25.0	15.0
McNeal	34.0	57.7	26.5	15.2
Choteau	33.8	57.5	23.8	15.0
Corbin	33.8	58.5	25.3	14.9
Fortuna	32.9	58.2	29.0	15.1
SY Tyra	32.1	59.0	22.6	14.2
Mean	34.9	58.3	25.3	14.8

Cooperator and Location: Brian Aklestad, Eastern Toole County.
Conducted by MSU Western Triangle Ag. Research Center.

Table 11. Off-station spring wheat variety trial located near the Knees. Chouteau County. Western Triangle Ag. Research Center, 2015.

Variety	Class	Yield bu/a	Test Wt lb/bu	Height inches	Protein %
MT1316	-	40.6	58.0	23.0	15.5
Duclair	**	37.8	58.9	26.7	13.9
Vida	*	37.6	57.8	25.3	14.8
Reeder	-	36.5	58.2	26.7	15.3
McNeal	-	35.7	54.4	27.0	15.4
MT1338	-	35.7	60.1	25.0	15.3
WB9879CLP	CL	34.3	57.4	25.3	15.2
SY Tyra	*	33.9	56.8	24.0	14.5
MT1219	-	33.1	56.0	24.7	14.4
MT1337	-	32.8	58.2	28.3	15.5
Choteau	**	32.6	57.8	24.7	14.7
WPSP2-VIDA1		32.5	58.9	24.7	13.9
Egan	-	32.3	54.6	24.0	16.5
SY Soren	-	32.0	57.7	23.3	15.3
Brennan	-	31.5	58.7	23.7	15.6
WB Gunnison	*	31.1	58.0	24.3	14.8
Corbin	*	30.5	57.6	29.3	14.3
Mott	-	25.5	55.4	26.3	15.3
ONeal	*	20.1	56.2	26.3	14.3
Fortuna	**	17.0	55.3	29.0	17.2
Mean		32.5	57.3	25.6	15.1
LSD (.05)		9.1	1.9	3.5	
C.V. 1 (%) (S/mean)*100		16.9	2.0	8.3	
P-Value		0.0080	<0.0000	0.0175	

Cooperator and Location: Aaron Killion, western Chouteau County.
Planted April 24, 2015 on chemical fallow. Harvested August 31, 2015.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and a 114-0-20 blend of urea and potash was broadcast at planting. Fertilizer rates are based on a yield goal of 45 bu/ac.
Herbicide: The plot area was pre-plant sprayed with 20 oz/ac RT3 on 4/24/2015. The plots were sprayed with Huskie at 11 oz/ac and Axial XL at 16.4 oz/ac on 6/1/2015.
** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
* = Less preferred by sawfly (behavioral preference) in small plots.
CL = Clearfield System
Conducted by MSU Western Triangle Ag. Research Center.

Table 12. 5-year Means, Off Spring Wheat Varieties, Knees, MT.

Variety	Yield bu/ac	Test Wt lb/bu	Height inches	Protein %
Duclair	48.5	58.1	27.1	14.0
Vida	46.2	59.3	27.3	13.9
WB Gunnison	45.8	60.1	26.4	14.0
WB9879CL	45.0	59.3	25.5	14.3
Choteau	44.3	59.1	25.3	14.3
Reeder	42.6	60.2	26.7	14.6
McNeal	42.2	58.4	27.9	14.4
Corbin	41.7	59.3	26.9	14.2
SY Tyra	38.8	57.9	23.6	13.8
Oneal	38.2	59.3	27.4	13.7
Fortuna	36.3	60.1	31.4	15.1
Means	42.7	59.2	26.9	14.2

Location: Killion Farms, Brady MT
MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 13. Off-station spring wheat SM1 trial located near the Valier. Pondera county. Western Triangle Ag. Research Center. 2015.

Variety	Yield bu/ac	Test Wt lb/bu	Height inches	Head Date	Protein %	Midge Head
12401277	86.5	62.6	29.0	184.0	17.6	0
12400877	83.9	62.8	28.0	180.0	17.2	0
Hank	78.4	60.6	28.0	184.3	15.2	1.3
12400817	77.2	63.6	29.0	185.0	18.1	0
12401227	66.7	62.5	27.3	183.3	17.5	0
12401502	65.9	61.9	28.3	185.0	17.3	0
12400592	64.1	61.0	26.7	184.3	17.7	0
12401424	63.9	62.4	27.5	181.3	18.2	0
12400976	63.8	62.1	29.0	184.0	18.1	0
12401182	63.5	63.0	28.3	184.0	17.2	0
12401236	63.1	61.6	28.0	186.0	18.7	0
12401322	61.7	61.8	30.7	184.7	18.4	0
12401161	60.1	62.4	26.8	181.2	17.4	0.1
12400725	59.1	61.4	28.3	183.3	17.7	0
12401935	59.0	62.2	27.7	181.3	19.0	0.2
12401218	57.1	62.0	27.0	183.3	18.8	0
12400038	55.1	62.5	28.0	183.0	18.2	0.1
Egan	54.5	60.1	29.7	183.3	20.3	0
12400986	53.4	62.2	27.7	181.0	18.9	0
12401117	52.7	63.7	30.0	180.0	18.5	0
Mean	63.5	62.0	28.2	183.0	18.0	0.1
LSD (.05)	27.0	0.9	2.6	2.0	1.6	0.3
C.V. 1 (%) (S/mean)*100	21.0	0.7	4.5	0.7	4.5	36.1
P-Value	ns	0.0000	0.0100	0.0000	0.0000	0.0000

Cooperator and Location: Crawford Farms Valier, MT.
Planted April 13,2015 on chem-fallow. Harvested September 2, 2015.
Fertilizer, actual lbs/a:11-22-0 with seed at planting, 105-0-20 broadcast while planting
Preplant sprayed with Roundup @ 22 oz/a on April 13, 2015, also sprayed with Huskie @ 11 oz/ac and Axial XL @ 16.4 oz/ac.
Conducted by MSU Western Triangle Ag. Research Center.

Table 14. Durum Variety Trial located WTARC. Pondera County. Western Triangle Ag. Research Center, 2015.

Variety	Yield bu/ac	Test Wt lb/bu	Height inches	Head Date	Protein %
MT112219	46.4	59.0	24.7	166.7	15.4
MT112444	44.0	57.2	26.7	167.0	15.0
Mountrail	43.7	57.2	33.0	173.0	15.8
Carpio	43.1	57.5	32.7	174.3	15.8
MT112463	42.3	57.8	26.7	167.0	15.3
Joppa	41.9	58.7	34.3	172.0	16.0
MT101694	41.3	59.8	33.0	172.0	16.1
MT112434	40.8	58.3	22.7	166.0	15.8
Silver	39.8	58.6	26.3	166.3	16.4
Alkabo	39.7	58.8	32.3	172.7	15.6
Grenora	39.4	58.2	29.3	172.0	15.9
Tioga	39.4	59.8	33.0	172.3	17.5
MT101717	36.5	61.2	24.7	170.0	15.7
Divide	35.7	58.3	32.3	170.7	17.2
Mean	41.0	58.6	29.3	170.1	16.0
LSD (0.05)	ns	1.5	2.4	0.9	1.0
C.V. (%)	12.7	1.5	4.8	0.3	3.9
P-Value	0.5452	0.0004	<0.0000	<0.0000	0.0032

Planted: April 9, 2015 on chemical fallow barley stubble and harvested on August 3, 2015.
Fertilizer: actual pounds/ac. of N-P-K: 11-22-0 applied with seed and a 172-0-20 blend of urea and potash was broadcast at planting. Fertilizer rates are based on a yield goal of 60 bu/ac.
Herbicide: The plot area was pre-plant sprayed with RT3 at 32 oz/ac on 4/8/2015.
Precipitation for growing season: 4.74 inches.

Table 15. Six-year means, dryland Durum varieties. Western Triangle Ag. Research Center Conrad, MT, Pondera County, 2010 – 2015.

		6 year mean				
Variety	Source	Yield bu/ac	Test weight	Height inches	Head date	Protein
Alkabo	N. Dak.	71.7	60.9	36.9	69.7	13.1
Grenora	N. Dak.	70.7	60.5	34.4	69.3	13.9
Tioga	N. Dak.	63.4	61.1	38.7	70.2	14.0
Silver (MT03012)	MSU	68.8	60.3	27.8	71.2	13.6
Mountrail	N. Dak.	65.1	59.2	37.7	70.8	13.6
Divide	N. Dak.	64.7	60.4	37.7	69.9	13.7
Nursery Mean		67.4	60.4	35.5	70.2	13.6

Spring Wheat Variety Notes & Comments

Western Triangle Agricultural Research Center, Conrad MT

Sawfly Tolerant & Semi-tolerant Hard Red Spring Wheat Varieties:

Resistance (stem-solidness) among varieties ranges from low to high and varies with yearly climate differences; none have total resistance. Stem-solidness scores range from 5 (hollow) to 25 (completely solid). Solidness should be at least 19 to provide a reliable level of sawfly tolerance. However, some partially-solid stem varieties, such as Conan and Corbin, are less attractive to sawflies and show higher tolerance than expected for their level of stem solidness.

Agawam: See Hard White Spring Wheat. (Solid stem score = 23).

Choteau (MSU, 2004): Semidwarf with good straw strength. Height is 2" shorter than McNeal and 4" shorter than Fortuna. Stems very solid with good sawfly resistance (more solid than Fortuna). Sawfly resistance comparisons (max rating = 25): Choteau = 21, Fortuna = 19, Ernest = 16. Medium-early, 2 days later than Hank, 0.5 day later than Ernest & Fortuna, 2 days earlier than McNeal. High yield, similar to McNeal on both dryland and irrigated. Yields substantially higher than Ernest and Fortuna. Above average test wt (similar to Fortuna, and higher than McNeal). Moderate resistance to Septoria, and good resistance to most stem rust races. Protein above average. Normal gluten strength and good milling and baking quality. Fair Hessian fly tolerance. Some tolerance to root-lesion nematode.

Conan (WPB, 1998): Semidwarf. Solid stem score is low (10), but has low levels of sawfly-attractant cis-3-hexenylacetate, which increases sawfly resistance to medium. Medium maturity. Average yield and test weight. Some tolerance to Wheat Streak M V. Protein 0.5-0.9% higher than Rambo, and better protein quality than Rambo.

Corbin (WPB, 2006). Semidwarf height, 1" taller than Conan. Stem-solidness score = 10, medium sawfly resistance. Medium maturity, 1 day earlier than Conan. Average yield. Above-average test weight. Higher yield and test weight than Conan. Moderate resistance to stripe rust. Average protein.

Duclair (MSU, 2011): Solid stemmed hard red spring wheat, with stem solidness score of 20, slightly less than Choteau and slightly more than Fortuna. Yields were comparable to Choteau, Reeder, and Vida. Maturiety is day earlier than Choteau. Plant heights average about 31 inches. Yields (66 bu/a) tend to be similar to Choteau (65 bu/a), Reeder (66 bu/a) and Vida (68 bu/a). The average test weight is 60 lbs/bu, with grain protein averaging 13.7%. Duclair showed good resistance to stripe rust at Kalispell in 2010.

Ernest (ND, 1995): Tall, weak straw. Medium sawfly resistance (solid stem score = 16). High level of sawfly-attractant cis-3-hexenylacetate. Moderately late maturing, slightly earlier than McNeal. Poor threshability. Tolerant to Far-go. Resistant to prevalent races of leaf & stem rust. Below average yield. High protein and test weight. Good quality.

Lillian (Sask.): Tall weak straw. Late heading. Partial stem solidness. Sawfly cutting for Lillian was 30% at Conrad 2008, compared to 65% for susceptible varieties. Below average test weight. Above average protein.

Fortuna (ND): Beardless, tall straw. Too tall for irrigated conditions, vulnerable to lodging. Good sawfly resistance (solid stem score = 19). Early maturity. Tolerant to Fargo. Very susceptible to Septoria. Medium to low yield except under severe sawfly conditions, where Fortuna often ranks high for yield. Susceptible to shattering, especially in conditions favoring development of large kernels. Average test weight and protein. Fair Hessian fly tolerance.

Triangle II (WestBred, bz9m1024, 2008): Clearfield version of Conan, 2-gene resistance. Stem solidness less than Conan. Yield 1 bu higher than Conan, otherwise similar to Conan.

WB Gunnison (WestBred): Gunnison is intended to replace Conan and Corbin acres. Gunnison is hollow stemmed, but shows good tolerance to cutting by the wheat stem sawfly. The yield (55) is similar to Corbin and slightly higher than Conan. Average test weight is 60 lbs/bu, with grain protein levels of 13.8%, a bit lower than both Conan and Corbin. Average plant height is 30 inches with similar maturity to Conan and Corbin. Gunnison has moderate resistance to stripe rust.

Hollow-Stem, Sawfly Intolerant Hard Red Spring Wheat Varieties:

Alsen (ND, 2004). Moderate Fusarium scab resistance (MR). Semidwarf height. Medium maturity. Average yield. High test weight. High protein. Very poor Hessian fly tolerance.

AP604CL (AgriPro-8): Medium height, med-early maturity. Avg yield. Above avg test weight & protein.

AP603CL (AgriPro): Two-gene IMI resistance for Clearfield System. Med-tall, med-late maturity. Below average yield. Above average test weight & protein. Medium scab tolerance.

Freyr (AgriPro-3, 2004): Semidwarf height. Good lodging resistance, but less than Norpro. Medium maturity, 2 days earlier than McNeal. Average yield. Above average test weight. Average protein. Fusarium Scab resistance slightly lower than for Alsen (MR). Stripe rust MR. Acceptable quality.

Hank (WestBred): Semidwarf height. Medium lodging resistance. Early heading, 3 days earlier than McNeal. Above average yield. Better shatter resistance than 926. Below average test weight. Good tolerance to dryland root rot, tolerant to Far-go. Protein above average. Good quality. Hessian fly tolerant (similar to Choteau).

Hanna (AgriPro): Fusarium Scab tolerant.

Jedd (WestBred, 2007): Clearfield System hard red with 2-gene resistance. BC-derived from Hank. Short semidwarf height, 3" shorter than Hank or Choteau. Medium heading. Above average yield and test weight, dryland or irrigated. Higher dryland yield than Hank. Average protein. High quality. Moderately susceptible to stripe rust. Tolerance to Hessian fly biotypes of Washington, but unknown for biotypes in Montana.

Kelby (AgriPro, 2006, AP06): Good scab tolerance. Semidwarf height, stiff straw. Early heading. Below average yield. Above average test weight and protein. Good foliar disease resistance.

Kuntz (AgriPro-7, 2006): Medium height and maturity. Average yield. Above avg test weight. Average protein.

McNeal (MSU, 1994): Red chaffed. Semidwarf. Good lodging resistance, but straw is less resilient, and is prone to breaking over in strong wind. Medium-late maturity. Fair tolerance to wheat streak mv (2.5 on scale of 1-3). Some tolerance to dryland root rot. Above average yield, similar to Reeder and Choteau. Average test weight. Very good quality with high protein and loaf volume. Medium-low Hessian fly tolerance. Some tolerance to root lesion nematode.

Norpro (AgriPro-1): Semidwarf, very strong straw. Medium-late maturity. Below avg yield and test weight. Average protein. Low flour yield and high ash. Not well-adapted for dryland in District 5 (Triangle), but **suitable for irrigated**.

ONeal (WestBred, bz999592, 2008): A McNeal/906R cross. Semidwarf height similar to McNeal. Head date similar to McNeal and one day later than Choteau. Above-average yield, 3-5 bu higher than McNeal and similar to Choteau. Average test weight, above-average protein. A high quality wheat for areas where McNeal is adapted. Hollow stemmed, but shows less sawfly damage than McNeal.

Outlook (MSU, 2002): Russian Wheat Aphid resistant, but susceptible to new biotype in 2004. Stiff straw, semidwarf, height equal to McNeal & Reeder. Med-late maturity = McNeal. Above average yield, similar to McNeal and Reeder. Below average test weight. Average protein. Quality acceptable, and superior to Reeder.

Reeder (ND, 1999): Semidwarf height. Medium head date, slightly earlier than McNeal, but maturity slightly later than McNeal. The "stay-green" trait provides a longer grain-fill period and higher yield, as long as moisture is available. Similar to McNeal for agronomics. Above average yield. Average test weight and protein. Quality is below average. Susceptible to Everest W.O. herbicide. Very poor Hessian fly tolerance.

Vida (MT 0245): Semidwarf height, medium straw strength. Med-late maturity, heading = McNeal, but stays green 3 to 4 days later than McNeal. High yield, 4 bu over McNeal. Average test weight and protein, acceptable quality. Possible replacement for Outlook and Reeder (except Outlook would remain in use for RWA resistance). MR stripe rust and Septoria. Partially-solid stem (stem score = 11), slightly less than Conan & Ernest for sawfly tolerance.

Volt (WestBred, 2007): Semidwarf height. Late heading. Average yield on dryland, above-average yield on irrigated. Above avg test wt. Average protein. Good tolerance to stripe rust and Fusarium head blight. Sawfly cutting similar to McNeal. A high yield, disease resistant variety **for irrigated conditions**.

WestBred - See also Agawam, Conan, Corbin, Hank, Jedd, ONeal, Triangle II, Volt.

Hard White Spring Wheat

Protein of hard white wheat for bread baking needs to be higher than wheat required for noodle markets. Some varieties are dual-purpose and can be used for both bread and noodles. Although not a concern for bread baking quality, varieties with low levels of polyphenol oxidase (PPO) are desirable for noodles, since high PPO levels are associated with noodle discoloration. At present, all Montana hard white spring varieties are high PPO, and thus better suited for bread baking. Many hard white varieties sprout more readily than hard reds, especially those developed from Australian germ plasm. The pure white trait is difficult to maintain, as pollen from red wheats may pollinate a white variety, causing a mixture of red kernels. It is very important to clean the combine, storage bins and other grain handling equipment prior to harvest to avoid mixing white wheat with other wheats. Seeding equipment and seedbed must also be free of red wheats. Seeding rate should be 10% higher than for red wheat to reduce late tillers and thereby reduce green kernels.

Agawam (WestBred, 2005): Hard White. Semidwarf height. Sawfly resistant: solid stem score = 22, similar to that of Choteau, and has a low level of sawfly-attractant cis-3-hexenylacetate . Early heading, similar to Explorer. Very high yield and test weight. Protein 1.4% lower than Explorer. Fair Hessian fly tolerance.

Blanca Grande (Gen Mills): Hard white. Short stiff straw. Early maturity. Medium high yield. High test weight and low protein.

Clarine (WestBred): Hard white. Clearfield system, 2-gene resistance. Very high milling/baking quality. A Clearfield version of Pristine. Available in 2009.

Explorer (MSU, 2002): Hard white, bread-baking type. Semidwarf, 2 inches shorter than McNeal. Slightly solid-stem, but not sufficient for sawfly resistance. Early maturing. Average yield and test weight. Very susceptible to Septoria, thus not recommended for far eastern Montana. High protein, and probably too high for noodles. Excellent bread baking quality.

Golden 86 (GP Seed & Research Inc, 1986): Hard white. Used by a commercial milling and baking firm north of Three Forks, Montana. High quality.

MTHW 9420 (MSU, 1999): Experimental for exclusive release. Medium height and maturity. Below average yield. Average test weight. Very susceptible to wheat streak mosaic virus. Excellent bread quality, but too high in protein for noodles.

Plata (Gen Mills): Hard white. Short stiff straw. Medium maturity. Medium yield & test wt. Med-low protein.

Pristine (WPB): Hard white. Semidwarf. 3 days earlier than McNeal. Yield = McNeal. Protein 0.5% < McNeal. Very high quality, and used for bread baking by industry in Mid-west. See also Clarine.

Durum

Durum is generally much more susceptible to wheat streak mv and Fusarium crown rot than spring wheat.

Quality durum has strong gluten. Growers who plan to grow weak-gluten varieties need to have a marketing organization identified that will purchase those varieties. Kernel color is a very important quality trait. Rainfall or irrigation after heading causes color loss (bleaching), but some varieties are less prone to color loss. Canadian varieties are screened for bleaching resistance. Such varieties are the preferred choice in areas of late-season rainfall. Varieties that lose color more readily may be okay for drier areas of Montana. Seeding rate for durum should be 30% higher than for spring wheat due to the larger durum kernel (fewer kernels per bushel). An additional seed-rate increase may be desirable to suppress late tillers and thereby decrease green kernels. Color score is important, and green kernels contribute to poor color and dockage. 23 to 29 seeds per square foot (approx 1.0 to 1.26 million seeds per acre) has normally been a good seeding rate for durum.

Alkabo (ND, 2006): Medium-tall height, very stiff straw. Medium maturity. Above average yield and test wt. Good quality.

Alzada (WestBred, 2005): Semidwarf height, short stiff straw. Early maturing. High yield, average test weight. Medium protein. Very good quality and gluten strength, and very good semolina color.

Avonlea (Can, 1997): Medium tall. Medium straw strength and lodging resistance. Early maturity. High yield and average test weight. Good quality and protein.

Dilse (ND): Medium height, late maturity. Below average yield. Average weight. High protein, excellent quality.

Divide: (ND, 2006): Medium-tall height, stiff straw. Medium maturity. Average yield. Above average test wt. Excellent quality.

Grenora (ND, 2006): Medium-tall height, stiff straw. Medium maturity. Average yield and test wt. Good quality.

Kyle (Canada, 1984): Very tall weak straw, poor lodging resistance. Very late maturing. Average yield and test weight, large kernel size. Kyle has the highest tolerance to color-loss (rain-bleaching). Above average protein. Strong gluten; good quality.

Lebsock (ND, 1999): Medium height, stiff straw. Late maturity. Below average yield. High test weight and excellent quality.

Levante (AllStar Seeds, 2007): Short semidwarf height. Early heading. Above average yield & test weight on dryland in 2007; and average performance on irrigated.

Maier (ND, 1998): Medium height, stiff straw, good lodging resistance. Medium maturity. Above-average yield. Medium large kernels, very high test weight. Average protein. Good milling quality.

Mountrail (ND,1998): Medium-tall, but stiff straw and fair lodging resistance. Medium-late maturity. Average yield and test weight. Medium large kernel and average protein. Medium quality, but kernel color more sensitive to late rain than some other varieties. (All durums are sensitive to late rain/irrigation relative to color loss).

Navigator (Can): Med short, but weak straw. Med late maturity. Medium test weight & protein, good quality.

Normanno (AllStar Seeds, 2007): Semidwarf height. Medium maturity. Average yield and below average test weight in 2007.

Pathfinder (Can): Med tall, weak straw. Med late maturity. Med test weight. Med low protein, good quality.

Pierce (ND): Medium-tall height and lodging resistance. Below average yield. High test weight. Average protein, good quality.

Plaza (ND): Med-short straw, med lodging resistance. Late maturity. Below-average yield on dryland; above-average yield on irrigated. Below average test weight. Low protein, medium quality.

Silver (MSU, 2011): Medium-short, with good lodging resistance, with maturity comparable to Alzada. Above average yield on dryland with slightly above average test weight on dryland and irrigated plots. Silver has average protein.

Strongfield (WestBred/Canada, 2005): Medium tall, med-late maturity. Above average yield. Average test weight. Above-average protein. Good color and quality. Low grain cadmium concentration.

MONTANA STATE UNIVERSITY
College of AGRICULTURE & MONTANA AGRICULTURAL EXPERIMENT STATION

Barley

Title: Spring Barley variety evaluations at Western Triangle Ag. Research Center

Principle Investigator: Gadi V.P. Reddy, Superintendent and Associate Professor of Entomology/Insect Ecology, Western Triangle Ag Research Center

Personnel: John H. Miller, Research Associate and Julie Prewett, Research Assistant WTARC, Conrad, MT, and Jamie Sherman and Liz Elmore, MSU PSPP Dept., Bozeman, MT.

Cooperators: Bradley Farms, north of Cut Bank, MT
Brian Aklestad, north of Devon, MT
Aaron Killion, east of Brady, MT
Inbody Farms, northeast of Choteau, MT

Objectives: There are diverse cropping environments within the area served by Western Triangle Agricultural Research Center. Each off station location has its own unique environment and soils. Producers in the various locations are interested in variety performance in the local area. To this end the objective is to evaluate spring barley varieties under the local conditions with respect to yield, test weight, plant height, plump seed, thin seed and seed protein. The environmental conditions at the off station nurseries can vary greatly from those at WTARC. The research center strives to provide growers of the western triangle area unbiased information of various spring barley varieties.

Methods: Barley was separated into malt/feed and hull-less varieties. On station nurseries consist of dryland and irrigated intrastate malt/feed barley, 49 entries, and dryland and irrigated hull-less barley, 16 entries. Off station barley nurseries consist of 16 entries replicated three times, seeded with a four row plot seeder on one foot spacing. All plots were planted on no-till chemical fallow. Plots were trimmed, measured for length, then harvested with a Hege 140 plot combine. Spring barley seed was cleaned prior to collecting data.

Results: Table 1 and 2 are data from the dryland intrastate malt/feed barley trial. Tables 3 and 4 are for the irrigated intrastate malt/feed barley nursery. Tables 5 thru 13 are for off station barley nurseries and tables 14 and 15 are for the dryland and irrigated hull-less intrastate nurseries.

Overall, the crop year temperatures where close to the 29 year average at the research center with the exception of 2.5 inches less moisture than the 29 year average. The winter temperature was close to average, with the exception of November being 8 degrees cooler than usual. March was 7 degrees warmer than the normal. Also June was 4.6 degrees warmer compared to the 29 year average.

Soil temperatures at the station under chemical fallow stubble stayed under 40 degrees at a depth of eight inches until mid April. May was cool with slightly above average precipitation. Early in June we received 0.95 inches, then it warmed up and remained dry for about 30 days, during that time the barley was running out of water as it was heading. July had normal amounts of rain.

Yields for the dryland intrastate malt/feed nursery ranged from 67.0 to 102.5 bu/ac with an average test weight of 51.0 bu/ac. Plump average was 92.2 % with an average of 9.4 % seed protein. Irrigated intrastate malt/feed nursery had a range of 90.2 to 144.0 bu/ac with a average test weight of 52.8. The nursery averaged 95.3% plump and 11.7 % seed protein.

The hull-less dryland barley intrastate nursery had an average yield of 3472.9 lbs/ac with an average test weight of 55.3 lbs/bu and 14.1 % grain protein. Irrigated hull-less barley trial had a average yield of 5042.8 lbs/ac and an average test weight of 57.7 lbs/bu and 14.8 % average seed protein.

Yields for the irrigated off station spring barley nursery, averaged 124.7 bu/ac, with an average kernel plumpness of 89.6%, a mean protein of 11.9%, and an average test weight of 51.1 lb/bu (Table 5). Three year means from the irrigated off station nursery are tabulated in Table 6.

Grain yields averaged 50.0 bu/acre at the Knees, 36.8 bu/ac north of Devon, and 82.6 bu/ac at the Choteau site. Kernel plumpness averaged 79.4 % and test weight averaged 50.7 lbs/bu at the Devon site while kernel plumpness averaged 83.2% and test weight averaged 45.2 lbs/bu at the Knees. Choteau kernel plumpness was 87.1 % and test weight averaged 52.0 lbs/bu. The nursery at Cut Bank averaged 60.7 bu/ac, 50.3 lb/bu, 93.5% plumps, with 11.1 % seed protein. Top yielding varieties at the Knees were Champion, Harrington and Metcalfe, yields were 58.3, 57.6, and 56.7 bu/a. Whereas, the top yielding barleys north of Devon, Champion, Lavina and Merit yielded 47.6, 46.4 and 43.8 bu/ac. Yielding highest at the Choteau site were Lavina, Haxby and the Montana State University experimental variety MT100126, with yields of 95.7, 92.4 and 90.7 bu/ac. High yielding varieties at Cut Bank were Hockett, 70.2 bu/ac, Champion, 68.2 bu/ac and Haxby, 67.8 bu/ac. There is no long term data table for the Cut Bank location as it has suffered severe hail damage for the last two out of five years.

Summary: The data from the off station plots is supported by the local producers and advisory committee as well as the seed industry. It is planned to continue the off station variety plots at the same locations as the environmental conditions at each location is unique to the western triangle area. No insect incidence or damage was noticed in any of the varieties.

These data should be used for comparative purposes rather than using absolute numbers. Statistics are used to indicate that treatment or variety differences are really different and are not different due to chance or error. The least significant difference (LSD) and coefficient of variability (CV) values are useful in comparing treatment or variety differences. The LSD value represents the smallest difference between two treatments at a given probably level. The LSD at p=0.05 or 5 % probability level is usually the statistic reported, and it means that the odds are 19 to 1 that treatment differences by the amount of the LSD are truly different. The CV value measures the variability of the experiment or variety trial, and a CV greater than 15 % indicates a high degree of variability and less accuracy.

Funding Summary: Office of Sponsored Programs will provide expenditure information. No other grants support this project.

Table 1. Intrastate barley, malt/feed variety trial, Conrad 2015.

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Protein %	Head Date	Height inches
Champion	102.5	53.5	93.8	4.5	9.0	167.3	30.7
ME3	95.8	51.8	95.4	3.8	9.5	167.7	30.3
ME5	94.8	50.4	96.7	4.3	9.1	170.7	28.7
MT124555	94.6	52.1	94.2	3.2	8.7	169.7	28.3
MT124025	93.9	52.2	95.4	3.0	10.1	169.7	31.3
ME1	91.6	51.9	94.0	2.5	9.2	170.7	24.3
MT124073	91.5	50.9	92.1	3.4	9.3	168.7	29.7
Haxby	90.8	54.2	87.7	10.1	9.9	167.6	30.6
MT124148	90.0	51.1	83.2	12.1	9.0	168.7	27.7
Stockford	89.7	48.0	94.9	2.8	9.4	167.0	29.3
MT124018	89.2	50.1	94.6	3.6	10.0	165.3	28.7
MT124113	88.3	52.4	97.7	1.0	9.7	162.3	29.3
MT124370	87.9	50.9	95.1	3.2	8.8	168.7	26.7
MT124112	87.8	52.8	98.5	.09	9.2	165.3	28.7
ME4	87.4	50.5	91.9	6.7	9.4	167.6	27.3
MT124118	87.3	52.5	93.5	4.8	10.0	165.3	32.3
ME2	87.2	50.7	91.2	6.1	9.4	170.3	24.3
MT124027	87.1	51.2	93.6	3.7	8.8	169.3	29.3
MT124008	86.8	51.3	94.3	5.4	10.1	167.6	31.3
MT124134	86.2	53.1	98.2	1.2	9.7	162.0	29.0
Hockett	86.0	52.1	95.9	2.9	9.2	167.6	30.7
MT124127	85.2	53.1	95.4	3.0	9.9	166.3	28.7
MT124128	84.9	52.6	98.5	1.0	9.7	162.0	27.3
MT124601	84.7	51.5	91.3	5.6	8.7	169.0	30.7
AC Metcalfe	84.6	51.1	81.7	8.3	9.3	168.0	29.7
MT124016	84.6	50.0	89.3	7.0	9.3	168.6	26.7
MT124457	84.5	52.0	95.4	3.1	9.4	166.0	29.0
MT124069	84.4	49.6	91.9	8.0	9.2	170.7	27.3
Craft	84.2	52.3	93.7	3.4	9.6	166.0	31.3
MT124645	83.3	50.6	92.2	5.6	9.4	167.0	28.7
MT124361	82.9	51.0	90.8	2.6	9.6	166.0	28.0
Conrad	82.0	51.3	92.2	3.9	9.6	170.0	27.3
MT124007	82.0	52.0	94.9	3.9	9.7	167.3	31.7
Harrington	80.9	50.3	90.6	5.9	10.1	169.0	28.3
MT124728	80.8	49.6	94.1	4.1	10.4	168.7	26.7
MT124677	80.8	51.9	91.1	4.0	9.5	164.3	28.3
MT124716	80.5	50.2	90.7	4.5	9.4	169.0	27.3
MT124454	80.3	52.0	95.2	4.4	9.7	167.3	30.7

Table 1 continued on next page

Table 1. Continued

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Protein %	Head Date	Height inches
MT124071	80.0	49.7	95.6	6.3	9.4	165.3	30.0
Merit	79.8	48.3	87.6	7.2	9.5	168.7	28.3
MT124380	79.2	48.7	93.2	4.5	9.5	168.0	26.0
MT124015	78.3	50.1	88.6	7.2	9.6	168.3	27.7
MT124673	77.2	51.3	97.0	2.3	9.2	166.0	27.7
Moravian 115	76.1	46.8	90.4	6.8	9.5	173.7	21.0
MT124001	76.0	51.2	92.2	5.3	9.9	167.6	28.7
MT124663	75.9	51.4	97.6	2.4	6.3	163.3	28.7
MT124026	72.0	51.3	93.5	3.3	9.3	168.3	30.3
Haybet	71.3	47.4	61.4	24.3	10.4	165.7	31.3
Lavina	67.0	48.5	77.4	10.5	9.0	168.0	30.0
Mean	84.5	51.0	92.2	5.0	9.4	167.5	28.7
LSD	14.1	1.4	7.3	5.9	ns	1.7	1.9
CV	10.3	1.7	4.9	71.6	9.1	0.6	4.2
P-value (0.05)	0.0162	<0.0000	<0.0000	<0.0000	0.2196	<0.0000	<0.0000

Planted April 10, 2015 on chemical fallow barley stubble. Harvest July 30, 2015.
Fertilizer, actual (lbs/a): 11-22-0 place with seed at planting, 12-0-20 broadcast while seeding.
Fertilizer rates are based on achieving malt grade barley.
Growing season precipitation: 4.74 inches.
Preplant sprayed with RT3 at 32 oz per acre on 4/8/15.
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 2. 5-year Means, intrastate barley (malt/feed) varieties, Conrad, MT, 2009, 2011-2015.

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Protein %	Plant height	Head date
Champion	107.4	53.6	93.9	22.3	10.1	179.4	29.6
Conrad	96.8	51.9	95.9	1.7	10.6	182.5	27.0
Harrington	95.7	51.0	91.7	3.0	10.3	181.4	28.4
Hockett	95.4	53.1	96.1	1.7	10.4	179.9	28.8
Craft	94.6	53.6	95.3	1.9	10.5	178.5	30.6
Haxby	90.7	54.4	92.7	3.5	10.2	180.2	28.5
Metcalfe	90.7	51.8	91.6	3.1	10.4	180.1	29.8
Mean	95.9	52.8	93.9	2.5	10.4	180.3	29.0

Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 3. Irrigated intrastate malt/feed barley variety trial, Conrad 2015.

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Protein %	Head Date	Height inches
Champion	144.0	53.7	97.0	0.9	10.2	172.7	34.3
ME1	138.0	53.4	96.4	1.3	11.4	177.0	28.7
Haxby	134.0	53.8	94.0	2.6	11.1	172.3	34.7
Conrad	131.9	52.0	95.3	1.6	13.9	176.3	31.7
MT124148	131.2	53.8	97.6	0.9	11.7	177.0	31.7
MT124677	129.1	53.4	96.5	1.3	11.0	169.7	30.0
Moravian 115	126.9	52.0	97.6	1.1	11.0	178.7	26.7
ME2	126.9	52.4	96.6	1.3	11.1	176.7	29.7
MT124555	126.8	53.7	97.7	0.9	10.7	175.6	32.7
MT124007	126.3	52.8	94.4	2.4	10.1	172.7	33.6
MT124370	125.0	52.3	93.1	3.3	11.3	174.7	30.7
MT124025	124.4	52.4	96.8	1.1	10.1	175.0	33.7
MT124071	124.2	52.9	97.3	0.8	11.6	173.0	32.0
MT124128	124.2	53.1	96.6	1.2	11.2	166.3	30.3
MT124027	123.2	53.0	97.5	0.9	11.3	175.0	31.3
Craft	123.1	52.9	92.9	1.5	11.5	171.3	35.0
MT124716	122.8	53.4	96.9	1.0	11.4	174.3	31.0
Merit	121.6	52.4	95.6	1.6	12.4	175.0	31.7
MT124380	121.5	52.3	96.4	1.2	10.7	174.0	28.3
MT124601	120.8	52.3	96.9	1.1	10.2	174.3	32.7
MT124015	120.7	53.8	96.3	1.6	12.2	176.7	32.3
MT124026	120.2	53.0	96.0	1.8	11.6	175.3	33.0
MT124069	118.3	53.3	97.3	0.9	12.4	177.3	33.3
MT124645	118.1	52.9	97.5	1.0	11.3	172.3	34.3
MT124073	117.8	53.9	96.9	1.2	11.5	175.3	34.3
MT124663	117.7	52.4	96.6	1.5	10.0	170.0	31.3
MT124134	117.2	53.2	98.6	0.5	11.9	166.3	31.7
MT124016	116.7	52.0	91.1	4.2	12.3	175.0	29.0
MT124018	116.4	53.1	98.0	0.6	12.1	171.3	31.0
MT124728	116.2	53.0	95.5	1.7	13.8	175.3	29.0
MT124118	115.8	53.8	96.3	1.5	12.0	171.7	32.3
MT124673	115.7	52.6	98.1	.07	10.7	171.7	29.7
MT124127	115.4	54.2	97.4	0.9	12.1	171.0	30.7
MT124112	115.2	51.8	96.5	1.3	11.2	170.7	31.0
MT124457	115.1	54.8	96.8	1.8	13.1	172.0	32.3
ME3	114.7	53.4	97.1	1.3	13.1	174.3	35.0
MT124454	113.8	54.1	97.1	1.2	12.1	172.3	33.7
AC Metcalfe	113.7	53.2	97.0	1.1	12.2	176.7	33.3

Table 3 continued on next page

Table 3. Continued

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Protein %	Head Date	Height inches
MT124001	113.2	53.0	96.8	1.0	11.3	173.3	33.3
ME4	110.9	53.8	97.5	1.1	13.5	174.0	30.3
MT124008	109.1	52.2	92.9	3.0	12.1	173.7	32.5
MT124361	107.5	53.3	97.7	0.7	12.6	171.7	30.7
ME5	107.4	52.3	98.7	0.5	12.8	176.7	32.3
MT124113	107.2	52.8	97.8	0.6	12.0	166.6	31.0
Harrington	106.6	52.3	94.8	2.1	13.1	177.0	32.7
Hockett	106.2	52.8	94.8	2.3	13.7	173.0	32.7
Stockford	101.4	50.6	94.8	1.4	10.7	174.0	34.0
Lavina	97.1	50.1	79.9	8.1	11.7	173.7	32.0
Haybet	90.2	46.4	63.0	17.3	11.9	172.0	36.3
Mean	118.7	52.8	95.6	1.7	11.7	173.5	32.0
LSD	16.4	1.5	ns	2.8	1.6	1.5	2.3
CV	6.9	1.4	2.5	80.7	7.2	0.5	3.6
P-value (0.05)	<0.0000	<0.0000	0.5370	<0.0000	<0.0000	<0.0000	<0.0000

Planted April 22, 2015 on fallow. Harvest August 19, 2015.
Fertilizer, actual (lbs/a): 11-22-0 place with seed at planting, 60-0-20 broadcast while seeding.
Fertilizer rates are based on a yield goal of 90 bu/a.
Growing season precipitation: 5.59 inches. Irrigation = 9.9 inches
Preplant sprayed with RT3 at 32 oz/a on 4/22/2015.
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 4. 5-year Means, Intrastate irrigated barley varieties, Conrad, MT, 2009, 2011-2015.

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Plant Height	Protein %	Head date
Champion	106.2	53.1	96.7	0.8	29.8	9.2	185.6
Conrad	101.5	52.2	96.3	1.3	28.0	10.2	187.8
Haxby	98.6	52.3	96.1	1.5	29.2	9.6	184.6
Craft	98.3	51.7	96.0	1.2	31.5	10.3	184.9
Metcalfe	97.3	51.2	96.9	1.3	32.2	10.3	185.5
Harrington	95.8	50.1	95.5	1.9	29.5	10.3	187.6
Hockett	94.6	51.9	96.7	1.2	29.5	10.7	186.1
Mean	98.9	51.8	96.3	1.3	30.0	10.1	186.0

Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 5. 2015 Irrigated off station barley variety trial, Conrad, MT.

Variety	Yield bu/ac	Test Wt lb/bu	Height inches	Plump %	Thin %	Heading Date	Protein %
Champion	155.7	52.5	36.7	91.9	3.2	171.0	15.3
Haxby	142.1	53.7	31.7	92.4	3.4	172.0	14.2
MT100120	141.5	53.8	36.3	96.5	1.4	175.0	14.9
MT124027	132.8	52.2	32.3	95.6	1.2	174.0	16.1
Merit	127.9	50.7	32.7	92.1	3.2	174.0	14.7
Conrad	126.7	51.4	33.0	92.7	2.9	175.7	12.9
Craft	124.9	53.6	35.3	96.6	1.8	172.0	14.4
Moravian 115	124.2	49.4	28.7	94.4	2.2	177.7	14.6
MT124728	123.5	51.9	30.0	95.1	2.0	175.0	15.7
Metcalfe	122.9	51.6	35.7	93.5	2.7	174.0	14.3
MT100126	119.9	55.0	36.7	95.2	2.0	174.0	15.5
Stockford	119.8	47.8	35.7	88.6	3.8	173.0	13.6
Harrington	119.5	49.3	34.7	97.0	6.8	173.7	14.2
Hockett	112.1	53.4	32.7	93.0	1.7	173.0	15.4
Lavina	110.5	49.8	33.2	70.7	13.3	173.0	15.7
Haybet	91.8	46.3	37.0	58.6	20.0	172.3	15.1
Mean	124.7	51.1	33.8	89.6	4.5	173.7	11.9
LSD (.05)	25.5	2.5	4.2	4.9	2.5	2.4	
C.V. (s/mean)*100	12.3	2.9	7.4	3.3	33.3	0.8	
P-Value	0.0103	<0.0000	0.0070	<0.0000	<0.0000	0.0006	

Planted April 22, 2015 on fallow. Harvest August 19, 2015
Fertilizer, actual (lbs/a): 11-22-0 place with seed at planting, 60-0-20 broadcast while seeding.
Fertilizer rates are based on achieving malt grade barley.
Growing season precipitation: 5.59 inches. Irrigation = 9.9 inches
Preplant sprayed with RT3 at 32 oz/a on 4/22/15.
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 6. 3-year Means, Irrigated off station barley varieties, Conrad, MT, 2013-2015.

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Protein %	Plant height	Head date
Champion	121.7	52.4	95.4	1.7	11.8	33.8	178.4
Haxby	115.8	53.3	95.7	1.8	11.4	32.0	178.3
Conrad	114.4	51.2	96.3	1.5	11.0	30.6	180.7
Metcalfe	111.6	50.9	95.3	1.8	11.6	32.8	179.9
Craft	111.5	50.3	97.7	1.0	11.6	30.8	179.3
Harrington	106.1	49.7	96.2	3.1	11.4	32.5	179.7
Hockett	99.7	52.0	95.8	1.3	11.2	30.8	179.1
Mean	111.5	51.4	96.1	1.7	11.4	31.9	179.3

Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 7. Off-station spring barley variety trial located in the Choteau area. Western Triangle Ag. Research Center. 2015.

Variety	Spike	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Protein %	Plant Ht inches
Lavina		95.7	48.8	68.0	21.6	15.5	25.7
Haxby	2	92.4	54.4	84.6	11.3	14.3	25.7
MT100126	2	90.7	54.2	90.9	5.9	13.5	26.7
Champion	2	88.9	54.0	93.6	4.5	14.3	27.0
Stockford	2	83.6	50.6	95.5	4.0	14.0	26.3
MT124728	2	82.8	51.4	81.7	13.3	15.6	25.7
Haybet		82.5	48.5	62.6	25.9	15.8	24.3
Moravian 115		81.9	51.1	91.4	6.7	14.3	24.0
MT100120	2	80.3	53.5	91.2	6.3	13.4	27.7
Hockett	2	79.9	53.0	93.2	4.7	15.4	26.3
MT124027		78.7	52.1	90.1	7.1	15.1	25.3
Metcalfe	2	77.8	52.2	92.7	6.2	15.5	25.0
Merit		77.3	50.1	83.0	11.3	15.9	24.3
Craft	2	77.2	54.7	96.5	2.7	15.3	29.3
Harrington	2	76.1	50.7	86.3	10.6	15.9	24.0
Conrad	2	75.4	51.9	91.6	6.4	16.7	25.3
Average		82.6	52.0	87.1	9.3	15.0	25.6
LSD (.05)		ns	0.9	6.3	4.5	0.7	1.9
C.V.		9.8	1.0	4.3	29.1	2.8	4.6
P-Value (0.05)		0.0918	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000

Planted April 24, 2015 on chemical fallow. Harvest August 11, 2015.
Fertilizer, actual (lbs/a): 11-22-0 place with seed at planting. Fertilizer rates are based on achieving malt grade barley.
Growing season Precipitation: Tipped over when ditches were pulled up to the road surface.
Herbicide: None
Conducted by MSU Western Triangle Ag Research Center, Conrad, MT.

Table 8. 4-year means, off station barley varieties, Choteau, MT, 2012-2015.

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Protein %	Plant height
Champion	69.6	51.4	76.2	7.8	13.7	27.6
Haxby	65.2	51.9	84.3	9.0	14.2	25.8
Craft	64.3	52.5	83.7	4.4	14.3	28.9
Hockett	63.4	49.9	80.2	11.3	14.9	26.2
Metcalfe	63.0	49.4	84.2	7.5	15.0	26.1
Conrad	61.0	49.7	80.9	9.6	15.6	25.0
Harrington	58.7	48.4	75.3	13.4	15.4	25.1
Mean	63.6	50.4	78.1	9.0	14.7	26.4

Location: Inbody Farms, Choteau, MT
MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 9. Off-station barley variety trial located north of Cut Bank, MT. Glacier county. Western Triangle Ag. Research Center. 2015.

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thins %	Height inches	Protein %
Hockett	70.2	52.0	96.8	1.3	22.0	10.5
Champion	68.2	52.1	95.0	1.9	21.3	10.8
Haxby	67.8	53.1	96.1	1.2	21.3	10.5
Lavina	63.4	48.1	87.0	4.0	21.7	10.8
Moravian 115	62.3	48.0	95.8	1.2	16.7	11.3
Stockford	61.8	48.6	96.2	1.2	21.0	11.2
MT100126	61.1	51.8	96.9	1.0	22.3	10.4
Conrad	61.0	54.6	96.5	1.5	19.7	11.5
Metcalfe	60.1	50.5	94.7	1.9	21.0	11.5
Harrington	60.0	49.8	94.6	2.0	19.3	11.1
MT100120	60.0	50.9	95.0	1.9	22.0	10.2
MT124027	59.8	49.8	95.0	2.0	20.3	10.6
MT124728	57.5	48.9	92.3	3.0	19.3	11.7
Merit	55.7	47.5	92.2	2.7	19.3	11.8
Craft	52.3	51.4	95.4	2.1	24.0	11.2
Haybet	49.2	47.9	77.4	5.9	23.0	12.3
Mean	60.7	50.3	93.5	2.2	20.9	11.1
LSD (.05)	9.0	3.6	3.0	1.3	2.5	
C.V. 1 (%) (S/mean)*100	8.9	4.2	1.9	34.7	7.2	
P-Value	0.0043	0.0068	0.0000	<0.0000	0.0004	

Cooperator and Location: Bradley Farms, northern Glacier county.
Planted April 30, 2015 on chem-fallow. Harvested August 24, 2015.
Fertilizer, actual lbs/a: 11-22.5-0 with seed at planting.
Sprayed with Huskie at 11 oz/a and Axial XL at 16.4 oz/a on 6/4/2015.
Precipitation from 4/30/2015 until harvest was: 4.2 inches.
Conducted by MSU Western Triangle Ag. Research Center.

Table 10. Off-station barley variety trial located north of Devon, MT. Toole county. Western Triangle Ag. Research Center. 2015.

Variety	Yield bu/ac	Test Wt lb/bu	Height inches	Plump %	Thin %	Protein %
Champion	47.6	51.8	18.0	77.6	15.7	15.2
Lavina	46.4	48.4	20.3	59.9	25.5	16.2
Merit	43.8	50.0	19.7	76.1	16.7	16.4
MT124728	42.1	50.7	20.3	78.2	15.4	16.1
MT100120	39.6	52.3	18.0	88.7	7.4	13.9
Conrad	38.9	50.7	18.3	88.9	9.3	16.7
MT100126	38.6	51.5	18.7	87.2	10.3	14.8
Haxby	38.4	51.5	19.3	74.9	20.0	15.7
Stockford	36.5	48.9	20.0	91.6	5.6	15.2
MT124027	36.2	50.4	18.0	81.2	13.0	16.0
Haybet	33.4	47.1	18.0	27.8	40.1	17.8
Craft	32.9	53.0	19.7	91.2	5.3	16.5
Moravian	30.6	50.9	19.3	90.2	6.3	16.9
Metcalfe	30.4	51.1	20.3	92.1	8.2	16.7
Hockett	26.9	52.3	19.0	89.2	6.7	17.6
Harrington	26.0	50.2	18.0	74.9	18.4	18.2
Mean	36.8	50.7	19.1	79.4	14.0	16.2
LSD (0.05)	10.6	1.2	ns	16.0	9.8	1.4
C.V. (s/mean)*100	17.2	1.4	7.2	12.1	42.1	5.2
P-Value	0.0039	<0.0000	0.2212	<0.0000	<0.0000	<0.0000

Cooperator and Location: Brian Aklestad farm, north east of Devon.
Planted April 27, 2015 on chemical fallow. Harvest August 12, 2015.
Fertilizer, actual (lbs/a): 11-22-0 place with seed at planting, 30-0-20 broadcast while seeding. Fertilizer rates are based on achieving malt grade barley.
Growing season precipitation: 1.25 inches. Rain gauge was cracked at some point during growing season.
Herbicide: The plot area was pre-plant sprayed with 32 oz/a RT3 on 4/27/2015. The plots were sprayed with Huskie at 11 oz/a and Axial XL at 16.4 oz/a on 6/11/2015.
Conducted by MSU Western Triangle Ag Research Center, Conrad, MT.

Table 11. 5-year means, off station barley varieties, Devon, MT, 2011-2015.

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Protein %	Plant height
Champion	57.5	51.2	82.8	6.5	10.9	22.3
Conrad	57.0	49.1	89.4	4.6	11.9	21.9
Hockett	54.4	49.3	83.8	6.2	11.6	22.8
Harrington	52.3	48.0	86.5	7.4	12.0	21.8
Craft	51.9	49.6	89.6	3.1	11.7	25.0
Haxby	49.8	50.8	83.2	8.2	11.2	22.8
Metcalfe	49.4	48.6	87.0	4.9	11.7	23.2
Mean	53.2	49.5	86.0	5.9	11.6	22.8

Location: Brian Aklestad
Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 12. Off-station spring barley variety trial located in the Knees area. Western Chouteau County. Western Triangle Ag. Research Center. 2015.

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Plant Ht. inches	Protein %
Champion	58.3	45.9	81.0	9.0	23.0	13.6
Harrington	57.6	45.4	85.1	7.2	21.0	14.7
Metcalfe	56.7	46.4	89.1	4.0	21.7	14.3
MT124728	56.2	48.0	89.5	3.1	20.3	14.6
Merit	56.1	45.1	87.4	5.5	19.3	14.5
MT124027	56.0	46.1	87.4	4.9	21.3	13.4
Moravin	55.8	44.6	91.2	4.0	13.3	13.7
Hockett	52.3	48.9	91.7	3.9	22.7	13.6
Haxby	52.3	48.9	88.9	4.1	21.0	13.5
Craft	52.2	47.9	88.8	5.3	22.7	13.8
MT100120	48.9	43.9	81.6	8.6	21.7	12.7
Lavina	44.0	40.4	62.9	19.5	20.7	13.8
Conrad	43.2	45.0	85.8	6.6	20.7	15.4
Haybet	41.3	42.5	60.9	14.4	23.3	15.2
MT100126	41.0	44.0	79.0	11.0	22.7	12.3
Stockford	36.1	40.3	81.3	9.2	22.3	13.7
Means	50.0	45.2	83.2	7.5	21.1	14.1
LSD (.05)	11.7	1.8	5.3	3.8	3.4	
C.V.	14.0	2.4	3.9	30.2	9.6	
P-Value (0.05)	0.0019	<0.0000	<0.0000	<0.0000	0.0006	

Cooperator and Location: Aaron Killion, western Chouteau County.
Planted April 23, 2015 on chemical fallow winter wheat stubble. Harvest August 31, 2015.
Fertilizer, actual (lbs/a): 11-22-0 place with seed at planting, 0-0-20 broadcast while seeding.
Fertilizer rates are based on achieving malt grade barley.
Growing season precipitation: 4.0 inches.
Herbicide: The plot area was pre-plant sprayed with 32 oz/a RT3 on 4/23/15.
Conducted by MSU Western Triangle Ag Research Center, Conrad, MT.

Table 13. 5-year means, off station barley varieties, knees area, MT, 2013-2015.

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Protein %	Plant height
Haxby	69.2	51.1	82.5	4.9	12.4	12.4
Harrington	67.9	48.6	87.2	4.2	12.8	25.5
Champion	67.8	50.1	84.3	5.1	12.4	25.7
Craft	65.9	50.2	87.5	4.2	13.1	27.7
Metcalfe	65.6	48.7	87.1	3.9	13.2	26.1
Hockett	65.6	50.1	87.2	4.8	12.4	25.9
Conrad	62.6	49.0	85.6	5.3	12.9	25.4
Mean	66.4	49.7	85.9	4.7	12.7	25.8

Location: Killion Farms, Brady MT
Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 14. Hull-less dryland intrastate barley variety trial, Conrad 2015.

Variety	Yield lbs/ac[1]	Test Wt lb/bu	Plump %	Thin %	Protein %	Head Date Julian	Plant Height inches
MT110065	4214.1	57.0	54.7	34.2	13.8	171.7	29.0
MT110061	4068.4	59.2	60.0	29.7	13.2	168.7	27.0
09WA-265.12	4026.5	57.5	67.1	22.0	12.9	169.7	29.3
MT110066	3799.8	58.7	54.1	31.6	13.7	168.7	27.3
MT110008	3665.8	56.1	66.8	23.6	13.1	167.3	29.7
X05013-T1	3638.6	54.5	71.1	20.8	13.4	170.3	27.0
MT110016	3597.6	57.3	73.5	19.7	13.0	167.3	29.3
X07G30-T131	3592.9	57.0	81.8	14.8	14.5	171.0	27.0
MT110009	3586.8	55.4	70.5	22.3	13.6	170.3	31.7
X0626-T229	3399.5	57.2	75.6	18.4	13.8	165.3	25.3
PI596299	3290.9	46.2	67.8	17.6	15.1	163.0	27.7
Goose 2	3168.7	63.3	54.4	33.7	15.0	165.0	30.0
Goose 6	3057.7	63.6	70.1	22.1	14.9	165.0	29.3
Goose 4	2894.5	63.4	71.1	22.2	15.2	164.3	29.7
Goose 1	2859.3	63.2	51.4	36.1	15.7	164.0	31.3
Goose 5	2704.9	62.9	45.4	38.9	15.2	164.0	30.0
Mean	3472.9	58.3	64.7	25.5	14.1	167.2	28.8
LSD	452.0	2.3	11.8	7.1		1.6	1.9
CV (%)	7.7	2.3	10.7	16.5		0.6	3.9
P-value (0.05)	<0.0000	<0.0000	0.0001	<0.0000		<0.0000	0.0003

Planted April 10, 2015 on chemical fallow barley stubble. Harvest August 3, 2015.
Fertilizer, actual (lbs/a): 11-22-0 place with seed at planting, 12-0-20 broadcast while seeding.
Fertilizer rates are based on achieving malt grade barley.
Growing season precipitation: 4.74 inches.
Preplant sprayed with RT3 at 32 oz per acre on 4/8/15.
[1] Yields for hull-less barley reported in lbs/ac
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 15 Hull-less irrigated intrastate barley variety trial, Conrad 2015.

Variety	Yield lbs/ac[1]	Test Wt lb/bu	Plump %	Thin %	Protein %	Head Date Julian	Plant Height inches
X05013-T1	6353.8	61.6	94.0	8.8	13.6	176.0	32.7
X0626-T229	6102.5	58.0	82.8	5.5	14.3	172.3	29.0
MT110016	6037.2	57.8	91.5	3.7	14.2	172.7	35.0
09WA-265.12	5941.2	60.6	89.1	3.4	12.9	175.7	34.0
MT110008	5763.3	58.1	87.4	4.6	14.4	174.7	32.3
X07G30-T131	5725.6	59.0	95.1	1.9	14.6	177.7	31.3
MT110061	5171.1	55.5	67.4	11.6	14.2	176.3	30.7
MT110009	5069.3	56.2	88.9	3.6	14.7	177.0	37.0
MT110066	4953.2	58.0	72.0	7.2	15.4	176.3	32.0
PI596299	4690.2	47.6	81.3	12.1	15.7	169.0	30.0
MT110065	4491.0	55.1	65.9	13.3	15.1	178.0	36.0
Goose 6	4349.6	59.0	80.7	7.0	15.3	171.3	32.7
Goose 2	4318.9	58.4	81.1	5.6	15.7	171.0	33.7
Goose 5	4126.8	59.7	80.4	5.0	15.5	171.0	32.7
Goose 4	3960.3	58.7	83.9	5.0	14.9	170.7	31.3
Goose 1	3629.8	59.4	79.0	7.0	16.1	170.3	32.7
Mean	5042.8	57.7	82.5	6.6	14.8	173.8	32.7
LSD	695.8	2.4	8.0	ns		1.2	2.7
CV (%)	8.1	2.5	5.7	58.7		0.4	4.9
P-value (0.05)	<0.0000	<0.0000	<0.0000	0.0759		<0.0000	0.0015

Location: MSU Western Triangle Ag Research Center, Conrad, MT.
Planted April 22, 2014 on chemical fallow barley stubble. Harvest August 3, 2014.
Fertilizer, actual (lbs/a): 11-22-0 place with seed at planting, 12-0-20 broadcast while seeding.
Fertilizer rates are based on achieving malt grade barley. Growing season precipitation: 4.54 inches.
Preplant sprayed with RT3 at 20oz per acre on 4/24/14.
[1] Yields for hull-less barley reported in lbs/ac
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Barley Variety Notes & Comments

Western Triangle Agricultural Research Center, Conrad, MT

Baroness (WestBred): 2-row feed. Short straw and good lodging resistance; 2.5" shorter than Harrington. Equal or slightly later maturity than Harrington. High yield when tested in favorable moisture conditions. Average test weight. Stripe rust resistant.

Boulder (WestBred, 2005): 2-row feed. Composite-cross, non-Baroness derived. Height similar to Haxby. Heading 1 day later than Haxby, and 1 day earlier than Baroness. High yield, similar to Haxby. High test weight, 0.5 lb less than Haxby. Replacement for Baroness and Xena.

Challenger (WestBred, 2008): 2-row feed. Above average yield and test weight. Average height and maturity.

Champion (WestBred, 2007): 2-row feed. Medium stiff straw. Heading one day later than Haxby and Boulder. Very high yield, greater than for Boulder & Baroness. High test weight, 1 lb less than Haxby.

Charles: 2-row malt. Grown as a winter barley in Idaho, but has very low winter hardiness. Winter survival on tillage-fallow at Conrad was 40% in 2007, and 10% in 2008.

Conlon (ND, 1996): 2-row malt. Medium height, weak straw. Early maturity, 1-2 days earlier and higher test weight than Bowman. Developed for areas of heat & drought stress. High resistance to net blotch; susceptible to spot blotch & Fusarium head blight.

Conrad (Busch Ag): 2-row malt, Busch Agr Resources. About 2 inches shorter than Harrington. Medium maturity, similar maturity as Harrington. Higher yield than Harrington. Slightly higher test weight and plump than Harrington.

Copeland (Sask. Canada, 1999): 2-row malt. Better straw strength and earlier maturity than Harrington. Similar yield, test weight, and plump than Harrington. Net blotch resistant. Scald & Septoria susceptible.

Craft (MT970116; MSU, 2006): 2-row malt. Taller than Harrington & Merit. 2 days earlier heading than Harrington, but later heading than Hockett. High yield, test weight, & plump. Moderate stripe rust resistance. Susceptible to net blotch. European style of malt enzyme activity for microbrew market. AMBA approved for organic malt production.

Drummond (ND 15477): 6-row malt. Stronger straw than other 6-row malt types. Improved yield over Morex, Robust and Foster. Plump higher than Morex.

Eslick (MSU, 2005): 2-row feed. Height 1” taller than Baroness, 1” shorter than Haxby. Heading date similar to Harrington, and 1-2 days later than Haxby. Yield similar to Baroness and Haxby. Test wt = Baroness, greater than Harrington, and 2# less than Haxby. Eslick has superior performance in areas of ample moisture, while Haxby is preferred where lower moisture conditions are expected.

Geraldine (MT960101; MSU, Miller Brewing): 2-row malt for Miller Brewing Co. One day later heading than Harrington. Good performance on irrigated conditions; below average performance on dryland. Moderate stripe rust resistance.

Harrington (Sask. Can): 2-row malt. Medium height; medium weak straw. Medium-late maturity. Sensitive to hot dry areas; yields good in moist areas. Can sprout or germinate (internal falling number) at a lower moisture content than other varieties.

Haxby (MSU, 2002): 2-row feed. 3 inches taller and two days earlier than Baroness. Among highest yielders in Triangle Area. Highest test weight of all varieties. High feed quality. Non-Baroness derived, providing good diversity. Haxby has superior yield performance in lower moisture conditions, while Eslick has a yield advantage in high moisture conditions.

Hays (MSU, 2004): Hooded 2-row forage. Shorter than Haybet and more resistant to lodging. Higher grain yield than Haybet. Low test weight. Higher forage yield than Haybet and Westford (8%). Harvest between heading stage and 5 days post-heading for highest protein. Caution: any cereal grain grown for hay should be tested for nitrate level prior to cutting. Nitrates decrease during grain filling, but in drought conditions, nitrates may be high all season, unless irrigation is available.

Hockett (MSU, MT910189): 2-row malt for dryland. 4 days earlier than Harrington, and retains plump on dryland much better than Harrington. 5 bu/a higher yield than Harrington. Very susceptible to stripe rust.

Kendall (Can): 2-row malt. High irrigated yield.

Lacey (M98, MN 1999): 6-row malt. Intended to replace Robust. Height intermediate between Robust & Stander. Lodging resistance greater than Robust, but less than Stander.

Legacy (Busch Ag): 6-row malt. 2 to 4 inches taller than Harrington. Higher yield than Morex and Robust, but lower than Harrington. Has 30% resistance to vomatoxin. Very susceptible to stripe rust.

Merit (Busch Ag): 2-row malt. Late maturing, too late for dryland. Lodges easier than Harrington, but yields higher. Very high diastatic power for excellent malting ability. Net blotch resistance, and moderate Scald resistance.

Metcalfe (Manitoba Canada, 1994): 2-row malt. Replacement for Harrington in Canada. Medium straw strength. Latitude sensitive - higher yield, test weight and plump than Harrington in Canada, but similar to Harrington in Montana. Similar protein as Harrington. Medium-late, slightly earlier to head than Harrington. Moderate resistance to spot-form net blotch. Susceptible to scald and Septoria.

Stellar (ND16301, 2005): 6-row malt. Medium-short. Good straw strength and widely adapted across North Dakota. Medium maturity. High plump and low protein. Excellent malt quality. Moderate spot-blotch resistance. Net-blotch susceptible.

Stockford (WestBred, 2005). 2-row hooded hay barley. Height is 2" taller than Hays. Heading is 2 days earlier than Hays. Forage yield is similar to Hays and Haybet. Harvest between heading stage and 5 days post-heading for highest protein. Caution: any cereal grain grown for hay should be tested for nitrate level prior to cutting (see note for Hays).

Tradition (Busch Ag,): 6-row malt. Stiffer straw than Legacy, good lodging resistance. Higher yield, test weight and plump than Legacy and other 6-row varieties. Very susceptible to stripe rust.

Xena (WPB bz594-19): baroness/stark cross. 2-row feed. Two inches taller and better boot emergence than Baroness. Lodging resistance equal to Baroness. Late maturity, similar to Baroness. Better adapted to dryland than Baroness, (higher test wt and plump than Baroness on dryland). Equal or better yield than Baroness on dryland.

"BG Barley": A food barley classification, and includes waxy hulless and waxy covered varieties. Beta glucan levels of BG varieties are 50% higher than for oats or pearled barley. Grain yields are generally lower than other barley varieties. End-use includes various foods, including rice-extender, 'Heart Balance Cereal' etc.

MONTANA STATE UNIVERSITY
College of AGRICULTURE & MONTANA AGRICULTURAL EXPERIMENT STATION

Canola

Project Title: Canola variety evaluations at Western Triangle Ag. Research Center

Principle Investigator: Gadi V.P. Reddy, Superintendent and Associate Professor of Entomology/Insect Ecology, Western Triangle Ag Research Center

Personnel: John H. Miller, Research Associate and Julie Prewett, Research Assistant WTARC, Conrad, MT, and Brooke Bohannon, MSU/MAES, Northwestern Ag. Research Center, Creston, MT.

Objectives: To evaluate canola varieties grown at Western Triangle Ag. Research Center.

Methods: All plots were planted on no-till chemical fallow with a 4-row drill with spacing set to one foot. Plots were trimmed, measured for length, and then harvested with a Hege 140 plot combine. Canola seed was cleaned prior to collecting data.

Results: The canola nursery was affected by the hotter than normal June and lack of precipitation. The nursery averaged 15 bu/ac (Table 1). Test weight averaged 50.8 lbs/bu with mean seed oil content being 40%. There was no lodging to report in the canola nurseries.

Overall, the crop year temperatures where close to the 29 year average at the research center with the exception of 2.5 inches less moisture than the 29 year average. March was 7 degrees warmer than the normal. Also, June was 4.6 degrees warmer when compared to the 29 year average.

Soil temperatures at the station under chemical fallow stubble stayed under 40 degrees at a depth of eight inches until mid April. May was cool and wet. Early in June we received 0.95 inches of moisture, it warmed up and remained dry for about 30 days, during that time the canola was flowering and setting pods. Overall, it was a very poor year for canola.

A similar project will be proposed for FY 2016. The continuation of canola variety trials help elucidate researchers and farmers which varieties are better suited for that particular region in Montana.

Table 1. Statewide Industry Canola Variety Trial - Dryland, No-Till Chemical Fallow. Western Triangle Ag. Research Center, Conrad, MT. 2015.

Variety	Seed Yield bu/a	Test Weight lb/bu	Oil %	Julian date	Plant Height inches	Plant per Ft^2
6044RR	11.9	51.2	38.7	179	31.3	6.0
6074RR	9.9	50.9	38.7	178	36.8	5.1
C1511	13.4	50.8	35.2	174	38.5	5.2
C1516	9.2	51.3	38.1	176	36.8	4.8
Cara	9.8	50.5	39.8	176	32.0	5.6
Arriba	12.2	50.4	38.9	175	27.3	5.1
HyClass 930	15.7	50.2	42.3	173	34.5	6.7
HyClass955	18.9	50.4	42.4	172	37.0	4.8
HyClass 970	13.6	51.1	40.0	177	35.5	4.9
InVigor L130	13.7	51.1	41.6	175	36.3	3.0
InVigor L140P	11.8	50.6	41.7	179	36.0	4.8
InVigor L252	11.9	50.7	42.0	177	35.8	3.6
InVigor 5440	16.3	51.7	39.7	180	35.5	4.8
DKL 38-48	15.4	50.6	40.1	173	36.3	5.0
DKL 70-07	20.4	50.5	40.6	177	37.3	6.2
DKL70-10	19.1	50.5	40.1	174	37.3	5.9
DKL 70-50CR	20.4	50.8	40.9	176	37.3	6.4
G28101	20.2	50.2	43.6	173	39.0	4.9
G49720	21.7	51.4	36.0	178	35.5	5.5
Mean	15.0	50.8	40.0	176	35.6	5.2
LSD (α = 0.05)	ns	0.5	1.4	ns	5.7	ns
CV (%)	43.1	0.7	2.5	2.3	11.4	37.1
P-value (0.05)	0.1050	0.0001	0.0001	0.1627	0.0415	0.06338

Grain yield is adjusted to a uniform moisture content of 10%.
Grain protein, grain oil, and oil yield are reported on a dry matter basis.
Seeding Date: 4/12/2015
Thrashing Date: 8/31/2015
Fertilizer (actual lbs/a): 120-22.5-55-20
Preplant sprayed with Roundup RT3at 16 oz/a on May 21, 2013.
Previous crop: barley
Tillage: chemical fallow
Seeding Rate 10 seeds/ft^2 in 12 inch rows

Soil Test Values

Table 1. Soil test values for off-station and on-station plots, 2015.

Location	N (lbs/a)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	8.3	21	355	7.7	2.1	0.61
Devon	11.4	11	388	7.2	1.1	0.33
Knees	23.3	11	652	8.1	2.8	0.69
Choteau	67.6	10	664	8.1	2.9	0.59
WTARC	15.1	17	375	7.8	2.4	0.47

[1]Nitrogen soil samples were to a depth of four feet in one foot increments. All other soil tests were for zero to six inches in depth.
WTARC- Western Triangle Ag. Research Center