41th ANNUAL RESEARCH REPORT

WESTERN TRIANGLE AGRICULTURAL RESEARCH CENTER

Montana Agricultural Experiment Station

Conrad, MT

2018 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 '17-18 crop year (September thru August) at the Western Triangle Agricultural Research Center, Conrad, MT.

Month and Year	Precipitation (inches)			Mean Temperature (°F)		
	Current Year	Average (32 yr)	Difference	Current Year	Average (32 yr)	Difference
September, 2017	1.59	1.23	+0.36	55.1	56.8	-1.7
October, 2017	1.21	0.68	+0.53	42.0	44.6	-2.6
November, 2017	0.40	0.31	+0.09	28.3	32.0	-3.7
December, 2017	0.48	0.22	+0.26	19.5	23.5	-4.0
January, 2018	0.28	0.29	-0.01	21.9	23.0	-1.1
February, 2018	0.65	0.23	+0.42	8.7	24.2	-15.5
March, 2018	0.94	0.42	+0.52	23.1	32.7	-9.6
April, 2018	1.05	1.05	0	35.4	42.5	-7.1
May, 2018	1.08	1.84	-0.76	56.9	51.7	+5.2
June, 2018	2.73	2.87	-0.14	58.9	59.4	-0.5
July, 2018	0.34	1.36	-1.02	66.5	66.9	-0.4
August, 2018	1.04	1.22	-0.18	63.0	65.9	-2.9
Total or Average	11.79	11.72	+0.07	39.9	43.7	-3.8

Last killing frost in spring (32 °F)
2018-------------------------------- May 27
Average 1986-2018-------------- May 17

First killing frost in fall (32 °F)
2018-------------------------------- September 11
Average 1986-2018-------------- September 25

Frost free period (days)
2018------------------------------ 105
Average-------------------------- 130

Maximum summer temperature------- 100 °F (August 10, 2018)
Minimum winter temperature------- -22 °F (January 01, 2018)

United States Department of Agriculture
National Institute of Food and Agriculture

USA Dry Pea & Lentil Council

Varietal Testing Program

U.S. CANOLA ASSOCIATION

Montana Wheat and Barley

Northern Pulse Growers Association

Project Title: Off-station winter wheat cultivar evaluations for the Western Golden Triangle area of Montana

Principal Investigator: Gadi V.P. Reddy, Professor of Entomology, Western Triangle Ag Research Center

Personnel: John H. Miller, Research Scientist and Julie Prewett, Research Assistant, WTARC, Conrad, MT, 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 (WTARC). 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: The on station Intrastate winter wheat nursery consists of 49 entries, replicated three times. Off station winter wheat nurseries consist of 25 entries, replicated three times. All plots were 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 or a Wintersteiger Classic plot combine. Winter wheat seed was cleaned prior to collecting data. Wheat midge pheromone baited traps were also installed at each off station plot.

Results: Results are tabulated in Tables 1 thru 10. Table 1 and 2 present the Intrastate winter wheat nursery data. Table 3 is for the Choteau location, with multi-year data presented in Table 4. Tables 7 and 8 are for the Devon location, with Tables 9 and 10 representing the 'Knees' location. The Cut Bank data are presented in Tables 5 and 6. Table 11 is the soil test results from each location.

Overall, the crop year temperatures where cooler than the 32 year average at the research center. May, when we could have used some cooler temperatures, was 5.2 degrees warmer than the average. But the overall average temperature for the year from September to August was 3.8 degrees cooler than the 32 year average. The winter temperature, from September to March was well below average, with February being 15.5 degrees colder than the 32 year average. March and April were 9.6 and 7.1 degrees colder than the 32 year average. May was the only month that had a temperature that was above the average with a temperature 5.2 degrees. September through March were at or above the average precipitation for those months. Then May through August were drier than the 32 year average. Overall, precipitation was average for the year with respect to the 32 year average.

The winter wheat plots were seeded into soil that had good soil moisture storage from the late summer and fall moisture in 2017. Overall, the winter wheat did not do as well at two off station locations when compared to the five year average and did better than the long term averages at two off station locations. A warmer, drier May and lack of summer moisture probably affected yield, test weight, and seed protein.

Grain yields at Choteau were about 5 bu/ac higher with test weights being the same as the five year average. Seed protein at Choteau was also the same as the five year average. The top yielding varieties at Choteau include the Montana State University experimental line MTS1588, Brawl CLP and MTCS1601 at 81.8, 80.3, and 76.0 bu/ac (Table 1 and 2). Grain yields and test weights at Cut Bank were 1.5 bu/ac higher and 1.7 lb/bu higher than the five year average. Seed protein at Cut Bank was 0.2 percent higher than the five year average. At Cut Bank, the top yielding winter wheat's were Yellowstone, Loma and Keldin with yields of 87.2, 87.0, and 85.2 bu/ac (Table 3 and 4).

In the Intrastate winter wheat nursery yields were much lower than the past few years as can be seen in the five-year mean table (Tables 1 and 2), whereas the 2018 intrastate seed protein was 1.8% higher than the five-year mean. Top yielding varieties in the Intrastate winter wheat trail were CO13003C at 76.5 bu/ac, followed by LWW14-73915 and 07CL046-2 at 72.8 and 71.5 bu/ac. Test weight averaged one half pound higher than the five-year average.

Grain yields and test weights at Devon were 25.1 bu/ac lower and 2.3 lb/bu lower than the five year average. Seed protein at Devon was 0.7 percent higher than the five year average. Top yielders at Devon include Montana State University experimental lines MT1642, MTS1588 and Northern at 50.2, 49.2, and 46.7 bu/ac (Table 5 and 6). Grain yields and test weights at the 'Knees' were 17.3 bu/ac lower and 2.8 lb/bu lower than the five year average. Seed protein at the 'Knees' was 1.4 percent higher than the five year average. The top yielding varieties at the 'Knees' include Loma, Montana State University experimental lines MTCS1601 and MTS1588 at 67.7, 64.3, and 62.9 bu/ac (Table 7 and 8).

All off station plots had some level of wheat stem sawfly cutting in the winter wheat, with significant sawfly cutting at the Choteau and Devon locations. Insignificant amount of adult wheat 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.

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 probability 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.

Table 1. 2018 Intrastate Winter Wheat Variety Nursery, Western Triangle Ag. Research Center, Conrad, MT.

Variety or ID	Source	Solid Stem score*	Yield[1] (bu/ac)	Test[1] weight (lb/bu)	Heading date (Julian)	Seed protein (%)
CO13003C			76.5	61.0	155.5	12.9
LWW14-73915			72.8	60.1	154.9	15.8
07CL046-2			71.5	61.5	156.4	13.4
MTCS1601		21.9	71.3	61.9	160.3	13.7
WB4623CLP	WestBred, 2015		71.0	61.9	160.2	14.3
SY 517 CL2			69.0	63.0	152.3	12.8
Langin	Colorado, 2016		69.0	61.8	152.4	12.3
Incline AX			68.3	61.3	157.1	11.9
WB4614	WestBred, 2014		67.4	62.9	161.4	13.9
MTS1588		24.9	67.0	62.7	160.9	14.5
LCS Jet	Limagrain, 2015		66.7	60.3	161.7	13.8
SY Clearstone 2CL	MT/SY, 2012		65.5	59.9	163.6	14.0
Brawl CLP	Colorado, 2011		65.5	63.6	152.5	13.1
Loma	Montana, 2016	24.5	64.6	62.6	162.9	14.9
WB4575			64.1	64.3	160.4	14.2
SY Sunrise	Syngenta, 2015		63.9	63.3	154.6	12.8
SY Wolf	Syngenta, 2010		63.9	62.9	158.0	14.0
Long Branch	Dyna-Gro, 2015		63.8	63.1	152.7	13.1
SY Monument	Syngenta , 2015		63.7	61.4	157.3	13.1
NSA10-2196			62.4	60.2	159.4	13.3
WB4483	WestBred, 2016	23.4	61.7	61.9	162.0	14.7
AAC Wildfire			61.7	60.7	166.0	13.7
Keldin	WestBred, 2011		61.5	62.4	160.9	13.8
Ray (MTF1432)	Montana, 2018		61.4	60.0	165.3	13.8
Oahe			61.2	61.7	155.5	13.3
MT1642			60.9	60.6	164.1	14.7
FourOSix (MT1465)	Montana, 2018		60.8	61.2	158.8	14.0
MT1547			59.8	61.3	159.7	14.1
PSB13NEDH-7-140			59.6	61.9	157.6	14.8
MT1563			59.6	60.7	163.5	14.3
MTF1631			59.1	61.3	161.7	13.7
MT1683			58.5	61.2	163.4	14.5
MT1265			58.1	61.6	164.5	14.4
MT1688			57.9	61.2	157.5	15.1
MTW1491			57.3	61.4	161.7	14.1
Judee	Montana, 2011	24.2	57.0	63.3	160.1	15.2

Table 1 continued.

Variety and Class	Source	Solid Stem score*	Yield[1] (bu/ac)	Test[1] weight (lb/bu)	Heading Date (Julian)	Seed Protein (%)
MT16101			56.6	62.5	156.4	13.9
MTF1435			56.5	61.0	164.0	13.8
Yellowstone	Montana, 2005	6.3	56.4	60.9	163.4	14.6
LCS Chrome	Limagrain, 2016		56.1	62.1	156.2	14.3
Northern	Montana, 2015		55.1	62.0	162.9	14.5
MT1687			54.1	61.9	157.6	15.3
MT1564			53.1	61.4	156.0	15.2
Decade	MT/ND, 2010		52.5	62.4	158.6	14.9
LCS Link			50.7	64.2	155.0	14.6
Warhorse	Montana, 2013	24.5	50.0	60.3	160.0	15.0
MTV1681			49.3	60.6	160.6	14.8
MT1695			48.9	61.5	156.1	14.6
Bearpaw	Montana, 2011	23.4	48.2	62.5	159.1	15.7
Mean		21.6	61.0	61.7	159.2	14.0
LSD (0.05)		1.9	11.0	1.4	2.1	0.8
C. V. (%)		5.0	10.4	1.4	0.8	3.2
P-value (Varieties)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Planted: 9/25/2017 on chemical fallow and harvested on 8/16/2018
Fertilizer: actual pounds/ac of N-P-K: 11-22.5-0 applied with seed and 30-0-20 broadcast at planting. 140 lbs N/ac as urea was broadcast on 4/30/2018. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: Huskie at 11.0 oz/ac and Axial XL at 16.4 oz/ac applied on 6/3/2018.
* Solid stem score of 19 or higher is generally required for reliable sawfly resistance, solid stem scores are for the plot located at WTARC.
CL = Clearfield System
[1] Yield and test weight are adjusted to 13% seed moisture.

Table 2. Five-year means, 2014 – 2018, Winter wheat varieties, Western Triangle Ag. Research Center, Conrad, MT.

Variety	Source	Solid stem* score	5-Year Means Yield bu/ac	Test Wt.	Height inch	Head date	Protein %	Winter survival class
SY Wolf	Syngenta	-	91.1	62.4		161	12.5	3
Northern	MSU	-	87.1	60.3		163	12.5	3
SY Clearstone 2CL	SY/MSU	-	87.1	60.2		162	12.7	3
Loma	MSU	18.8	84.4	60.1		164	13.2	4
Decade	MSU/ND	-	79.6	61.4		160	12.6	4
Bearpaw	MSU	19.7	76.4	61.0		161	13.0	2
Judee	MSU	18.5	76.1	62.8		161	13.3	2
Keldin			91.3	62.0		161	12.7	3
Warhorse	MSU	20.4	70.1	59.8		162	13.1	4
Brawl Cl Plus			87.1	63.4		155	13.0	
SY Monument			90.6	60.2		160	12.1	
Mean			83.7	61.2		161	12.8	

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

Table 3. Off-station Winter Wheat variety trial located near the Choteau. Teton County.
Western Triangle Ag. Research Center. 2018.

Variety	Solid Stem Score[1]	Yield (bu/ac)	Test Wt (lb/bu)	Height (inch)	Lodging (%)	Protein (%)
MTS1588	**	81.8	59.2	27.2	4	15.3
Brawl CLP		80.3	62.6	25.5	23	14.3
MTCS1601		76.0	60.6	25.8	78	14.5
SY Monument		74.3	58.8	26.5	98	14.0
Loma	**	74.1	57.3	26.1	90	15.3
MT1547		74.1	57.7	28.0	99	14.5
Decade		73.8	59.4	29.9	82	15.2
MT1564		73.4	60.4	26.9	96	14.4
Northern		72.2	59.4	26.6	94	14.6
FourOsix		71.9	57.5	25.8	100	14.8
LCS Jet		71.7	55.7	25.5	96	14.7
Keldin		70.8	60.5	27.3	88	15.2
Judee	**	70.6	58.7	27.5	87	15.8
Yellowstone		70.6	57.6	27.9	98	14.8
MTW1491		68.4	58.8	28.4	97	14.5
SY Clearstone 2CL		67.5	57.4	28.1	100	14.8
Warhorse	**	66.3	58.2	26.1	12	14.9
MT1563		65.8	57.9	28.5	93	14.7
MT1642		65.5	56.7	29.2	83	15.4
SY Wolf		65.2	60.8	25.8	76	15.2
MT1265		62.7	57.2	28.8	97	15.1
Ray		62.6	56.8	31.8	99	14.4
WB4483		62.6	57.4	26.4	87	16.5
MTV1681		59.2	57.5	28.3	83	15.2
MTF1435		58.2	57.3	35.4	93	14.6
Mean		69.6	58.5	27.7	82.1	14.9
LSD (.05)		9.3	1.3	2.9	14.5	0.6
C.V. (%)		7.7	1.3	4.7	28.4	6.8
P-Value		0.0003	<0.0001	<0.0001	<0.0001	0.0001

Cooperator and Location: Inbody Farms TetonCounty.
Planted on 9/29/2017 on chemical fallow durum stubble. Harvested on 8/10/2018.
Fertilizer, actual lbs/ac: 11-22-0 with seed at planting, 30-0-20 side shot while planting. Spring top dressing took place on 4/15/2018 with 90-0-0. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: Plots were sprayed on 5/15/2018 with Huskie @ 11 oz/ac and Axiel XL @ 16 oz/ac.
Conducted by MSU Western Triangle Ag. Research Center.
[1]** = Solid stem sawfly-resistant (solid stem score of 19 or higher - behavioral preference) in small plots.
Conducted by MSU Western Triangle Ag. Research Center.

Table 4. Five-year means, Winter Wheat varieties, Choteau area, Teton County. 2014-2018.

Variety Or ID	Solid Stem Score[1]	5-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Height (inch)	Protein (%)
Keldin		73.1	60.3	30.6	14.7
Loma	**	69.5	57.7	30.3	15.2
SY Wolf		68.4	60.6	30.0	15.0
Warhorse	**	65.0	57.8	31.1	14.9
Northern (MT0978)		63.2	57.8	32.0	15.0
Yellowstone		62.4	58.3	30.3	15.2
Judee	**	61.8	57.2	30.3	15.4
Decade		61.7	59.4	30.3	15.1
SY Clearstone 2CL		59.1	58.2	29.5	14.8
Mean		64.9	58.6	30.4	15.0

[1]** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
Cooperator and Location: Inbody Farms, Teton County.
Conducted by MSU Western Triangle Ag. Research Center.

Table 5. Off-station Winter Wheat variety trial located north of Cut Bank, MT.
Glacier County. Western Triangle Ag. Research Center. 2018.

Variety	Solid Stem Score[1]	Yield (bu/ac)	Test Wt (lb/bu)	Height (inch)	Protein (%)	Lodging (%)
Yellowstone		87.2	60.6	29.	45.4	12.5
Loma	**	87.0	61.3	23.7	3.5	12.7
Keldin		85.2	62.3	23.0	11.3	11.6
WB4483		83.9	62.0	25.3	28.7	12.4
SY Clearstone 2CL		83.4	59.7	28.0	22.8	13.0
MTS1588	**	82.5	61.7	23.0	6.5	12.2
LCS Jet		79.3	58.6	22.7	6.2	12.1
Ray		78.6	59.2	31.3	65.4	12.8
MT1563		77.7	61.0	26.7	30.2	12.7
Judee	**	77.3	62.0	27.0	11.1	13.5
MTW1491		75.8	62.3	24.7	20.2	12.6
Northern		75.3	61.8	22.7	11.6	12.4
MTCS1601		75.0	62.1	22.7	21.9	12.8
MT1265		74.5	61.4	27.0	49.4	12.3
SY Wolf		70.1	61.9	21.7	15.5	12.7
Decade		69.3	61.8	22.7	12.7	13.8
Warhorse	**	68.8	60.6	23.0	0.0	13.5
MTV1681		67.8	60.8	23.3	33.3	13.0
FourOsix		65.8	61.8	23.7	12.7	12.9
MT1547		65.4	60.9	23.0	18.0	13.2
SY Monument		63.6	61.6	18.7	12.8	12.2
MTF1435		63.2	60.5	31.7	72.8	13.1
MT1564		62.4	61.0	21.3	25.3	12.9
Brawl CLP		62.3	63.4	20.7	35.5	14.2
MT1642		57.2	61.2	26.7	37.2	12.9
Mean		74.7	61.3	24.5	24.4	12.8
LSD (.05)		15.9	1.1	4.5	26.6	1.0
C.V. (%)		11.9	0.9	11.3	62	4.3
P-Value		<0.0119	<0.0001	<0.0001	0.0018	0.0065

Cooperator and Location: Bradley Farms, northern Glacier County.
Planted on 10/12/2017 on chem-fallow. Harvested on 9/11/2018.
Fertilizer, actual lbs/ac: 11-22.5-0 with seed at planting, 30-0-20 side shot while planting. Top dressed with 130-0-0 on 4/17/2018. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: Sprayed with Huskie @ 11 oz/ac and Axial XL at 16.4 oz/ac on 5/2/2018.
[1]** = 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. Five-year means, Winter Wheat varieties, Cut Bank area, northern Glacier County. 2014-2018.

Variety Or ID	Solid Stem Score[1]	5-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Height (inch)	Protein (%)
Keldin		83.2	60.2	29.3	12.6
Warhorse	**	76.8	59.2	29.0	12.5
Loma	**	76.3	59.5	28.5	12.4
SY Wolf		75.2	60.4	28.4	12.7
Yellowstone		73.6	59.0	32.1	12.8
Northern		72.1	59.6	30.0	12.7
Judee	**	71.2	60.3	29.8	12.8
Decade		68.3	59.2	29.1	12.8
SY Clearstone CL2		62.3	58.6	32.4	13.1
Mean		73.2	59.6	29.8	12.6

[1]** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
Cooperator and Location: Bradley Farms, Glacier County.
Conducted by MSU Western Triangle Ag. Research Center.

Table 7. Off-station Winter Wheat variety trial located near the Devon. Toole County. Western Triangle Ag. Research Center. 2018.

Variety	Solid Stem Score[1]	Yield (bu/ac)	Test Wt (lb/bu)	Height (inch)	Lodging (%)	Protein (%)
MT1642		50.2	57.8	23.3	26.6	12.6
MTS1588	**	49.2	60.2	19.2	1.2	12.3
Northern		46.7	58.9	20.9	31.8	12.6
Loma	**	45.1	58.5	20.4	10.4	12.8
MTW1491		44.6	58.3	22.6	40.0	12.5
Yellowstone		44.2	58.0	23.6	23.5	12.5
MT1563		43.8	58.5	23.3	38.6	12.3
LCS Jet		43.1	55.4	19.5	21.8	12.0
Judee	**	41.7	60.1	23.0	00.6	12.9
WB4483		41.6	58.4	20.8	13.3	13.1
FourOsix		41.3	58.4	22.3	30.0	12.3
MTCS1601		41.1	59.8	20.9	13.0	12.3
Warhorse	**	41.0	59.4	23.6	1.4	13.3
SY Clearstone 2CL		40.9	57.7	23.0	41.9	12.4
MT1265		39.9	57.7	23.8	36.7	12.9
Keldin		39.9	59.5	20.1	26.8	11.9
MT1547		39.8	58.3	24.1	40.3	12.6
MTV1681		39.2	57.4	20.2	21.8	13.0
MT1564		38.8	58.8	19.5	15.1	13.2
Decade		37.8	58.9	21.3	15.0	12.7
Ray		37.6	56.0	29.9	33.6	12.6
SY Wolf		36.9	59.6	20.0	21.4	12.8
MTF1435		36.3	57.7	28.5	29.9	12.6
SY Monument		33.9	57.0	20.7	25.0	12.6
Brawl CLP		32.5	61.5	18.5	13.0	13.4
Mean		41.1	58.5	22.1	23.4	12.7
LSD (.05)		5.0	0.8	2.6	12.8	0.7
C.V. (%)		6.6	0.8	6.6	32.7	3.1
P-Value		<0.0001	<0.0001	<0.0001	0.0183	0.5443

Cooperator and Location: Brian Akelstad, Toole County.
Planted on 9/27/2017on chem-fallow. Harvested on 8/9/2018.
Fertilizer, actual lbs/ac: 11-22-0 with seed at planting, 30-0-20 side shot while planting. Spring topdressing took place on 4/30/2018 with 130-0-0. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: Sprayed with Huskie @ 11 oz/ac and Axial XL @ 16.4 oz/ac on 5/21/2018.
[1]** = 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 8. Five-year means, Winter Wheat varieties, Devon area, Toole County, MT. 2014- 2018.

Variety Or ID	Solid Stem Score[1]	5-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Height (inch)	Protein (%)
Yellowstone		69.8	60.2	28.4	11.8
Northern		69.6	60.7	26.2	12.0
Loma	**	68.3	60.4	25.4	12.0
Keldin		68.2	61.4	26.4	11.6
Decade		66.1	60.9	26.9	11.8
SY Wolf		65.4	61.9	25.6	11.9
SY Clearstone 2CL		64.7	60.0	28.7	11.7
Judee	**	62.5	61.2	26.4	12.4
Warhorse	**	61.4	60.8	26.5	12.5
Mean		66.2	60.8	26.7	12.0

[1]** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
Cooperator and Location: Aklestad farms, Toole County.
Conducted by MSU Western Triangle Ag. Research Center.

Table 9. Off-station Winter Wheat variety trial located near the Knees. Chouteau County. Western Triangle Ag. Research Center. 2018.

Variety or ID	Solid Stem Score[1]	Yield (bu/ac)	Test Wt. (lb/bu)	Height (inch)	Lodging (%)	Protein (%)
Loma	**	67.7	58.2	23.3	35.9	13.7
MTCS1601		64.3	58.5	26.8	42.6	13.5
MTS1588	**	62.9	57.0	23.8	0.0	13.5
MT1642		62.8	55.4	27.5	57.7	13.8
Judee	**	62.3	56.8	25.3	66.8	14.3
Ray		62.3	54.3	31.3	82.4	13.3
MT1564		61.7	57.0	25.0	50.4	13.2
Brawl CLP		60.5	60.1	24.7	13.9	14.1
WB4483		60.2	56.6	23.0	37.2	14.4
Keldin		60.2	57.7	23.8	36.6	14.3
Warhorse	**	60.1	57.4	23.3	1.6	14.3
Northern		59.1	56.3	27.2	83.8	13.9
MT1563		57.3	56.9	28.0	61.3	13.2
MTW1491		56.8	56.2	27.2	78.0	13.5
SY Wolf		56.5	58.9	24.2	26.7	13.9
Yellowstone		56.5	55.1	25.7	73.6	13.7
SY Monument		56.3	55.8	23.3	45.8	12.8
SY Clearstone 2CL		55.9	55.1	28.5	80.1	13.4
MT1265		54.7	55.0	27.3	63.8	13.7
LCS Jet		54.2	53.6	20.0	77.9	13.4
FourOsix		54.0	55.5	25.0	66.4	13.6
MTF1435		53.0	55.3	33.7	75.7	13.5
Decade		52.2	57.4	23.0	45.2	14.6
MTV1681		50.7	58.0	24.3	32.0	14.1
MT1547		50.7	55.9	23.3	68.1	13.6
Mean		58.1	56.6	25.5	52.1	13.7
LSD (.05)		7.9	1.8	3.0	23.8	0.5
C.V. (%)		7.5	1.8	7.2	26.0	1.9
P-Value		0.0034	<0.0001	<0.0001	0.0001	<0.0001

Cooperator and Location: Aaron Killion, western Choteau County.
Planted on 9/28/2017 on chem-fallow. Harvested on 8/8/2018
Fertilizer, actual lbs/ac: 11-22-0 with seed at planting, 30-0-20 side shot while planting. Spring topdressing took place on 4/15/2018 with 130-0-0. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: Pre-plant sprayed with RT3 @ 40 oz/ac 9/28/2017. The plots were sprayed on 5/26/2018 with Huskie @ 11 oz/ac and Axial XL @ 16.4 oz/ac.
[1]** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
Conducted by MSU Western Triangle Ag. Research Center.

Table 10. Five-year means, Winter Wheat varieties, Knees area, Chouteau County, MT. 2014-2018.

Variety Or ID	Solid Stem Score[1]	5-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Height (inch)	Protein (%)
Keldin		84.8	60.2	29.2	11.0
SY Wolf		77.9	61.1	29.4	11.8
Yellowstone		76.8	58.4	29.9	12.3
Loma	**	76.6	58.9	30.3	12.4
SY Clearstone 2CL		75.9	58.2	31.9	12.3
Judee	**	74.6	60.3	29.4	13.0
Northern		72.4	58.7	29.6	12.7
Warhorse	**	69.7	59.5	27.8	12.8
Decade		69.5	59.7	28.6	12.8
Mean		75.4	59.4	29.6	12.3

[1]** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
Conducted by MSU Western Triangle Ag. Research Center.

Table 11. Soil test values for off-station and on-station plots, 2018.

Location	N (lbs/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	19.1	13	449	7.9	2.7	0.55
Devon	5.1	21	400	6.4	1.2	0.19
Knees	23.8	19	568	7.4	3.4	0.55
Choteau	57.8	10	556	8.1	2.7	0.75
WTARC-Var Fall	21.1	17	257	8.1	2.8	0.29
WTARC-N Fall	15.5	30	421	7.5	2.6	0.57
WTARC Spring	15.9	30	528	7.4	2.6	0.36

[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

Project Title: Winter Cereal forage cultivar evaluations for the Western Golden Triangle area of Montana

Principal Investigator: Gadi V.P. Reddy, Professor of Entomology/Ecology, John H. Miller, Research Scientist, MAES, Western Triangle Ag Research Center, Conrad, MT.

Personnel: Julie Prewett, Research Assistant, MAES, WTARC, Conrad, MT, and Pat Carr and Simon Fordyce, MSU/MAES, Central Ag. Research Center, Moccasin, MT.

Objectives: The objective is to evaluate winter cereal forage varieties under the local conditions with respect to yield, test weight, plant height, and seed protein. The research center strives to provide growers of the western triangle area unbiased information of various winter cereal forage varieties.

Methods: Plots were seeded with a four row plot seeder on one foot spacing and planted on no-till chemical fallow barley stubble. Plots were trimmed, measured for length, and then harvested with a Wintersteiger Classic plot combine. Forage samples were harvested and wet weight and dry weight were recorded. Winter wheat seed was cleaned prior to collecting data.

Results: A winter cereal forage trial was seeded the fall of 2017. Grain harvest data are presented in Table 1. Grain yields ranged from 41.7 bu/ac for T1310-219 to 55.6 bu/ac for Flex. Of the top three seed yielding varieties two were Montana State University experimental lines. Seed yield was 55.6 bu/ac for Flex, 55.6 bu/ac for MTF1432 and 53.7 bu/ac for MTF1631.

Table 2 is the soil test results from each location.

Overall, the crop year temperatures where cooler than 32 year average at the research center, May, when we could have used some cooler temperatures, was 5.2 degrees warmer than the average. But the overall average temperature for the year from September to August was 3.8 degrees cooler than the 32 year average. The winter temperature, from September to March was well below average, with February being 15.5 degrees colder than the 32 year average. March and April were 9.6 and 7.1 degrees colder than the 32 year average. May was the only month that had a temperature that was above the average with a temperature 5.2 degrees. September through March were at or above the average precipitation for those months. Then May through August were drier than the 32 year average. Overall, precipitation was average for the year with respect to the 32 year average.

The winter cereal forage plots were seeded into soil that had good soil moisture storage from the late summer and fall moisture in 2017. A warmer and dryer May and lack of summer moisture probably affected yield, test weight, and seed protein.

Summary: The data for the winter cereal forage plots are supported by the local producers and advisory committee as well as the seed industry. It is planned to continue the winter cereal variety plots at WTARC.

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 probability 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.

Table 1. 2018 Winter Cereal Forage, Western Triangle Ag Research Center, Conrad, MT.

Treatment	Head Date (Julian)	Seed Protein (%)	Lodging (%)	Test Wt (lb/bu)	Grain Yield (bu/ac)	Plant Height (inches)
Flex 719	163.3	13.5	3.5	50.7	55.6	44.5
MTF1432	168.0	13.8	67.5	58.2	55.6	33.3
MTF1631	167.8	14.2	62.5	59.9	53.7	34.3
WCF1078	163.0	13.3	5.0	53.3	53.3	50.0
MT1759	166.0	14.2	53.8	60.4	53.3	36.5
WCF1440	161.8	13.5	3.0	53.4	52.6	51.3
WCF1020	163.8	13.2	4.8	53.9	52.4	50.8
Trical 102	165.5	14.2	17.5	49.3	52.2	46.8
MTF1884	168.3	14.2	45.0	60.3	51.0	34.3
T1310-230	163.3	13.4	5.0	53.6	50.0	54.3
WCF1216	164.5	13.5	21.3	53.6	49.1	49.3
MTF1883	167.5	14.0	43.8	60.7	48.8	34.8
T1310-218	162.3	13.3	3.3	53.2	48.2	52.5
WCF1060	163.3	14.1	3.5	49.2	47.4	47.3
T1310-221	163.0	13.4	4.0	53.8	47.1	48.3
MTF1435	168.3	13.9	46.3	59.5	45.5	34.3
WCF0013	165.0	14.3	3.3	53.4	43.0	52.8
Willow Creek	173.5	15.3	77.5	58.5	42.8	48.0
T1310-219	160.5	13.6	1.8	54.1	41.7	48.3
Mean	165.2	13.8	24.8	55.2	49.6	44.8
CV%	0.9	2.0	57.7	1.8	15.4	5.7
LSD(0.05)	2.1	0.4	20.3	1.4	ns	3.6
P-Value	0.0000	0.0000	0.0000	0.0000	0.2740	0.0000

Planted: 10/9/2017 on chemical fallow Grain harvested 8/16/2018.
Fertilizer: actual pounds/ac of N-P-K: 11-22.5-0 applied with seed and 30-0-20 side shot during planting. 180 lbs N/ac as urea was broadcast on 4/27/2018. For fertilizer rates, a yield goal of 70 bu/ac was used.
Herbicide: Huskie at 11.0 oz/ac and Axial XL at 16.4 oz/ac applied 6/3/2018.
Conducted by MSU Western Triangle Ag. Research Center.

Table 2. Soil test values for off-station and on-station plots, 2018.

Location	N (lbs/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	19.1	13	449	7.9	2.7	0.55
Devon	5.1	21	400	6.4	1.2	0.19
Knees	23.8	19	568	7.4	3.4	0.55
Choteau	57.8	10	556	8.1	2.7	0.75
WTARC-Var Fall	21.1	17	257	8.1	2.8	0.29
WTARC-N Fall	15.5	30	421	7.5	2.6	0.57
WTARC Spring	15.9	30	528	7.4	2.6	0.36

[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

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.

<u>Genou</u> (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.

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

<u>Hatcher</u> (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.

<u>Jagalene</u> (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).

<u>Jerry</u> (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.

<u>Judee</u> (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.

<u>Ledger</u> (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.

<u>Loma</u> (MTS1224, MSU 2015): Is a hard red winter wheat developed by Montana Agricultural experiment station. Loma is high yielding, winter hardy winter wheat. Loma is a semi-dwarf height wheat with semi-solid stem. Providing moderate wheat stem saw fly resistance but susceptible to Russian wheat aphid. Loma is a medium to late maturing variety, with medium to high protein. Which make it acceptable for milling and baking. Loma is also resistant to stem rust and strip rust.

<u>Morgan</u> (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.

<u>MT08172</u> (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.

<u>Neeley</u> (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.

<u>Norris</u> (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.

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.

Title: Off-station spring wheat cultivar evaluations for the Western Golden Triangle area of Montana

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Personnel: John H. Miller, Research Scientist, Julie Prewett, Research Assistant, WTARC, Conrad, MT, Luther Talbert and Hwa-Young Heo, 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 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. Spring wheat seed was cleaned prior to collecting data. Wheat midge pheromone baited traps were also installed at each off station plot.

Results: Results are tabulated in Tables 1 thru 12. 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 10 are for the off station locations and Table 13 contains soil test data.

Overall, the crop year temperatures where cooler than the 32 year average at the research center. May, when we could have used some cooler temperatures, was 5.2 degrees warmer than the average. But the overall average temperature for the year from September to August was 3.8 degrees cooler than the 32 year average. The winter temperature, from September to March was well below average, with February being 15.5 degrees cooler than the 32 year average. March and April were 9.6 and 7.1 degrees cooler than the 32 year average. May was the only month that had a temperature that was above the average with a temperature 5.2 degrees. September through March were at or above the average precipitation for those months. Then May through August were drier than the 32 year average. Overall, precipitation was average for the year with respect to the 32 year average.

The spring wheat plots were seeded into soil that had good soil moisture storage from the late summer and fall moisture in 2017. Overall, the spring wheat did very well this year. Late seeding, a warmer and drier May and lack of summer moisture probably affected yield and seed protein.

The Annual Yield Trial for spring wheat yielded 7.8 bu/ac less than the five-year average. Test weight was 1.7 lbs/bu less for the 2018cropping season when compared to the five-year average. Seed protein was 0.8% higher than the five-year mean. The highest yielding varieties were Montana State University experimental varieties MT 1621, MT 1617 and MT 1770 at 85.9, 84.3, and 83.8 bu/ac (Tables 1 and 2).

Varieties with top yields for the off station irrigated spring wheat nursery were WB Gunnison, Lanning and Alum at 87.2, 86.2 and 85.2 bu/ac (Table 3). Top yielding varieties at Choteau were SY Ingmar, Brennan, and Montana State University line MT 1621. The yields of the top three varieties at Choteau were 41.8, 41.4, and 38.7 bu/ac, respectively (Table 5). Vida was the top yielder at Devon with SY Ingmar and MT 1673 the other high yielding varieties at, 45.3, 43.5 and 42.9 bu/ac (Table 9). The 'Knees' high yielders at 95.3, 87.2, and 86.7 bu/ac, were Vida, NS Presser CLP, and Montana State University line MT 1651 (Table 11). The yields at the 'Knees' were very high when compared to the five year average. The best yielding varieties, at the Cut Bank location were LCS Pro, Montana State University line MT 1525 and Vida were 56.1, 56.0 and 55.2 bu/ac (Table 7).

At Devon the 2018 yield was 3.6 bu/ac higher than the five year average; with 1/2 percent higher grain protein and a half pound higher test weight (Tables 9 and 10). The 'Knees' location had higher yields by 30 bu/ac, 1/2 percent higher grain protein and 3 lb/bu higher test weight when compared to the five year mean (Tables11 and 12). When compared to the five year averages, yields at Cut Bank were about 6 bu/ac higher in 2018, with 1/2 percent higher protein for the year, and 3.5 lb/bu higher test weights (Tables7 and 8). When comparing the five year means at Choteau, the yields were 8.3 bushels lower, seed protein was about 1 ½ percent higher and the test weights were about 0.8 lbs/bu higher (Table 5 and6).

Insignificant amount of adult Wheat 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 are 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 probability 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.

Table 1. 2018 Spring Wheat Advanced Yield Nursery, Western Triangle Ag. Research Center, Conrad, MT.

ID or Variety	Yield (bu/ac[1])	Test weight (lb/bu[1])	Heading Date Julian	Plant height (inches)	Protein %
MT 1621	85.9	59.2	174.7	30.5	15.1
MT 1617	84.3	57.9	179.3	29.7	14.2
MT 1770	83.8	57.0	179.0	29.0	15.3
MT 1748	80.1	56.0	181.7	32.5	15.4
MT 1653	80.0	56.6	174.3	31.0	15.3
MT 1732	78.8	59.5	176.3	31.4	15.2
WB 9719	77.3	60.1	179.0	28.9	14.6
NS Presser CLP	76.6	56.1	184.0	32.1	14.9
Lanning	76.3	58.2	177.7	29.2	15.3
SY Valda	76.0	58.0	176.0	30.1	14.6
MT 1750	76.0	59.9	174.7	30.4	14.8
MT 1716	75.8	58.4	175.7	29.3	14.7
MT 1775	75.5	56.1	178.0	30.6	14.3
MT 1743	74.8	56.1	178.3	29.6	15.0
MT 1766	73.6	58.8	174.0	29.1	14.1
MT 1739	73.2	59.8	175.7	30.0	14.1
Duclair	73.0	58.1	175.0	29.3	14.6
WB Gunnison	72.1	59.7	178.3	29.6	13.7
ND 828	71.9	58.6	178.7	34.0	16.4
MT 1729	71.8	58.6	175.0	28.8	15.0
MT 1736	71.8	57.5	177.7	30.6	14.8
MT 1714	71.2	59.0	175.7	29.3	14.9
Vida	71.1	56.8	177.7	28.7	14.4
MT 1719	71.1	59.9	175.0	28.8	15.0
MT 1601	71.0	57.9	178.7	30.7	15.2
MT 1711	70.4	56.1	178.0	28.8	15.0
LCS Rebel	70.1	58.3	176.0	30.0	15.2
MT 1767	69.9	56.8	176.0	27.1	14.6
SYN 183	69.3	59.2	175.7	27.6	15.0
Corbin	69.3	59.2	175.0	28.2	14.4
Reeder	69.2	57.8	177.3	30.2	15.5
MT 1451	68.7	58.2	176.7	30.0	14.5
MT 1625	68.6	58.6	175.7	29.0	15.5
SYN 181	67.7	59.4	176.0	29.2	15.4
Choteau	67.0	58.1	177.3	27.5	15.1
MT 1754	67.0	57.0	179.7	35.9	14.7
MT 1773	66.8	57.9	178.3	30.6	14.8
WB 9590	66.5	58.5	175.3	27.1	15.5

Table 1 Continued.

ID or Variety	Yield (bu/ac[1])	Test weight (lb/bu[1])	Heading Date Julian	Plant height (inches)	Protein %
MT 1742	66.0	58.2	175.3	28.4	14.6
MT 1731	65.9	56.5	174.3	29.5	14.9
WB 9879 CLP	65.8	57.2	178.7	28.5	15.7
SYN 182	65.8	56.8	177.0	25.9	14.9
SY Rockford	65.5	56.5	178.3	28.4	14.6
SY Ingmar	65.3	58.2	176.0	27.7	15.6
MT 1673	65.2	56.5	174.0	27.7	15.6
MT 1749	65.2	54.0	178.0	29.8	16.2
MT 1509	64.8	56.1	179.0	29.2	15.5
HRS 3419	64.2	53.0	182.3	28.2	16.5
WB 9653	63.7	55.7	176.3	27.0	14.2
LCS Pro	63.1	56.6	174.3	33.0	15.4
Egan	62.8	56.5	177.7	27.6	16.1
MT 1745	62.7	59.2	177.7	26.8	15.0
LCS Cannon	61.5	49.8	173.7	25.4	14.7
MT 1713	61.1	58.2	174.7	26.9	15.2
McNeal	60.3	56.9	178.0	28.3	14.8
Fortuna	60.2	58.8	178.0	31.4	14.7
MT 1734	60.0	58.9	174.7	31.2	15.6
MT 1738	60.0	56.6	184.0	31.1	15.4
MT 1756	59.6	55.9	176.7	29.5	15.0
Alum	57.4	57.7	177.7	26.9	15.0
MT 1764	56.9	57.5	177.7	28.9	16.5
Thatcher	56.5	56.2	179.7	35.2	14.9
HRS 3504	54.7	55.0	177.7	25.5	14.7
Mean	68.8	57.5	177.1	29.5	15.1
LSD (0.05)	-	3.9	2.8	3.1	0.8
C.V. (%)	14.2	4.0	1.0	6.2	3.1
P-value (Varieties)	ns	<0.005	<0.001	<0.001	<0.001

Planted: 5/4/2018 on chemical fallow spring wheat stubble and harvested on 8/23/2018.
Fertilizer: actual pounds/ac. of N-P-K: 11-22-0 applied with seed and a 200-0-20 blend of urea and potash was broadcast at planting. Fertilizer rates are based on a yield goal of 70 bu/ac.
Herbicide: Pre-plant sprayed with RT3 at 40 oz per acre on May 3, 2018. Then sprayed with 11 oz/ac Huskie and 16.4 oz/ac Axial XL on June 13, 2018.
Precipitation for growing season: 4.38 inches.
[1] Yield and test weight are adjusted to 13% seed moisture.
Conducted by MSU Western Triangle Ag. Research Center.

Table 2. 5-year Means, Advanced spring wheat varieties, Conrad, MT, 2014 - 2018.

Variety	Yield (bu/ac)	Test Wt. (lb/bu)	Head date (Julian)	Height (inch)	Protein (%)
Choteau	59.5	58.8	175.2	28.3	14.4
Corbin	65.8	60.1	173.4	29.4	14.0
Duclair	65.5	58.1	172.7	29.8	14.2
Egan	61.8	58.6	175.1	29.5	15.3
Fortuna	58.7	59.6	175.8	34.5	14.1
McNeal	65.3	58.6	177.0	30.3	14.1
Reeder	70.5	59.8	175.1	30.9	14.3
Vida	67.0	59.0	175.8	30.1	13.6
WB Gunnison	65.4	60.4	174.6	29.6	13.3
WB9879CLP	63.7	59.2	175.9	28.9	14.7
SY Ingmar	59.6	60.1	176.0	29.4	14.8
Lanning	70.6	59.1	173.7	29.4	14.7
NS Presser	73.7	57.3	178.5	31.7	13.6
Alum	67.0	59.8	176.0	28.9	13.9
Means	65.3	59.2	175.3	30.0	14.3

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. 2018.

Variety	Class	Yield (bu/ac[1])	Test Wt. (lb/bu[1])	Heading Date	Height (inch)	Protein (%)
WB Gunnison	*	87.2	60.7	192.3	27.0	15.0
Lanning	-	86.2	59.5	193.3	27.0	15.8
Alum	-	85.2	61.1	192.7	29.3	14.5
SY Ingmar	-	82.9	60.9	191.3	23.0	15.9
Choteau	**	81.0	58.7	192.0	27.7	15.9
MT1651	-	79.7	60.1	190.7	28.0	17.2
ONeal	-	79.2	61.8	191.7	25.7	15.1
NS Presser CLP	CL	78.4	59.3	196.7	29.3	16.3
MT 1621	-	74.2	60.0	189.0	28.0	16.3
Duclair	**	73.5	59.0	189.3	27.3	16.0
MT 1673	-	72.5	58.5	189.0	26.3	17.3
Egan	-	71.2	58.9	192.3	27.3	17.3
Reeder	-	70.4	60.4	193.7	29.3	15.9
Vida	*	69.7	59.1	190.7	28.7	15.2
WB9879CLP	CL	69.2	58.2	193.0	26.0	16.7
Corbin	*	66.2	59.2	191.3	24.3	16.4
LCS Pro	-	65.8	58.6	192.0	30.3	16.3
SY Soren	-	64.7	60.0	191.3	30.7	16.5
Fortuna	*	63.3	58.6	193.7	32.7	15.8
Brennan	-	58.8	58.6	190.8	25.0	17.1
Mean		74.0	59.6	191.8	27.35	16.1
LSD (.05)		9.13	0.86	1.54	3.21	0.83
C.V. 1 (%) (S/mean)*100		7.47	0.88	0.49	7.11	3.10
P-Value		0.0000	0.0000	0.0000	0.0001	0.0000

Cooperator and Location: WTARC, Pondera County.
Planted on 5/25/2018 on chemical fallow barley stubble. Harvested on 10/23/2018.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and 250-0-20 side shot while planting. Fertilizer rates are based on a yield goal of 80 bu/ac.
Herbicide: The plot area was pre-plant sprayed with 32 oz/ac RT3 5/13/2018. Sprayed with Huskie @ 11.4 oz/ac and Axial XL @ 16.4 oz/ac on 7/10/2018.
Growing season precipitation: 6.17 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
[1] Yield and test weight are adjusted to 13% seed moisture.
Conducted by MSU Western Triangle Ag. Research Center.

Table 4. 5-year means, off station irrigated spring wheat varieties, Conrad, MT, 2013-2018.

Variety	Yield (bu/ac)	Test Wt. (lb/bu)	Height (inch)	Head Date	Protein (%)
Duclair	86.2	60.9	28.6	182.8	14.7
WB Gunnison	84.3	62.4	29.9	184.7	14.3
SY Soren	72.1	61.7	31.2		14.2
WB9879CL	78.8	60.9	31.1	184.7	14.3
Choteau	78.3	60.4	30.3	184.3	14.1
Corbin	75.1	62.1	30.1	184.0	14.0
Egan	75.1	60.8	30.9	184.7	15.6
Oneal	72.5	60.4	31.4	184.9	13.9
Vida	74.8	60.8	33.3	185.0	13.9
Brennan	69.3	61.6	28.1	183.6	15.1
Reeder	73.3	62.1	33.0	185.1	13.9
Fortuna	68.6	61.4	37.6	184.9	13.3
Means	75.7	61.3	31.2	184.4	14.2

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

Table 5. Off-station spring wheat variety trial located north of Choteau, MT. Teton County. Western Triangle Ag. Research Center. 2018.

Variety	Class	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (inch)	Lodging (%)	Protein (%)
SY Ingmar	-	41.8	58.8	19.3	1.7	17.2
Brennan	-	41.4	59.6	18.7	1.0	16.3
MT 1621	-	38.7	59.1	20.0	2.0	16.5
LCS Pro	-	38.3	58.0	25.0	6.7	15.9
SY Soren	-	37.9	57.9	17.7	1.7	17.2
Corbin	-	37.4	58.9	19.0	1.7	17.0
MT 1651	-	36.4	57.4	19.0	2.0	17.6
Lanning	-	36.2	57.5	19.3	4.0	16.7
MT 1673	-	36.2	56.0	20.3	2.0	17.5
WB Gunnison	*	36.1	58.6	21.0	1.0	15.4
Egan	-	34.6	58.1	20.3	2.0	18.7
Alum	-	33.2	59.1	21.0	2.0	16.2
Oneal	-	32.3	59.2	21.0	1.7	16.8
Choteau	-	32.1	57.7	18.7	1.0	17.3
Duclair	**	31.7	55.8	20.7	1.7	16.6
Vida	*	31.6	58.5	20.7	1.7	16.8
WB9879 CLP	CL	27.2	56.4	19.7	1.7	16.9
Reeder	-	26.7	58.5	19.3	2.0	17.2
Fortuna	-	23.6	58.4	23.0	3.0	17.2
NS Presser CLP	CL	20.3	57.7	20.0	3.7	17.7
Mean		33.7	58.07	20.2	2.20	17.0
LSD (.05)		8.49	1.25	2.06	1.77	1.10
C.V. 1 (%) (S/mean)*100		15.24	1.31	6.16	48.74	3.93
P-Value		0.0003	0.0000	0.0000	0.0000	0.0007

Cooperator and Location: Inbody Farms, Teton County.
Planted on 5/30/2018 on chemical fallow durum stubble. Harvested on 9/12/2018.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and 80-0-20 side shot while planting. Fertilizer rates are based on a yield goal of 50 bu/ac.
Herbicide: Pre-plant sprayed on 5/15/2018 28 oz/ac RT3. The plots were sprayed on 6/28/2018 with Huskie at 11 oz/ac and Axial XL at 16.4 oz/ac.
** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
* = Less preferred by sawfly (behavioral preference) in small plots.
CL = Clearfield
[1] Yield and test weight are adjusted to 13% seed moisture.
Conducted by MSU Western Triangle Ag. Research Center.

Table 6. Five-year means, Spring Wheat varieties, Inbody, Teton County. 2014-2018.

Variety or ID	5-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Height (inch)	Protein (%)
Duclair	46.2	55.9	26.5	15.4
Vida	45.3	57.4	25.7	15.7
WB Gunnison	44.7	57.9	25.9	14.7
Corbin	44.2	57.6	25.4	15.7
Egan	43.3	56.8	25.3	16.6
Brennan	43.3	59.0	24.0	15.4
WB9879CLP	42.1	56.1	25.4	15.6
Choteau	41.4	56.7	25.2	15.7
SY Soren	41.4	58.2	23.3	15.7
ONeal	40.2	57.5	26.6	15.9
Reeder	40.1	57.4	25.7	15.7
NS Presser CLP	38.6	56.2	27.7	15.2
Fortuna	35.5	58.1	31.1	15.5
Mean	42.0	57.3	26.0	15.5

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

Table 7. Off-station spring wheat variety trial located at the Cut Bank, MT. Glacier County. Western Triangle Ag. Research Center. 2018.

Variety	Class	Yield (bu/ac[1])	Test Wt. (lb/bu[1])	Height (inch)	Lodging (%)	Protein (%)
LCS Pro	-	56.1	59.0	24.7	20.0	15.4
MT 1621	-	56.0	59.7	20.3	1.0	15.6
Vida	*	55.2	58.0	19.3	2.0	15.2
Brennan	-	54.4	60.0	20.0	0.0	15.3
WB Gunnison	*	54.4	59.7	18.7	0.0	14.7
Egan	-	54.0	59.2	21.3	1.0	15.9
Oneal	*	51.6	60.9	21.3	1.0	15.3
MT 1651	-	51.1	58.8	19.0	1.7	16.3
SY Soren	-	50.7	57.8	19.0	0.0	15.8
MT 1673	-	50.1	55.6	21.3	1.3	16.4
Corbin	*	49.9	58.4	19.3	0.0	15.5
SY Ingamar	-	49.9	59.2	19.0	0.3	15.5
Lanning	-	49.0	57.5	20.7	9.0	15.8
NS Presser CLP	CL	47.0	57.7	20.3	6.7	15.3
Alum	-	45.5	59.1	21.0	1.0	16.0
Choteau	-	45.2	57.0	18.7	0.0	15.6
Reeder	-	45.1	57.5	20.0	0.7	16.2
Duclair	**	43.7	56.5	22.0	2.3	15.6
Fortuna	*	42.3	58.9	25.3	1.7	15.9
WB9879CLP	CL	42.1	57.2	19.7	0.0	16.1
Mean		49.8	58.4	20.6	2.5	15.7
LSD (.05)		ns	2.37	2.18	7.38	ns
C.V. 1 (%) (S/mean)*100		14.67	1.99	6.41	179.91	3.81
P-Value		0.2145	0.0003	0.0000	0.0007	0.1334

Cooperator and Location: Kevin and Don Bradley, Glacier County.
Planted on 5/30/2018 on chemical fallow. Harvested on 10/20/2018.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and 130-0-20 side shot while planting. Fertilizer rates are based on a yield goal of 50 bu/ac.
Herbicide: The plots were sprayed by the farmer on 5/17/2018.
** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
* = Less preferred by sawfly (behavioral preference) in small plots.
CL = Clearfield
[1] Yield and test weight are adjusted to 13% seed moisture.
Conducted by MSU Western Triangle Ag. Research Center.

Table 8. Five-year means, Spring Wheat varieties, Cut Bank, Glacier County. 2014-2018.

Variety or ID	5-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Height (inch)	Protein (%)
Vida	48.9	56.3	27.5	14.2
WB Gunnison	47.8	56.1	25.3	13.9
Duclair	46.9	53.7	27.4	14.8
Brennan	45.2	57.6	24.9	15.2
Choteau	44.7	54.1	26.4	15.0
Reeder	44.3	54.2	27.3	15.3
Corbin	44.3	55.9	26.7	14.7
Egan	43.2	55.7	25.8	16.3
Oneal	42.2	54.4	27.4	14.9
WB 9879 CL	41.3	53.1	26.3	15.3
NS Presser CLP	41.0	52.3	28.1	14.2
Sy Soren	40.9	54.8	25.3	14.8
Fortuna	34.7	53.9	32.5	15.0
Mean	43.5	54.8	27.0	14.9

Table 9. Off-station spring wheat variety trial located north of Devon, MT. Toole County. Western Triangle Ag. Research Center. 2018.

Variety	Class	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Lodging (%)	Height (inch)	Protein (%)
Vida	*	45.3	58.5	1.3	24.3	13.1
SY Ingmar	-	43.5	59.6	1.0	25.0	13.9
MT 1673	-	42.9	56.9	1.0	23.7	14.2
Lanning	-	42.9	58.8	1.3	25.7	13.4
MT 1621	-	40.6	58.9	1.3	24.7	13.7
Choteau	**	40.2	58.6	0.7	23.7	14.0
NS Presser CLP	CL	39.9	58.2	5.3	25.3	13.2
SY Soren	-	39.4	58.5	1.0	23.3	14.2
MT 1651	-	39.4	59.3	1.3	23.3	13.9
Duclair	**	38.8	57.0	2.3	25.0	13.8
LCS Pro	-	38.1	59.0	1.0	26.0	13.5
Brennan	-	38.1	60.3	1.0	22.3	13.7
Corbin	*	36.5	41.4	1.3	25.0	13.5
Egan	-	36.2	57.4	2.0	24.7	15.4
Oneal	*	35.8	59.2	1.3	24.7	13.9
WB Gunnison	*	32.9	59.8	0.7	23.0	12.7
WB9879 CLP	CL	32.8	58.3	1.0	23.0	14.0
Alum	-	30.9	61.2	1.3	25.3	12.6
Fortuna	*	23.0	59.7	1.7	27.3	13.4
Reeder	-	20.7	60.3	1.0	25.0	13.2
Mean		36.9	58.0	1.5	24.5	13.7
LSD (.05)		12.2	ns	1.9	ns	0.97
C.V. 1 (%) (S/mean)*100		20.04	12.06	77.19	7.39	4.28
P-Value		0.0181	0.4691	0.0110	0.2272	0.0010

Cooperator and Location: Brian Aklestad, Toole County.
Planted on 5/22/2018 on chemical fallow. Harvested on 9/4/2018.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and 130-0-20 side shot while planting. Fertilizer rates are based on a yield goal of 50 bu/ac.
Herbicide: Pre-plant sprayed on 5/21/2018 with 28 oz/ac RT3. The plots were sprayed on 6/29/2018 with Huskie at 11 oz/ac and Axial XL at 16.4 oz/ac.
** = Solid stem sawfly-resistant (solid stem score of 19 or higher).
* = Less preferred by sawfly (behavioral preference) in small plots.
CL = Clearfield
[1] Yield and test weight are adjusted to 13% seed moisture.
Conducted by MSU Western Triangle Ag. Research Center.

Table 10. Five-year means, Spring Wheat varieties, Devon, Toole County. 2014-2018.

Variety or ID	5-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Height (inch)	Protein (%)
Vida	37.0	58.7	24.3	13.8
SY Soren	36.5	59.4	22.3	14.9
NS Presser CLP	36.2	58.3	24.6	13.7
Duclair	35.9	58.0	23.8	13.9
WB Gunnison	33.7	59.3	23.4	13.2
Reeder	33.3	59.7	24.6	14.1
Egan	32.9	57.3	24.3	15.6
Choteau	32.9	58.5	22.8	14.6
Brennan	32.4	60.0	21.9	14.8
WB9879CLP	32.0	58.7	22.2	14.6
Corbin	31.7	55.5	23.8	13.9
Oneal	31.5	59.3	23.6	14.2
Fortuna	26.7	58.6	27.2	14.5
Mean	33.3	58.6	23.8	14.3

Table 11. Off-station spring wheat variety trial located at the Knees area, Chouteau County. Western Triangle Ag. Research Center. 2018.

Variety	Class	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (inch)	Lodging (%)	Protein (%)
Vida	*	95.3	59.5	28.7	1.7	13.9
NS Presser CLP	CL	87.2	58.9	32.0	1.5	14.3
MT 1651	-	86.7	61.3	28.3	2.0	15.7
Corbin	*	86.4	61.7	27.3	2.0	13.0
Choteau	**	85.7	60.2	27.0	1.0	14.3
LCS Pro	-	83.3	61.0	31.0	2.0	14.9
Duclair	**	81.9	59.8	28.0	1.3	14.0
MT 1673	-	81.2	58.6	26.7	2.0	14.5
Lanning	*	81.1	53.1	27.3	1.7	15.2
WB Gunnison	*	76.2	61.4	26.3	1.3	13.1
ONeal	*	75.3	59.9	27.7	2.0	14.2
WB9879 CLP	CL	74.2	59.6	24.7	1.3	14.5
Reeder	-	73.6	59.0	27.0	2.0	15.2
MT 1621	-	71.2	60.5	25.7	2.0	14.9
SY Soren	-	70.8	61.3	23.7	2.0	14.4
SY Ingmar	-	70.8	61.2	24.3	2.0	14.6
Alum	-	67.5	61.8	26.3	1.7	14.1
Egan	-	66.5	59.0	26.7	3.0	15.0
Fortuna	-	62.1	59.6	33.3	5.0	14.3
Brennan	-	54.5	61.0	23.7	2.0	14.7
Mean		76.4	59.9	27.2	2.0	14.4
LSD (.05)		17.6	ns	2.3	1.1	0.7
C.V. 1 (%) (S/mean)*100		11.36	4.43	4.76	26.76	2.4
P-Value		0.0003	0.1302	0.0000	0.0000	0.0000

Cooperator and Location: Aaron and Jerry Killion, Chouteau County.
Planted on 5/15/2018 on chemical fallow. Harvested on 8/30/2018.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and 115-0-20 side shot while planting. Fertilizer rates are based on a yield goal of 50 bu/ac.
Herbicide: Pre-plant sprayed on 5/15/2018 with 40 oz/ac RT3. The plots were sprayed on 6/28/2018 with Huskie at 11 oz/ac and Axial XL at 16.4 oz/ac.
** = Solid stem sawfly-resistant (solid stem score of 19 or higher). * = Less preferred by sawfly (behavioral preference) in small plots. CL = Clearfield
[1] Yield and test weight are adjusted to 13% seed moisture.
Conducted by MSU Western Triangle Ag. Research Center.

Table 12. Five-year means, Spring Wheat varieties, Knees area, Chouteau County. 2014-2018.

Variety or ID	5-Year Mean Yield (bu/ac[1])	Test weight (lbs/bu)	Height (inch)	Protein (%)
Duclair	47.4	55.8	25.3	14.6
Vida	46.9	55.6	26.3	14.6
WB Gunnison	44.7	57.5	25.4	14.0
Choteau	44.4	56.1	24.6	14.9
NS Presser CLP	43.1	53.9	28.1	14.7
Corbin	41.2	57.0	26.4	14.4
Reeder	41.0	56.7	26.1	15.3
WB 9879 CL	40.7	55.6	25.1	14.1
Egan	40.3	55.4	25.3	16.4
SY Soren	38.8	56.3	23.8	15.7
Oneal	37.6	56.0	26.5	14.5
Brennan	36.0	57.1	24.3	15.9
Fortuna	34.9	56.9	30.6	15.6
Mean	36.8	56.8	25.5	14.9

Cooperator and Location: Aaron Killion, Chouteau County.
[1]Yields were affected by stripe and tan rust for the 2016 crop year. All varieties had some level of infection.
Conducted by MSU Western Triangle Ag. Research Center.

Table 13. Soil test values for off-station and on-station plots, 2018.

Location	N (lbs/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	19.1	13	449	7.9	2.7	0.55
Devon	5.1	21	400	6.4	1.2	0.19
Knees	23.8	19	568	7.4	3.4	0.55
Choteau	57.8	10	556	8.1	2.7	0.75
WTARC-Var Fall	21.1	17	257	8.1	2.8	0.29
WTARC-N Fall	15.5	30	421	7.5	2.6	0.57
WTARC Spring	15.9	30	528	7.4	2.6	0.36

[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

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.

WB9879CLP – WB9879CLP was derived from the cross of Choteau*3//Choteau/IMI8134 made in 2004 to be used as a Clearfield wheat. WB9879CLP is an awned semidwarf hard red spring wheat heading one and a half days later than Choteau while plant height is 30 inches the same as Choteau. WB9879CLP has solid stems similar to Choteau averaging 20-23 over two years. WB9879CLP exhibits acceptable milling and baking quality traits similar to Choteau. WB9879CLP is currently licensed exclusively toWestBred-Monsanto with PVP title V protection.

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.

Lanning (MSU, 2016): ‘Lanning’ hard red spring wheat was released by the Montana Agricultural Experiment Station due to its yield potential in dryland areas of Montana and its superior end-use quality. Lanning was derived from the cross ‘Glenn’/MT0747 by single seed descent beginning in the F2 generation. Lanning has grain yield similar to ‘Vida’ with higher grain protein and stronger gluten characteristics than Vida. Lanning is hollow-stemmed, suggesting that it will be susceptible to damage caused by the wheat stem sawfly (*Cephus cinctus* Nort.). This variety is protected under the Plant Variety Protection Act and can only be sold or advertised by variety name as a class of certified seed.

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**.

NS PRESSER CLP: ‘NS Presser CLP’ hard red spring wheat (*Triticum aestivum* L.) was developed by the Montana Agricultural Experiment Station and released in 2016 to the commercial partner Northern Seed LLC. NS Presser CLP is a two-gene Clearfield wheat intended for use with the selective imidazolinone herbicide imazamox (Beyond, BASF Corp.). NS Presser CLP was developed by a single backcross of alleles for resistance to the imidazolinone herbicide class into the recurrent parent 'Vida'. Yield trials at sites in Montana showed that NS Presser CLP has yield potential under dryland production similar to Vida. This variety is protected under the Plant Variety Protection Act and can only be sold or advertised by variety name as a class of certified seed.

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.

Title: Durum cultivar evaluations for the Western Golden Triangle area of Montana

Principal Investigator: Gadi V.P. Reddy, Professor of Entomology/Ecology, Western Triangle Ag Research Center

Personnel: John H. Miller, Research Scientist, Julie Prewett, Research Assistant, WTARC, Conrad, MT, and Mike Giroux and Andrew Hogg, MSU PSPP Dept., Bozeman, MT.

Objectives: The objective is to evaluate durum varieties under the local conditions with respect to yield, test weight, plant height, and seed protein. The research center strives to provide growers of the western triangle area unbiased information of various durum varieties.

Methods: Plots were seeded with a four row plot seeder on one foot spacing and planted on no-till chemical fallow barley stubble. Plots were trimmed, measured for length, and then harvested with a Wintersteiger Classic plot combine. Durum wheat seed was cleaned prior to collecting data.

Results: Results are tabulated in Tables 1 and 2. Table 3 is the soil test results from each location.

Overall, the crop year temperatures where cooler than 32 year average at the research center, May, when we could have used some cooler temperatures, was 5.2 degrees warmer than the average. But the overall average temperature for the year from September to August was 3.8 degrees cooler than the 32 year average. The winter temperature, from September to March was well below average, with February being 15.5 degrees colder than the 32 year average. March and April were 9.6 and 7.1 degrees colder than the 32 year average. May was the only month that had a temperature that was above the average with a temperature 5.2 degrees. September through March were at or above the average precipitation for those months. Then May through August were drier than the 32 year average. Overall, precipitation was average for the year with respect to the 32 year average.

The durum plots were seeded into soil that had good soil moisture storage from the late summer and fall moisture in 2017. Overall, the durum did well this year. Late seeding, a warmer and dryer May and lack of summer moisture probably affected test weight and seed protein.

Durum yields ranged from 76.1 to 51.2 bu/acre (Table 1). With Montana State University line MTD16006, Riveland, and MTD16007 being the top three yielding varieties at 76.1, 75.3, and 70.5 bu/ac. The 2018 yields were about 3.8 bu/ac higher than the five year average (Table 2). Test weights were 0.2 lbs/bu lighter than the long term average. Durum seed protein was 1.2 percent higher than the five year average.

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 are 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 probability 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.

Table 1. Durum Variety Trial located WTARC. Pondera County. Western Triangle Ag. Research Center. 2018.

Variety	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (inches)	Head Date	Protein (%)	Lodging (%)
MTD16006	76.1	60.1	36.0	177.7	14.6	11.7
Riveland	75.3	60.4	34.3	177.0	15.4	8.3
MTD16007	70.5	60.5	33.0	177.3	15.4	6.7
MTD112219	69.9	61.6	25.7	174.0	13.9	1.3
MTD16010	69.6	60.4	35.3	179.3	15.6	5.7
MTD16004	69.6	60.3	32.0	177.7	14.9	15.0
Fortitude	69.1	59.4	31.7	177.3	15.9	2.0
MTD16001	68.7	58.3	34.0	180.0	15.1	1.7
Grano	68.0	59.4	35.0	178.3	15.9	11.7
Alzada	67.7	59.7	30.3	174.3	14.7	5.7
Carpio	67.4	58.7	33.0	178.7	15.0	4.7
MTD16005	67.1	59.4	34.7	179.7	15.4	4.7
Dynamic	65.8	57.8	34.0	178.3	16.6	8.7
Mountrail	65.8	58.3	31.3	177.7	15.3	2.7
Alkabo	61.4	59.4	32.3	176.3	15.3	8.0
Joppa	61.0	59.3	32.3	176.7	15.2	8.0
MTD16011	60.2	57.9	34.3	178.7	16.5	5.0
Grenora	59.6	58.8	30.7	174.0	14.4	5.7
Vivid	59.6	59.3	32.7	178.3	16.5	2.3
MTD16003	59.4	59.4	32.0	177.7	14.6	4.0
Precision	57.1	59.0	33.3	177.3	17.1	3.7
MTD16002	56.7	58.7	35.7	181.3	15.8	2.0
Tioga	55.7	58.0	33.7	178.0	17.1	4.0
MTD16009	52.6	55.2	32.7	180.3	16.9	4.3
MTD16008	51.3	57.0	32.7	177.3	16.6	5.7
Divide	51.2	58.8	33.0	179.3	16.4	1.7
Mean	63.7	59.1	32.9	177.8	15.7	5.5
LSD (.05)	16.5	1.6	2.7	1.9	1.4	7.1
C.V.	15.8	1.6	5.0	0.7	5.6	79.3
P-Value	0.1279	<0.0000	<0.0000	<0.0000	0.0006	0.0425

Cooperator and Location: WTARC Pondera County.
Planted on 5/4/2018 on chemical fallow barley stubble. Harvested 8/23/2018.
Fertilizer, actual lbs/ac: 11-22-0 applied with seed and 230-0-20 side shot while planting. Fertilizer rates are based on a yield goal of 70 bu/ac.
Herbicide: The plot area was pre-plant sprayed with 40 oz/ac RT3 on 5/3/2018.
Precipitation from seeding to harvest: 4.92 inches
[1] Yield and test weight are adjusted to 13% seed moisture.
Conducted by MSU Western Triangle Ag. Research Center.

Table 2. Five-year means, dryland Durum varieties. Western Triangle Ag. Research Center Conrad, MT, Pondera County, 2012 – 2015 and 2017.

		6 year mean				
Variety	Source	Yield (bu/ac)	Test weight (lb/bu)	Height (inches)	Head[1] date	Seed Protein (%)
Alzada	ND	63.6	58.8	33.7	62.3	14.0
Alkabo	ND	61.6	59.4	33.6	64.9	14.0
Grenora	ND	61.3	58.9	33.3	64.7	14.5
Tioga	ND	58.3	59.4	27.9	65.5	15.3
Mountrail	ND	57.6	57.6	31.1	66.0	14.6
Divide	ND	56.9	59.2	32.7	64.9	14.8
Nursery Mean		59.9	58.9	32.0	64.7	14.5

[1] Days from seeding to heading.

Table 3. Soil test values for off-station and on-station plots, 2018.

Location	N (lbs/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	19.1	13	449	7.9	2.7	0.55
Devon	5.1	21	400	6.4	1.2	0.19
Knees	23.8	19	568	7.4	3.4	0.55
Choteau	57.8	10	556	8.1	2.7	0.75
WTARC-Variety Fall	21.1	17	257	8.1	2.8	0.29
WTARC-N Fall	15.5	30	421	7.5	2.6	0.57
WTARC Spring	15.9	30	528	7.4	2.6	0.36

[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

<u>Title:</u> Off-station spring barley cultivar evaluations for the Western Golden Triangle area of Montana

<u>Principal Investigator:</u> Gadi V.P. Reddy, Professor of Entomology/Ecology, Western Triangle Ag Research Center

<u>Personnel</u>: John H. Miller, Research Scientist, Julie Prewett, Research Assistant, WTARC, Conrad, MT, Jamie Sherman and Liz Elmore, MSU PSPP Dept., Bozeman, MT.

<u>Cooperators:</u> Mark Suta, East of Cut Bank, MT
Brian Aklestad, North of Devon, MT
Aaron Killion, East of Brady, MT
Inbody Farms, Northeast of Choteau, MT

<u>Objectives</u>: 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.

<u>Methods:</u> Off station barley nurseries consist of 25 entries replicated three times, seeded with a four row plot seeder on one foot spacing. On station barley nurseries consist of 49 entries replicated three times. All plots were planted on no-till chemical fallow. Plots were trimmed, measured for length, and then harvested with a Hege 140 or a Wintersteiger Classic plot combine. Spring barley seed was not cleaned prior to collecting yield data.

<u>Results</u>: Results are tabulated in Tables 1 thru 14. 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. The irrigated off-station spring barley nursery data are presented in Tables 5 and 6. Table 7 is for the Choteau location, with multi-year data presented in Table 8. Tables 11 and 12 are for the Devon location, with Table 13 and 14 representing the ‘Knees’ location. The Cut Bank data are presented in Tables 9 and 10. Table 15 is the soil test results from each location.

Overall, the crop year temperatures where cooler than the 32 year average at the research center.May, when we could have used some cooler temperatures, was 5.2 degrees warmer than the average. But the overall average temperature for the year from September to August was 3.8 degrees cooler than the 32 year average. The winter temperature, from September to March was well below average, with February being 15.5 degrees colder than the 32 year average. March and April were 9.6 and 7.1 degrees colder than the 32 year average. September through March were at or above the average precipitation for those months. Then May through August were drier than the 32 year average. Overall, precipitation was average for the year with respect to the 32 year average.

The spring barley plots were seeded into soil that had good soil moisture storage from the summer and fall 2017. Overall, the barley did not do as well as the past few years. Late seeding, a warmer, drier May and lack of summer moisture probably affected yield and seed protein.

Grain yields averaged 96.7 bu/acre for the dryland intrastate barley nursery. High yielding varieties are all Montana experimental entries: MT16M00202, MT16M01705 and MT16M01809 at 119.7, 118.1 and 117.8 bu/acre (Table 1). Seed protein was high with an average of 14.7%, this could have been caused by the dry summer. Some lines held their plumps well and other lines did not hold their plumps well (Table 1).

The irrigated intrastate barley nursery high yielding barley was a Montana experimental line, MT16M00105, with 126.3 bu/acre, followed by Hockett and MT16M06110 at 122.8 and 120.1 bu/acre. Seed protein was acceptable with an average of 12.5%, with a high of 13.6% and a low of 10.8% (Table 3).

Yields for the irrigated off station spring barley nursery, averaged 116.7 bu/ac, with Conrad, Moravian 165, and Bill Coors 100 being the top yielders at 133.0, 132.4, and 130.9 bu/ac. There was an average kernel plumpness of 97.7%, a mean protein of 12.5%, and an average test weight of 50.5 lb/bu (Table 5). Five year means for the irrigated off station nursery are tabulated in (Table 6).

Grain yields averaged 58.2 bu/acre at the Knees, 44.5 bu/ac north of Devon, 58.2 bu/ac at the Choteau site, and 52.0 bu/ac at the site east of Cut Bank. Kernel plumpness averaged 66.2 % and test weight averaged 45.5 lbs/bu at the Devon site, while kernel plumpness averaged 91.8% and test weight averaged 48.1 lbs/bu at the Knees. Choteau kernel plumpness was 80.9 % and test weight averaged 48.1 lbs/bu. The nursery at Cut Bank averaged 46.3 lb/bu, 79.0% plumps, with 12.0 % seed protein (Tables 7 thru 14).

Top yielding varieties at the Knees were Odyssey, Bill Coors 100, and Esma, yields were 70.3, 68.2, and 66.9 bu/ac. Whereas the top yielding barleys north of Devon were Lavina, Esma, and Hays yields were 51.6, 51.4 and 50.1 bu/ac. Yielding highest at the Choteau site were Odyssey, Bill Coors 100, and Esma with yields of 70.3, 68.2 and 66.9 bu/ac. High yielding varieties at Cut Bank were Hockett, 59.0 bu/ac, Hays, 58.1 bu/ac and Synergy, 57.2 bu/ac (Tables 7 thru 14).

No insect incidence (wheat stem sawfly or wireworms) was noticed in any of the barley varieties, on or off station. Insignificant amount of adult wheat 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 are unique to the western triangle area.

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 probability 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.

Table 1. Intrastate barley, malt/feed variety trial, WTARC, Conrad 2018.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Plump (%)	Thin (%)	Protein (%)	Head Date	Height (in)
MT16M00202	119.7	55.7	88.7	1.6	13.8	177.0	35.3
MT16M01705	118.1	55.3	95.0	1.5	14.0	181.0	30.7
MT16M01809	117.8	55.9	64.9	11.7	14.2	180.0	36.0
Synergy	117.6	55.2	68.0	11.4	13.6	177.0	32.0
Metcalfe	115.4	55.3	67.2	10.8	13.2	180.0	34.3
Bow	113.7	55.6	67.0	10.4	13.1	180.0	32.3
2B11-5166	111.5	54.2	70.1	11.6	13.5	179.0	33.0
Fraser	110.0	54.9	67.5	13.6	14.7	179.0	30.7
MT16M01709	109.6	14.7	87.0	4.2	14.7	178.0	31.7
Genie	107.2	52.5	40.0	34.3	15.3	179.0	33.0
MT16M00105	104.8	54.8	85.8	4.3	13.6	176.0	33.3
MT16M00707	101.3	54.0	93.6	1.7	14.5	178.0	32.6
MT16M01804	100.8	51.8	90.6	3.3	15.0	180.0	32.0
MT16M07108	99.9	52.7	77.1	7.5	14.7	181.0	32.4
MT16M06404	99.8	54.3	62.0	9.1	13.8	177.0	30.3
MT16M00305	99.7	53.5	93.0	2.0	14.6	177.0	33.7
MT16M00508	98.6	54.8	97.5	0.9	14.4	178.0	33.7
MT16M01204	98.4	52.9	97.5	0.9	14.6	180.0	31.7
MT16M00603	97.3	53.4	94.2	1.7	14.7	175.0	31.7
MT16M01106	97.3	54.2	74.8	6.9	14.4	180.0	29.6
MT16M01903	96.9	54.0	84.8	5.5	14.7	176.0	32.0
Hockett	96.1	53.8	65.6	11.8	15.0	180.0	30.0
MT16M06110	95.2	51.9	90.6	3.5	14.8	178.0	29.0
MT16M01805	94.7	49.9	85.6	5.3	15.3	181.0	32.0
MT16M01812	94.5	52.9	89.9	3.6	14.1	180.0	30.0
MT16M02107	94.4	51.0	74.5	8.6	15.7	179.0	30.0
MT16M00801	94.3	52.5	89.9	3.2	14.3	179.0	31.3
2B11-4949	94.3	51.9	45.5	30.3	14.4	175.0	30.4
MT16M02204	93.4	51.6	89.8	3.6	14.8	180.0	31.3
MT16M01904	93.3	53.6	96.7	1.2	14.7	178.0	31.7
MT16M01901	93.0	53.2	91.7	2.3	13.9	177.0	30.0
MT16M07706	92.8	52.1	74.8	8.2	14.7	177.0	29.0
MT16M06409	92.4	51.2	51.4	15.3	15.2	179.0	32.0
MT16M08601	92.0	52.2	67.6	11.4	15.7	180.0	32.0
MT16M06402	91.7	50.9	71.5	9.6	16.1	180.0	29.6
MT16M01701	91.6	54.5	81.3	5.2	14.0	176.0	31.7
MT16M00407	91.3	52.0	94.6	2.0	14.3	177.0	30.7
MT16M01409	91.2	53.6	94.2	2.3	13.8	178.0	32.0
MT16M05909	90.4	53.3	85.7	4.4	14.3	178.0	27.7
MT16M08502	89.2	53.8	44.0	22.9	15.4	178.0	30.7
MT16M00307	88.5	50.4	95.1	1.7	15.1	181.0	32.0
MT16M07806	87.3	52.5	74.9	9.1	15.3	177.0	29.0
Odyssey	87.0	52.4	69.5	9.9	15.4	183.0	31.7

Table 1. Continued

MT16M02004	80.5	51.7	92.1	2.5	14.8	180.0	28.7
MT16M02106	80.5	51.7	85.9	4.9	14.8	180.0	28.7
MT16M01801	79.9	53.0	63.8	13.1	16.3	178.0	31.0
MT16M08808	79.9	51.6	84.3	8.4	14.7	180.0	29.0
MT16M00806	76.4	50.4	76.0	8.6	15.5	183.0	29.3
Merit 57	75.3	49.5	66.3	14.0	16.3	178.0	30.0
Mean	96.7	53.0	78.8	7.8	14.7	178.0	31.3
LSD (0.05)	30.3	4.1	25.8	14.9	2.1	4.2	11.8
C.V. (s/mean)*100	19.3	4.8	20.2	96.0	9.0	1.4	9.1
P-value (0.05)							

Planted May 7, 2018 on chemical fallow barley stubble. Harvest August 22, 2018.
Fertilizer, actual (lbs/a): 11-22.5-0 place with seed at planting, 75-0-20 side shot while seeding.
Fertilizer rates are based on achieving malt grade barley.
Growing season precipitation: 4.38 inches.
Preplant sprayed with RT3 at 40 oz per acre on May 6, 2018. Then sprayed with 11 oz/ac Huskie and 16.4 oz/ac Axial XL on June 13, 2018.
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 2. 5-year Means, intrastate barley (malt/feed) varieties, WTARC, Conrad, MT, 2014-2018.

Variety	Yield bu/ac	Test Wt lb/bu	Plump %	Thin %	Protein %	Plant height	Head date
Synergy	101.6	51.5	90.5	4.5	10.8	27.7	173.7
Hockett	101.5	52.9	88.3	5.3	11.2	28.0	174.3
Genie	99.8	51.2	71.8	14.8	10.6	26.7	176.0
Odyssey	99.8	50.3	89.4	3.2	10.9	26.7	178.0
Metcalfe	93.6	51.7	86.4	6.5	11.0	28.0	175.1
Mean	99.2	51.5	85.3	6.9	10.9	27.4	175.4

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

Table 3. Irrigated Intrastate barley, malt/feed variety trial, WTARC, Conrad 2018.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Heading Date	Thin (%)	Lodging (%)	Plump (%)	Protein (%)	Plant Ht (Ins)
MT16M00105	126.3	50.7	194.7	0.4	7.3	98.6	11.5	22.7
Hockett	122.8	51.4	193.0	0.9	23.3	97.9	12.0	25.0
MT16M06110	120.1	51.4	190.7	1.0	17.3	97.5	11.6	22.0
Odyssey	119.5	51.4	194.0	0.5	8.3	98.7	11.2	23.7
MT16M01804	119.2	51.0	187.0	1.4	28.3	97.0	13.2	25.0
MT16M02004	118.6	50.2	190.7	0.4	15.0	98.9	13.6	25.0
MT16M01106	117.9	50.3	192.0	0.3	18.3	99.1	12.2	21.3
MT16M00202	117.7	50.3	189.3	0.7	33.3	98.2	12.8	24.3
MT16M01903	117.5	51.6	189.7	0.8	16.7	97.8	12.7	25.3
MT16M08502	117.1	50.6	193.0	0.5	21.7	97.8	13.2	24.0
MT16M01801	116.8	50.8	192.7	0.5	20.0	97.4	12.2	24.0
MT16M01204	115.5	50.7	189.3	1.8	21.7	95.1	11.5	21.0
MT16M00407	115.5	49.3	190.0	0.4	5.7	98.3	11.5	21.3
MT16M01904	114.9	50.1	189.3	0.4	23.3	99.0	11.3	25.3
MT16M07806	113.2	50.9	194.3	0.3	20.0	99.4	11.3	23.7
MT16M07108	113.1	51.2	190.7	0.6	16.7	98.5	13.2	21.7
2B11-4949	111.6	51.2	193.3	0.5	6.7	99.2	12.6	23.0
MT16M02107	111.4	50.5	188.7	0.6	33.3	98.3	12.0	23.3
MT16M08601	109.2	51.3	189.7	0.4	13.3	99.3	11.5	22.0
Merit 57	108.7	50.8	193.0	0.7	6.7	98.3	13.0	22.0
MT16M00801	108.6	50.8	189.3	0.4	11.7	98.8	12.2	23.7
MT16M06409	108.0	50.7	192.0	0.7	18.3	98.3	12.2	22.7
MT16M02204	107.7	50.5	192.0	2.0	8.3	98.0	13.6	22.7
MT16M01805	106.8	50.7	190.0	0.8	30.1	98.8	12.4	23.0
MT16M01705	106.6	59.9	188.7	0.9	27.3	98.2	13.2	22.0
Genie	106.0	50.5	193.7	0.9	27.3	98.1	12.0	22.0
MT16M01901	105.3	50.7	192.0	0.4	25.0	99.0	13.2	21.7
MT16M01812	105.2	50.4	189.3	0.4	5.0	99.1	12.9	21.7
MT16M01809	105.0	50.6	191.0	0.3	11.7	99.1	13.6	25.0
MT16M07706	104.9	51.2	190.3	0.6	11.7	98.5	13.2	23.3
Bow	104.8	51.1	194.7	0.3	11.7	99.1	14.7	24.0
MT16M00603	103.9	51.1	192.0	0.7	26.7	98.7	12.2	24.0
MT16M01701	103.9	50.1	190.3	0.4	18.3	99.0	12.7	23.7
MT16M08808	103.5	51.2	190.3	0.2	20.0	99.2	13.1	25.7
MT16M06404	102.6	51.5	193.7	0.4	20.7	99.2	12.0	23.0
MT16M01409	102.4	50.6	190.7	0.5	30.0	99.0	12.6	23.0
MT16M05909	101.8	50.7	190.0	0.4	20.0	99.0	12.6	24.7
Fraser	100.1	50.2	196.0	0.8	30.0	97.8	12.7	23.0
Synergy	99.9	51.1	192.7	0.7	23.3	98.6	10.8	22.0
MT16M00508	98.3	49.9	190.0	0.5	36.7	98.9	12.8	23.3
MT16M00707	97.7	49.0	191.7	0.7	5.7	98.4	12.6	21.3
MT16M00806	96.8	49.0	192.3	0.3	20.0	99.0	11.3	23.0

Table 3 continued

MT16M00307	96.0	49.6	189.0	0.5	6.7	98.5	13.0	24.0
MT16M00305	96.0	50.3	189.7	0.4	18.3	99.0	12.7	24.7
Metcalfe	94.9	49.7	194.0	0.4	23.3	98.9	13.0	22.7
MT16M02106	93.0	51.1	191.7	0.6	25.0	98.5	12.3	23.3
2B11-5166	92.8	49.0	191.3	0.4	6.7	98.9	13.2	23.0
MT16M01709	89.5	51.2	192.3	1.0	24.0	97.6	12.4	22.7
MT16M06402	89.5	49.8	191.0	0.5	14.0	98.8	12.4	23.7
Mean	107.3	50.5	191.4	0.6	18.4	98.5	12.5	23.2
LSD (0.05)	22.4	1.4	2.6	1.1	23.6	2.1	2.3	3.1
C.V.	12.9	1.7	0.9	92.7	78.9	1.3	11.2	8.2
P-value (0.05)	0.1360	0.0073	0.0000	0.2501	0.5087	0.5811	0.6490	0.2086

Planted on 5/25/2018 into chemical fallow barley stubble. Harvested on 10/2/2018.
Fertilizer, actual (lbs/a): 11-22-0 place with seed at planting, 88-0-20 side shot while planting.
Fertilizer rates are based on achieving malt grade barley.
Growing season precipitation: 6.17 inches. Irrigation = 9.9 inches
Herbicide: Pre-plant sprayed with RT3 at 32 oz/ac on 5/13/2018. The plot was sprayed with Huskie @ 11 oz/ac and 16.4 oz/ac of Axial XL on 7/10/2018.
[1] Yield and test weight are adjusted to 13% seed moisture
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 4. 2018 Irrigated Intrastate Barley 5 yr. Mean 2014-2018

	Yield	Test Wt	Plump (%)	Thin (%)	Plant Height (inches)	Protein (%)	Hd Date
Odyssey	121.2	51.1	97.6	1.0	25.8	10.7	184.4
Genie	117.5	51.9	97.2	1.2	26.9	11.2	183.9
Hockett	112.6	51.7	97.0	1.2	29.3	11.8	181.1
Synergy	106.0	50.6	97.4	1.1	30.2	11.5	183.4
Metcalfe	105.8	50.6	97.4	1.0	29.5	9.2	183.1
Mean	112.6	51.2	97.3	1.1	28.3	10.9	183.2

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

Table 5. 2018 Irrigated off station barley variety trial, Conrad, MT.

Variety	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (inch)	Head Date	Plump (%)	Thin (%)	Protein (%)	Lodging (%)
Conrad	133.0	50.4	22.0	195	96.9	0.8	12.1	6
Moravian165	132.4	50.3	23.3	194	98.2	0.4	13.1	17
Bill Coors 100	130.9	50.4	21.7	194	98.7	0.4	13.3	5
Metcalfe	129.9	50.2	23.0	194	96.4	1.4	12.4	14
Genie	129.3	50.6	24.0	196	98.1	1.1	12.4	11
Esma	128.8	50.6	22.3	193	97.7	0.8	12.7	15
Bow	125.9	50.4	22.0	196	96.8	1.4	12.9	6
Lavina	123.8	50.3	23.3	192	98.3	0.7	13.1	6
Champion	123.4	51.5	22.0	194	99.0	0.3	12.0	4
Hays	122.6	51.0	21.0	195	99.1	0.3	11.6	5
MT124069	121.9	50.3	22.0	196	95.6	1.5	12.2	12
Merit 57	120.0	51.1	23.7	194	97.7	0.6	12.5	16
Fraser	119.7	51.4	24.3	196	98.5	0.6	12.2	10
Copeland	118.4	50.1	22.0	195	97.9	0.9	12.4	3
Balster	114.0	52.0	24.7	193	98.8	1.1	12.1	7
MT124112	113.0	50.2	22.7	191	98.1	0.7	12.8	12
Hockett	112.9	50.9	23.7	193	98.4	0.6	12.5	15
Growler	112.5	51.0	25.0	195	98.9	0.4	12.3	11
Accordine	111.3	50.1	23.3	193	96.4	1.7	12.0	27
Haxby	111.2	50.9	24.7	191	98.4	0.5	12.2	15
Odyssey	110.2	50.9	23.3	197	98.5	0.7	12.1	6
Synergy	102.9	50.0	23.3	194	96.7	1.1	13.2	9
MT124071	95.5	49.9	24.0	191	98.9	0.6	12.3	7
Haybet	95.4	49.6	23.3	193	95.4	1.9	12.0	12
MT090134	77.9	49.0	23.3	188	95.2	1.6	13.0	27
Mean	116.7	50.5	23.1	194	97.7	0.9	12.5	11.0
LSD (.05)	31.7	1.4	3.5	2.5	3.4	1.2	8.0	98.6
C.V. (s/mean)*100	16.5	1.6	9.2	0.79	2.1	84.0	1.6	17.8
P-Value	0.1515	0.0518	0.8095	0.0000	0.4823	0.3125	0.9064	

Planted on 5/25/2018 into chemical fallow barley stubble. Harvested on 9/25/2018.
Fertilizer, actual (lbs/a): 11-22-0 place with seed at planting, 88-0-20 side shot while planting.
Fertilizer rates are based on achieving malt grade barley.
Growing season precipitation: 6.17 inches. Irrigation = 9.9 inches
Herbicide: Pre-plant sprayed with RT3 at 32 oz/ac on 5/13/2018. The plot was sprayed with Huskie @ 11 oz/ac and 16.4 oz/ac of Axial XL on 7/10/2018.
[1] Yield and test weight are adjusted to 13% seed moisture

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

Table 6. 5-year Means, Irrigated off station barley varieties, Conrad, MT, 2014-2018.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Plump (%)	Thin (%)	Protein (%)	Plant height (inch)	Heading date
Champion	115.1	51.5	97.1	0.8	28.7	10.1	183.8
Haxby	111.7	50.9	97.2	1.0	29.7	10.8	182.6
Metcalfe	109.9	50.2	96.5	1.3	29.5	10.8	185.1
Hockett	108.8	50.9	97.0	1.1	28.3	11.4	183.6
Mean	111.4	50.9	96.9	1.0	29.1	10.7	183.8

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

Table 7. Off-station spring barley variety trial located in the Choteau area. Teton County. Western Triangle Ag. Research Center, 2018.

Variety	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (inch)	Plump (%)	Thin (%)	Protein (%)
Odyssey	70.3	49.3	23.0	96.2	0.9	14.8
Bill Coors 100	68.2	49.0	19.6	93.0	1.6	15.2
Esma	66.9	48.4	21.7	77.4	3.7	14.6
Lavina	66.1	47.0	22.7	61.2	6.5	14.9
Moravian165	63.8	49.0	22.7	88.5	2.6	15.4
MT124112	62.7	48.4	22.3	94.4	1.5	12.7
Balster	62.3	47.8	21.3	82.5	3.9	15.4
MT124071	62.0	48.6	21.0	90.5	2.0	13.2
Growler	61.8	47.7	20.7	84.0	3.8	16.5
Champion	61.5	50.3	22.7	91.7	2.2	14.2
Haxby	61.3	50.6	21.7	78.4	4.3	15.0
Genie	60.0	47.8	19.0	54.9	10.7	15.9
Merit 57	59.7	47.7	21.0	76.3	5.6	15.7
MT124069	57.9	48.4	21.0	89.2	2.8	14.5
MT090134	57.6	49.9	24.0	97.3	0.7	12.6
Synergy	57.0	47.9	22.0	81.4	4.5	15.2
Accordine	56.5	49.2	24.0	89.4	2.0	15.3
Hays	55.8	46.5	20.0	69.5	10.7	16.4
Conrad	55.1	47.2	19.7	67.3	8.5	16.8
Copeland	52.4	47.2	20.0	84.3	4.5	16.0
Fraser	51.7	46.9	20.0	86.2	3.8	14.7
Hockett	48.9	49.1	22.0	89.4	2.6	15.9
Haybet	48.3	45.0	22.0	30.9	26.7	17.5
Metcalfe	47.5	47.9	22.0	81.1	5.2	16.5
Bow	41.3	46.9	21.7	86.4	.3.	15.1
Mean	58.2	48.1	21.5	80.9	5.0	15.2
LSD (.05)	15.1	1.4	1.9	9.4	3.8	0.9
C.V. (s/mean)*100	12.9	1.4	5.3	7.1	46.8	3.4
P-Value	0.0025	0.0000	0.0000	0.0000	0.0000	0.0000

Cooperator and Location: Inbody Farms, Teton County.
Planted: 5/30/2018 on chem-fallow. Harvested: 9/6/2018.
Fertilizer, actual lbs/a: 11-22.5-0 with seed at planting.
Herbicide: Pre-plant sprayed with RT3 at 28 oz/ac on 5/15/2018. Plot was sprayed with Huskie @ 11 oz/ac and 16.4 oz/ac of Axial XL on 6/28/2018.
[1] Yield and test weight are adjusted to 13% seed moisture
Conducted by MSU Western Triangle Ag. Research Center.

Table 8. Five-year means, Barley varieties, Choteau area, Teton County 2014-2018.

Variety Or ID	6-Year Mean					
	Yield (bu/ac)	Test weight (lbs/bu)	Plump (%)	Thins (%)	Height (inch)	Protein (%)
Champion	83.2	50.8	81.5	4.6	13.3	26.1
Haxby	78.1	50.6	79.9	8.0	13.8	25.5
Hockett	71.8	48.4	82.5	14.2	14.1	25.5
Metcalfe	69.6	48.0	80.7	7.7	14.6	25.3
Mean	75.7	49.4	81.2	8.6	13.9	25.6

Conducted by MSU Western Triangle Ag. Research Center.

Table 9. Off-station spring barley variety trial located in the Cut Bank area. Glacier County. Western Triangle Ag. Research Center, 2018.

Variety	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (inch)	Plump (%)	Thin (%)	Protein (%)
Hockett	59.0	48.4	21.0	88.2	2.3	11.4
Hays	58.1	44.2	21.7	72.9	7.9	12.8
Synergy	57.2	46.0	23.0	80.3	4.5	11.6
Odyssey	56.5	46.8	21.7	89.7	1.3	12.3
MT124112	55.1	47.6	21.7	93.9	0.8	11.1
Genie	54.4	47.0	17.0	50.0	13.0	11.1
Metcalfe	54.3	47.2	23.0	78.9	4.0	12.8
MT124071	54.0	47.3	22.0	87.8	2.6	11.2
Balster	53.6	45.5	21.3	70.9	4.5	12.1
Esma	53.6	46.1	21.3	81.9	2.3	11.7
Haxby	53.6	49.1	21.3	66.0	6.4	11.7
MT090134	53.6	49.2	21.7	95.1	0.4	11.0
MT124069	53.0	46.7	22.3	85.3	2.9	11.7
Moravian165	52.8	46.8	23.3	85.8	2.1	12.3
Champion	51.1	48.3	22.3	83.7	3.4	12.4
Fraser	51.1	44.4	21.3	85.5	3.8	12.1
Growler	50.9	45.4	22.0	78.7	5.4	11.7
Accordine	50.6	47.3	22.7	84.6	2.0	12.4
Lavina	50.6	44.6	22.3	75.7	9.4	11.5
Bill Coors 100	50.0	46.7	18.7	88.1	2.0	12.3
Merit 57	49.6	44.1	21.7	68.3	9.9	12.2
Copeland	49.0	45.1	22.3	81.9	5.0	12.4
Conrad	48.0	45.6	20.0	81.9	3.8	12.5
Bow	42.7	43.9	22.3	88.5	3.4	12.2
Haybet	38.3	44.0	23.7	31.4	14.7	12.6
Mean	52.0	46.3	21.7	79.0	4.7	12.0
LSD (.05)	5.4	0.8	1.9	14.5	2.6	1.1
C.V. (s/mean)*100	6.4	1.1	5.3	11.1	33.2	5.6
P-Value	0.0000	0.0000	0.0000	0.0000	0.0000	0.0173

Cooperator and Location: Mark Suta, Glacier County.
Planted: 6/5/2018 on chemical fallow wheat stubble. Harvested: 9/6/2018.
Fertilizer, actual lbs/ac: 11-22.5-0 with seed at planting, 48-0-20 side shot while planting.
Herbicide: Pre-plant sprayed with 20 oz/ac Roundup by the farmer. Sprayed with 2 oz/ac Sharpen on 5/29/2018.
[1] Yield and test weight are adjusted to 13% seed moisture
Conducted by MSU Western Triangle Ag. Research Center.

Table 10. Four-year means, Barley varieties, Cut Bank area, Glacier County 2015-2018.

Variety Or ID	4-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Plump (%)	Thins (%)	Height (inch)	Protein (%)
Champion	83.7	51.2	88.3	2.9	12.9	26.0
Haxby	69.5	51.7	89.6	2.7	12.7	25.8
Hockett	75.9	50.6	93.5	2.0	12.9	25.9
Metcalfe	70.5	50.0	91.5	2.4	13.4	26.1
Mean	74.9	50.9	90.7	2.5	13.0	25.9

Conducted by MSU Western Triangle Ag. Research Center.

Table 11. Off-station spring barley variety trial located in the Devon, Toole County. Western Triangle Ag. Research Center, 2018.

Variety	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (inch)	Plump (%)	Thin (%)	Protein (%)
Lavina	51.6	43.6	24.7	51.3	17.7	14.6
Esma	51.4	43.5	22.3	45.6	20.4	13.6
Hays	50.1	43.3	24.0	58.6	15.4	14.0
Accordine	48.9	46.4	23.7	75.4	6.8	13.3
MT090134	48.9	48.2	24.0	88.6	3.3	12.8
MT124112	47.0	46.2	23.0	76.7	9.3	13.2
Haxby	46.4	46.3	24.3	36.6	18.9	13.4
Champion	45.7	48.2	24.0	80.0	4.8	13.0
Odyssey	45.7	42.7	21.3	66.4	10.2	14.5
MT124069	45.5	46.4	24.0	69.8	10.0	13.4
MT124071	45.3	46.0	24.3	78.5	6.9	13.9
Growler	45.0	44.0	21.7	80.5	6.3	14.1
Conrad	44.4	52.7	20.0	71.0	8.7	15.5
Metcalfe	44.4	45.3	24.3	66.5	10.3	15.9
Fraser	43.8	44.2	19.7	79.6	5.9	14.3
Bill Coors 100	43.7	45.0	20.0	70.3	10.9	15.3
Balster	43.6	45.0	22.3	60.2	15.9	15.6
Moravian165	43.6	46.3	23.3	65.9	11.9	14.5
Synergy	42.9	45.0	21.0	72.7	9.1	14.6
Genie	41.9	45.7	19.3	41.8	26.4	15.1
Hockett	40.8	47.5	22.3	72.7	9.2	14.2
Merit 57	40.6	44.5	21.0	61.2	13.9	15.7
Copeland	37.8	43.8	20.7	71.2	8.6	16.0
Bow	37.7	46.3	24.3	89.6	3.0	14.4
Haybet	35.6	42.1	24.6	24.1	33.4	14.1
Mean	44.5	45.5	22.6	66.2	11.9	14.4
LSD (.05)	9.4	4.0	2.6	18.7	7.0	2.0
C.V. (s/mean)*100	12.8	5.4	7.0	17.2	48.5	8.5
P-Value	0.1117	0.0051	0.0001	0.0000	0.0000	0.0510

Cooperator and Location: Brian Aklestad Farms, Toole County.
Planted: 5/22/2018 on chemical fallow winter wheat stubble. Harvested: 9/4/2018.
Fertilizer, actual lbs/a: 11-22.5-0 with seed at planting, 53-0-20 side shot while planting.
Herbicide: Pre-plant sprayed with RT3 at 40 oz/ac on 5/21/2018. Plot was sprayed with Huskie @ 11 oz/ac and 16.4 oz/ac of Axial XL on 6/29/2018.
[1] Yield and test weight are adjusted to 13% seed moisture
Conducted by MSU Western Triangle Ag. Research Center.

Table 12. Five-year means, Barley varieties, Devon area, Toole County 2012, 2014-2017.

Variety Or ID	5-Year Mean					
	Yield (bu/ac)	Test weight (lbs/bu)	Plump (%)	Thins (%)	Height (inch)	Protein (%)
Champion	58.9	49.7	85.2	6.0	20.7	12.6
Haxby	49.7	48.6	68.5	12.0	21.5	13.0
Hockett	48.6	48.1	82.7	6.5	21.1	13.2
Metcalfe	44.2	47.1	82.7	6.3	21.5	13.9
Mean	50.4	48.4	79.8	7.7	21.2	13.2

Conducted by MSU Western Triangle Ag. Research Center.

Table 13. Off-station spring barley variety trial located in the Knees area. Western Chouteau County. Western Triangle Ag. Research Center. 2018.

Variety	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (inch)	Plump (%)	Thin (%)	Protein (%)	Lodging (%)
Odyssey	70.3	49.2	27.7	93.4	1.6	13.2	0
Bill Coors 100	68.2	49.0	27.0	95.7	1.4	11.6	0
Esma	66.9	48.4	27.0	70.4	7.5	12.8	0
Lavina	66.1	47.0	35.7	85.8	3.8	12.7	3
Moravian165	63.8	49.0	35.3	93.2	2.0	13.1	3
MT124112	62.7	48.4	32.0	98.6	0.4	11.3	0
Balster	62.3	47.8	32.7	88.8	3.9	13.2	0
MT124071	62.0	48.6	33.0	97.0	0.7	11.7	0
Growler	61.8	47.7	33.7	94.1	1.8	12.7	0
Champion	61.5	50.3	32.0	98.3	0.4	12.9	0
Haxby	61.3	50.6	33.0	96.9	0.9	12.1	3
Genie	60.0	47.8	28.3	77.6	8.3	13.1	0
Merit 57	59.7	47.7	33.0	94.2	1.5	11.6	0
MT124069	57.9	48.4	32.3	98.6	0.4	11.1	0
MT090134	57.3	49.9	30.3	98.6	0.4	11.1	0
Synergy	57.0	47.9	34.0	89.3	3.3	13.0	3
Accordine	56.5	49.2	29.3	87.7	2.9	12.5	0
Hays	55.8	46.5	32.7	90.7	2.9	12.5	7
Conrad	55.1	47.2	29.7	93.3	1.7	13.5	0
Copeland	52.4	47.2	36.0	95.8	1.0	13.5	13
Fraser	51.7	46.9	32.7	93.9	1.6	12.1	7
Hockett	48.9	49.1	33.0	89.7	3.2	12.6	10
Haybet	48.4	45.0	37.7	84.2	2.8	14.1	3
Metcalfe	47.5	47.9	33.7	96.5	0.8	13.0	0
Bow	41.3	46.9	33.0	91.8	2.3	13.4	3
Mean	58.2	48.1	32.2	91.8	2.3	12.6	2.3
LSD (.05)	15.1	1.4	1.9	11.5	4.7	1.0	0.8
C.V. (s/mean)*100	12.9	1.4	5.3	7.1	46.4	3.4	36.4
P-Value	0.0025	0.0000	0.0000	0.0000	0.0000	0.0000	0.6827

Cooperator and Location: Aaron Killion, western Chouteau County.
Planted: 5/15/2018 on chemical fallow winter wheat stubble. Harvested: 08/30/2018.
Fertilizer, actual lbs/a: 11-22.5-0 with seed at planting, 50-0-20 side shot while planting.
Herbicide: Sprayed with RT3 at 28 oz/ac on 5/15/2018. Plot was sprayed with Huskie @ 11 oz/ac and 16.4 oz/ac of Axial XL on 6/29/2018.
[1] Yield and test weight are adjusted to 13% seed moisture
Conducted by MSU Western Triangle Ag. Research Center.

Table 14. Six-year means, barley varieties, Knees area, Chouteau county 2012-2017.

Variety Or ID	6-Year Mean					
	Yield (bu/ac)	Test weight (lbs/bu)	Plumps (%)	Thins (%)	Height (inch)	Protein (%)
Champion	69.8	46.8	78.1	9.1	27.9	13.2
Hockett	67.9	48.3	80.5	6.8	28.4	13.3
Haxby	68.0	47.7	86.8	5.0	28.0	13.2
Metcalfe	65.5	45.5	84.6	5.0	28.3	14.1
Mean	67.8	47.6	84.6	6.5	28.1	13.5

Conducted by MSU Western Triangle Ag. Research Center.

Table 15. Soil test values for off-station and on-station plots, 2018.

Location	N (lbs/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	19.1	13	449	7.9	2.7	0.55
Devon	5.1	21	400	6.4	1.2	0.19
Knees	23.8	19	568	7.4	3.4	0.55
Choteau	57.8	10	556	8.1	2.7	0.75
WTARC-Var Fall	21.1	17	257	8.1	2.8	0.29
WTARC-N Fall	15.5	30	421	7.5	2.6	0.57
WTARC Spring	15.9	30	528	7.4	2.6	0.36

[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

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.

Project Title: Winter Pea Variety Evaluation 2017 – 2018.

Principal Investigator: John H. Miller, Research Scientist, and Gadi V.P. Reddy, Professor of Entomology/Ecology, Western Triangle Ag Research Center

Project Coordinators: George Vandemark and Rebecca McGee, USDA/ARS, Pullman, WA.

Personnel: Julie Prewett, Research Assistant, and Alysha Miller, Research Assistant, WTARC, Conrad, MT.

Objectives: The objective is to evaluate winter pea varieties under the local conditions with respect to yield, test weight, plant height, and thousand kernel weight.

Methods: Winter pea nursery consisted of 10 entries replicated four 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 harvested with a Hege 140 plot combine. Winter pea seed was cleaned prior to collecting data.

Results: Results are tabulated in Table 1.

Overall, the crop year temperatures where cooler than 32 year average at the research center, May, when we could have used some cooler temperatures, was 5.2 degrees warmer than the average. But the overall average temperature for the year from September to August was 3.8 degrees cooler than the 32 year average. The winter temperature, from September to March was well below average, with February being 15.5 degrees colder than the 32 year average. March and April were 9.6 and 7.1 degrees colder than the 32 year average. May was the only month that had a temperature that was above the average with a temperature 5.2 degrees. September through March were at or above the average precipitation for those months. Then May through August were drier than the 32 year average. Overall, precipitation was average for the year with respect to the 32 year average.

The winter pea plots were seeded into soil that had good soil moisture storage from the late summer and fall moisture in 2017.

Two varieties were not harvest for data as there was not a sufficient stand to produce data due to winter kill. Grain yields were 1572.0, 1547.1, and 1435.1 lb/ac for PS11300289, Lakota and PS12300058. With an average yield of 1267.6 lb/ac. Test weight of the winter pea averaged 65.3 lb/bu.

Summary: It is planned to continue the variety plots for the 2018 – 2019 growing season. 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 probability 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.

Table 1. 2018 Winter Pea Western Triangle Agriculture Research Center, Pondera County, Conrad, MT.

Variety	Harvest Date[1]	Yield (lb/ac)	Test Weight (lb/bu)	TKW (g)	Plant Height (inch)	Fall Stand (plants/ft²)	Spring Stand (plants/ft²)	Flower Date (Julian)
PS11300289W	II	1572.0	65.1	191.0	20.0	5.3	5.3	168.0
Lakota	I	1547.1	65.4	158.7	14.7	5.1	5.4	156.0
PS12300058W	II	1435.1	65.4	156.0	22.3	5.6	4.9	160.0
PS12300049W	II	1189.8	65.2	175.7	23.3	6.2	4.6	171.7
Pro 124-7146	II	1176.9	65.3	194.7	20.3	4.9	4.7	163.0
Koyote	I	1138.7	65.9	172.0	16.0	5.2	4.3	163.0
Chelan	II	1085.4	65.1	169.3	43.7	5.7	3.3	166.3
Windham	I	1012.1	65.2	154.7	18.0	5.8	5.0	157.3
Mean		1267.6	65.3	170.7	22.3	5.5	4.7	163.2
LSD (0.05)		479.8	2.2	17.7	7.2	2.4	3.2	5.7
C. V. (%)		17.4	1.5	4.8	18.4	25.5	39.3	1.99
P-value (Varieties)		0.0848	0.9801	0.0003	0.0000	0.9531	0.8930	0.0005

Seeding Date: 9/30/2018.
Harvest Date: I = 7/19/2018 and II = 7/24/2018.
Fertilizer (actual lbs/ac): 11-22-20. 11-22-0 was applied with the seed with 0-0-52 being side shot while planting.
Precipitation: April through August: 6.52 inches.
Herbicide: None
Insecticide: Sprayed with Sevin XLR at 1½ qt/ac on 5/8/2018.
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Title: Statewide and Western Regional Spring Pea, Lentil and Chickpea Variety Evaluation.

Principal Investigators: John H. Miller, Research Scientist, Gadi V.P. Reddy, Professor of Entomology/Ecology, Western Triangle Ag Research Center.

Project Coordinators: Statewide pulse: Chengci Chen and Yesuf Mohammed, MSU/MAES, Eastern Ag. Research Center, Sidney, MT. Western Regional pulse: George Vandemark and Rebecca McGee, USDA/ARS, Pullman, WA.

Project Personnel: Julie Prewett, Research Assistant, and Alysha Miller, Research Assistant, WTARC, Conrad, MT.

Objectives: To this end the objective is to evaluate spring pulse varieties under the local conditions with respect to yield, test weight, plant height, one thousand kernel weight and seed protein. The research center strives to provide growers of the western triangle area unbiased information of various spring pulse varieties.

Methods: Statewide and Western Regional spring pulse variety trials were seeded for the 2018 growing season. Statewide pea nursery had 35 entries replicated four times, with the Western Regional pea trial having 8 entries replicated three times. Western Regional lentil nursery had 7 entries replicated three times and the Statewide lentil trial had 17 entries replicated four times, while the Statewide chickpea trial had nine entries replicated four times and the Western Regional chickpea had six entries replicated three times. All pulse nurseries were 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.

Results: Pulse variety data are summarized in Tables 1 thru 7, with Table 8 having soil test data. Tables 1 thru 3 are pea data, with Tables 4 thru 5 representing lentil data. Table 6 and 7 are a summarization of chickpea data.

Overall, the crop year temperatures where cooler than 32 year average at the research center, May, when we could have used some cooler temperatures, was 5.2 degrees warmer than the average. But the overall average temperature for the year from September to August was 3.8 degrees cooler than the 32 year average. The winter temperature, from September to March was well below average, with February being 15.5 degrees colder than the 32 year average. March and April were 9.6 and 7.1 degrees colder than the 32 year average. May was the only month that had a temperature that was above the average with a temperature 5.2 degrees. September through March were at or above the average precipitation for those months. Then May through August were drier than the 32 year average. Overall, precipitation was average for the year with respect to the 32 year average.

The chemical fallowed soils generally had good moisture while seeding spring pulses during the spring of 2018. Overall, considering the lack of moisture and heat this past summer, the pulse crops did quite well.

Statewide yellow pea data are summarized in Table 1. Yellow pea varieties grown at WTARC yielded between 769 lb/ac for Spider and 2657 lb/ac for Pro 1336-6243. Yellow pea averaged 2147 lb/acre with an average test weight of 68.3 lb/bu and an average plant height at maturity of 61 cm (24 inches). The top three yielding yellow pea were: Pro 133-6243, Pro 093-7410 and Pro 143-6236 at 2657, 2526, and 2454 lb/ac.

Statewide green pea data are presented in Table 2. Green pea varieties grown at WTARC yielded from 1637 lb/ac for Majoret to 2431 lb/ac for Hampton. Green pea averaged 2098 lb/ac with an average test weight of 67.8 lb/bu and an average plant height at maturity of 64 cm (25.2 inches). Yielding well in the statewide trial were Hampton at 2431 lb/ac followed by PSO877MT076 and Greenwood at 2421 and 2255 lb/ac.

Western Regional (WR) pea date are summarized in Table 3. Hampton a green pea and DS Admiral a yellow pea are in the WR trial as checks. The WR nursery is made up of experimental varieties. The pea trial had a mean of 1653.9 lb/ac. Yields ranged from 1010.7 lb/ac for PS1410007to 2056.3 lb/ac for PS0810100.

Statewide Lentil data are summarized in Table 4. The lentil nursery grown at WTARC yielded between 809 lb/ac for LC9976079 and 1412 lb/ac for CDC Impala CL (Table 4). With the small green Viceroy lentil yielding the best followed by the small green Eston lentil. The lentils grew to an average mature canopy height of 29 cm (11.4 in), with an average yield of 1180 lb/ac.

Western Regional lentil data are presented in Table 5. Avondale a medium green lentil and Pardina a small brown lentil are included in the WR nursery as checks. The WR nursery is made up of experimental varieties. The lentil trial had a mean of 1663.2 lb/ac. Yields ranged from 1287.4 lb/ac for Avondale to 2099.9 lb/ac for Pardina.

Statewide Chickpea data are presented in Table 6.
Western Regional chickpea data are presented in Table 7. The WR nursery is made up of experimental varieties. The WR chickpea trial had a mean of 1782.0 lb/ac. Yields ranged from 1305.8 lb/ac for CA0790B05 to 2214.7 lb/ac for CA1390015.

Summary: A similar project will be proposed for FY 2018.

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 probability 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.

Table 1. Statewide Dry Pea Variety Evaluation. Yellow pea. Western Triangle Ag. Research Center. 2018.

Yellow pea variety/line	Yield (lb/ac)	TKW (g)	Test Wt. (lb/bu)	Plant Ht (cm)	Flowering date (DAP)[1]
Pro 133-6243	2657	254	67.88	59	56
Pro 093-7410	2526	205	68.85	62	57
Pro 143-6236	2454	207	67.95	57	56
Salamanca	2391	234	68.33	57	58
Korando	2363	241	66.98	63	56
Jetset	2312	225	68.63	64	56
Navarro	2303	253	68.05	64	57
Pro 143-6230	2298	207	66.78	62	58
Hyline	2269	219	67.70	59	57
Nette 2010	2268	218	68.60	62	57
PSO8101022	2199	234	68.88	60	57
LG Amigo	2170	204	67.88	65	57
Delta	2161	216	67.50	59	56
PSO877MT632	2152	208	68.68	62	57
PSO7100925	2148	233	68.20	57	58
PSO826MT492	2140	244	68.65	65	56
LG Sunrise	2130	225	68.78	64	56
DS Admiral	2126	218	68.18	65	56
Bridger	2085	209	68.33	62	56
Durwood	2046	221	68.75	67	58
PSO826MT460	1942	228	68.98	62	57
AAC Profit	1488	216	69.08	65	59
Spider	769	215	68.90	65	57
Mean	2147	223	68.28	61	57
P-Value	<0.001	<0.0001	0.0004	0.5901	0.0007
LSD (0.05)	398	12.6	1.03	NS	1.2
CV (%)	13.13	4.02	1.07	10.41	1.53

Seeding Date: 04/30/2018.
Harvested Date: Different based on cultivars, 07/28/2018 and 8/7/2018.
Precipitation: 4.15 inches.
Fertilizer (actual): 11-22-0 was applied with the seed with 0-0-20 being side shot while planting.
Herbicide: Pre-plant sprayed with Spartan at 3 oz/ac and RT3 at 32 oz/ac on 04/28/18.
[1]DAP = Days after planting.
Located at Western Triangle Ag. Research Center, Conrad, MT.

Table 2. Statewide Dry Pea Variety Evaluation. Green pea. Western Triangle Ag. Research Center. 2018.

Green pea variety/line	Yield (lb/ac)	TKW (g)	Test weight (lb/bu)	Plant height (cm)	Flower date (DAP)[1]
Hampton	2431	200	68.38	66	59
PSO877MT076	2421	204	67.63	61	60
Greenwood	2255	199	68.25	61	56
Banner	2249	190	67.83	60	56
Pro 131-7123	2248	178	66.48	68	59
PS0877MT457	2168	215	68.00	68	56
Pro 121-7126	2095	216	67.35	61	55
Shamrock	2061	202	69.28	67	60
Ginny	2049	201	67.30	67	57
Aragorn	1892	203	66.63	60	56
PSO826MT190	1676	207	67.63	66	58
Majoret	1637	221	68.70	69	59
Mean	2098	203	67.78	64	58
P-Value	0.0054	<0.0001	0.0003	0.2975	<0.0001
LSD (0.05)	417	9.6	2.28	NS	2.1
CV (%)		3.28		9.56	2.58

[1] DAP = Days after planting.

Seeding Date: 04/30/2018.
Harvested Date: Different based on cultivars, 07/28/2018 and 8/7/2018.
Precipitation: 4.15 inches.
Fertilizer (actual): 11-22-0 was applied with the seed with 0-0-20 being side shot while planting.
[1]DAP = Days after planting.
Herbicide: Pre-plant sprayed with Spartan at 3 oz/ac and RT3 at 32 oz/ac on 04/28/2018.
Located at Western Triangle Ag. Research Center, Conrad, MT.

Table 3. Western Regional Pea Variety Evaluation. Western Triangle Ag. Research Center. 2018.

Variety	Yield (lbs)	Test WT (lbs)	Flowering Date	Stand Count	Shatter (%)	TKW (gm)
PS0810100	2056.3	64.5	184.8	13.8	3.3	229.0
PS0810102	2050.9	62.5	180.5	13.5	14.0	232.8
PS0710092	1883.3	63.7	182.3	12.8	10.5	230.3
PS1410B00	1856.1	63.6	188.0	11.8	0.5	201.5
Hampton	1523.1	64.2	188.0	12.5	1.5	212.3
DS Admiral	1461.8	62.1	183.5	11.3	6.5	234.0
PS1514B00	1388.8	63.9	186.3	13.3	15.0	220.8
PS1410007	1010.7	63.3	182.0	14.8	48.8	232.3
Mean	1653.9	63.5	184.4	12.9	12.5	224.1
LSD(0.05)	670.4	2.0	1.5	2.9	14.3	15.8
C.V.(s/mean)*100	27.6	2.2	0.6	15.3	77.7	4.8
P-value(0.05)	0.0415	0.2389	0.0000	0.3017	0.0000	0.0024

Seeding Date: 05/08/2018
Harvest Date: 08/13/2018
Fertilizer (actual): 11-22.5-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 4.15 inches
Herbicide: Pre-plant sprayed with Roundup RT3 at 40oz/ac on 05/03/2018.
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Table 4. Statewide Lentil Variety Evaluation. Western Triangle Ag. Research Center. 2018.

Variety/lines	Yield (lb/ac)	TKW (g)	Test wt (lb/bu)	Plant ht. (cm)	Flower date
CDC Impala CL	1412	25	63.90	27	61
LC146000088R	1406	46	60.73	33	59
LC08600113P	1377	36	62.60	31	54
CDC Richlea	1326	49	60.08	29	57
LC9977116	1289	32	62.98	27	61
LC9979016	1269	31	63.48	30	63
CDC Maxim CL	1195	35	62.13	29	56
CDC Imvincible CL	1194	28	62.98	29	59
LC146000100L	1180	76	58.07	29	55
LC9977019	1128	31	62.85	29	56
WA8649090	1104	27	63.23	25	60
LC9979120	1096	27	63.45	31	65
LC99780571	1078	31	63.50	29	60
LC9978094	1075	32	63.08	32	61
Avondale	1062	48	60.10	29	55
LC99709065	1053	29	63.50	27	60
LC9976079	809	31	58.70	28	60
Mean	1180	36	62.1	29	59
P-Value	0.0001	<0.0001	<0.0001	0.0016	0.0015
LSD (0.05)	204	3.2	2.3	2.9	4.6

Seeding Date: 05/08/2018
Harvest Date: 08/14/2018
Fertilizer (actual): 11-22.5-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 4.15 inches
Herbicide: Pre-plant sprayed with Roundup RT3 at 32oz/ac, Prowl H2O at 2 qt/ac, and Sharpen at ¾ oz/ac on 04/28/18.
Western Triangle Ag. Research Center, Conrad, MT.

Table 5. Western Regional Lentil Variety Evaluation. Western Triangle Ag. Research Center. 2018.

Variety	Lentil Type	Yield[1] (lbs/ac)	Mature Canopy Height (in)	Test[1] Weight (lbs/bu)	1000 Kernel Weight (g)
Pardina	Small/ brown	2099.9	11.3	63.6	31.8
LC01602273E		1765.3	11.5	62.3	31.5
LC08600005E		1685.0	12.5	62.3	38.5
LC10600494P		1647.3	12.5	62.8	38.5
LC14600023P		1618.5	11.3	62.8	35.0
LC09600507P		1539.0	12.0	61.9	37.3
Avondale	Medium/ green	1287.4	12.3	60.8	39.5
Means		1663.2	11.9	62.4	36
$LSD_{0.05}$ (by t)		403.4	1.9	1.5	4.5
CV% (s/means)		16.3	10.5	1.6	8.4
P-Value		0.0239	0.5853	0.0357	0.0043

Seeding Date: 05/08/2018
Harvest Date: 08/14/2018
Fertilizer (actual): 11-22.5-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 4.15 inches
Herbicide: Pre-plant sprayed with Roundup RT3 at 40oz/ac on 05/03/2018.
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Table 6. Statewide Chickpea Variety Evaluation. Western Triangle Ag. Research Center. 2018.

Variety/lines	Yield (lb/ac)	Test Wt. (lbs/bu)	TKW (g)	Flowering Date (Julian)	Plant Ht. (cm)
CDC Orion	2203	58.2	439.3	176	36.2
CDC Palmer	2200	59.1	450.8	176.3	35.6
Royal	2157	57.5	548.3	179.0	47.0
Sawyer	2115	58.9	447.0	177.0	38.7
CDC Leader	2018	59.2	437.5	177.8	35.6
CDC Frontier	1925	59.2	406.0	178.5	38.1
Myles	1828	55.0	189.0	175.3	38.1
Sierra	1786	57.9	456.0	177.5	41.3
Nash	1694	57.8	520.5	180.3	40.0
Mean	1992	58.1	432.7	177.5	38.9
LSD (0.05)	290.0	0.7	84.2	2.0	3.6
C.V. (%)	10.0	0.8	13.3	0.8	6.1
P-Value	0.0059	0.0000	0.0000	0.0005	0.0000

Seeding Date: 05/03/2018
Harvest Date: 08/24/2018
Fertilizer (actual): 11-22.5-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 4.38 inches
Herbicide: Pre-plant sprayed with Roundup RT3 at 40 oz/ac on 05/3/18
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Table 7. Western Regional Chickpea Variety Evaluation. Western Triangle Ag. Research Center. 2018.

Variety	Yield (lbs)	Test WT (lbs)	Flowering Date	Stand Count	Shatter (%)	TKW (gm)
CA1390015	2214.7	61.7	182.0	8.3	18.5	432.3
CA1390012	2164.8	60.9	182.3	9.8	16.5	468.3
CA1390016	1719.1	61.1	180.0	8.5	15.3	510.5
CA0790B00	1662.2	60.8	179.8	10	17.8	506.0
CA0890B04	1414.6	60.1	180.8	7.3	16.3	561.3
CA0790B05	1305.8	60.7	180.8	8	16.0	453.7
Mean	1782.0	60.9	180.9	8.6	16.7	487.0
LSD(0.05)	687.8	1.3	1.1	2.5	2.2	44.0
C.V.(s/mean)*100	21.9	1.2	0.3	19.1	8.7	5.1
P-value(0.05)	.0646	.2133	.0003	.2084	.0596	.0002

Seeding Date: 05/08/2018
Harvest Date: 09/7/2018
Fertilizer (actual): 11-22.5-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 5.19 inches
Herbicide: Pre-plant sprayed with Roundup RT3 at 40 oz/ac on 05/03/2018.
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Table 8. Soil test values for off-station and on-station plots, 2018.

Location	N (lbs/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	19.1	13	449	7.9	2.7	0.55
Devon	5.1	21	400	6.4	1.2	0.19
Knees	23.8	19	568	7.4	3.4	0.55
Choteau	57.8	10	556	8.1	2.7	0.75
WTARC-Var Fall	21.1	17	257	8.1	2.8	0.29
WTARC-N Fall	15.5	30	421	7.5	2.6	0.57
WTARC Spring	15.9	30	528	7.4	2.6	0.36

[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

Title: Western Regional Cool Season Food Legume Evaluation.

Principal Investigators: John H. Miller, Research Scientist, Gadi V.P. Reddy, Professor of Entomology/Ecology, Western Triangle Ag Research Center

Project Coordinators: Western Regional pulse: George Vandemark and Rebecca McGee, USDA/ARS, Pullman, WA.

Project Personnel: Julie Prewett, Research Assistant, and Alysha Miller, Research Assistant, WTARC, Conrad, MT.

Objectives: To this end the objective is to evaluate spring pulse varieties under the local conditions with respect to yield, test weight, plant height, one thousand kernel weight and seed protein. The research center strives to provide growers of the western triangle area unbiased information of various spring pulse varieties.

Methods: Western Regional spring pulse variety trials were seeded for the 2018 growing season. The Western Regional pea trial had eight entries replicated three times. Western Regional lentil nursery had 7 entries replicated three times and the Western Regional chickpea had six entries replicated three times. All pulse nurseries were 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.

Results: Pulse variety data are summarized in Tables 1 thru 3, with Table 4 having soil test data. Table 1 is pea data, with Table 2 representing lentil data. Table 3 is the summarization of chickpea data.

Overall, the crop year temperatures where cooler than 32 year average at the research center, May, when we could have used some cooler temperatures, was 5.2 degrees warmer than the average. But the overall average temperature for the year from September to August was 3.8 degrees cooler than the 32 year average. The winter temperature, from September to March was well below average, with February being 15.5 degrees colder than the 32 year average. March and April were 9.6 and 7.1 degrees colder than the 32 year average. May was the only month that had a temperature that was above the average with a temperature 5.2 degrees. September through March were at or above the average precipitation for those months. Then May through August were drier than the 32 year average. Overall, precipitation was average for the year with respect to the 32 year average.

The chemical fallowed soils generally had good moisture while seeding spring pulses during the spring of 2018. Overall, considering the lack of moisture and heat this past summer, the pulse crops did quite well.

Western Regional (WR) pea date are summarized in Table 1. Hampton a green pea and DS Admiral a yellow pea are in the WR trial as checks. The WR nursery is made up of experimental varieties. The pea trial had a mean of 1653.9 lb/ac. Yields ranged from 1010.7 lb/ac for PS1410007to 2056.3 lb/ac for PS0810100.

Western Regional lentil data are presented in Table 2. Avondale a medium green lentil and Pardina a small brown lentil are included in the WR nursery as checks. The WR nursery is made up of experimental varieties. The lentil trial had a mean of 1663.2 lb/ac. Yields ranged from 1287.4 lb/ac for Avondale to 2099.9 lb/ac for Pardina.

Western Regional chickpea data are presented in Table 3. The WR nursery is made up of experimental varieties. The WR chickpea trial had a mean of 1782.0 lb/ac. Yields ranged from 1305.8 lb/ac for CA0790B05 to 2214.7 lb/ac for CA1390015.

Summary: A similar project will be proposed for FY 2018.

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 probability 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.

Funded by the US Dry Pea and Lentil council.

Table 1. Western Regional Pea Variety Evaluation. Western Triangle Ag. Research Center. 2018.

Variety	Yield (lbs/acre)	Test WT (lbs/bu)	Flowering Date	Stand Count	Shatter (%)	TKW (gm)
PS0810100	2056.3	64.5	184.8	13.8	3.3	229.0
PS0810102	2050.9	62.5	180.5	13.5	14.0	232.8
PS0710092	1883.3	63.7	182.3	12.8	10.5	230.3
PS1410B00	1856.1	63.6	188.0	11.8	0.5	201.5
Hampton	1523.1	64.2	188.0	12.5	1.5	212.3
DS Admiral	1461.8	62.1	183.5	11.3	6.5	234.0
PS1514B00	1388.8	63.9	186.3	13.3	15.0	220.8
PS1410007	1010.7	63.3	182.0	14.8	48.8	232.3
Mean	1653.9	63.5	184.4	12.9	12.5	224.1
LSD(0.05)	670.4	2.0	1.5	2.9	14.3	15.8
C.V.(s/mean)*100	27.6	2.2	0.6	15.3	77.7	4.8
P-value(0.05)	0.0415	0.2389	0.0000	0.3017	0.0000	0.0024

Seeding Date: 05/08/2018
Harvest Date: 08/13/2018
Fertilizer (actual): 11-22.5-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 4.15 inches
Herbicide: Pre-plant sprayed with Roundup RT3 at 40oz/ac on 05/03/2018.
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Table 2. Western Regional Lentil Variety Evaluation. Western Triangle Ag. Research Center. 2018.

Variety	Lentil Type	Yield[1] (lbs/ac)	Mature Canopy Height (in)	Test[1] Weight (lbs/bu)	1000 Kernel Weight (g)
Pardina	Small/ brown	2099.9	11.3	63.6	31.8
LC01602273E		1765.3	11.5	62.3	31.5
LC08600005E		1685.0	12.5	62.3	38.5
LC10600494P		1647.3	12.5	62.8	38.5
LC14600023P		1618.5	11.3	62.8	35.0
LC09600507P		1539.0	12.0	61.9	37.3
Avondale	Medium/ green	1287.4	12.3	60.8	39.5
Means		1663.2	11.9	62.4	36
$LSD_{0.05}$ (by t)		403.4	1.9	1.5	4.5
CV% (s/means)		16.3	10.5	1.6	8.4
P-Value		0.0239	0.5853	0.0357	0.0043

Seeding Date: 05/08/2018
Harvest Date: 08/14/2018
Fertilizer (actual): 11-22.5-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 4.15 inches
Herbicide: Pre-plant sprayed with Roundup RT3 at 40oz/ac on 05/03/2018.
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Table 3. Western Regional Chickpea Variety Evaluation. Western Triangle Ag. Research Center. 2018.

Variety	Yield (lbs/acre)	Test Wt (lbs/bu)	Flowering Date	Stand Count	Shatter (%)	TKW (gm)
CA1390015	2214.7	61.7	182.0	8.3	18.5	432.3
CA1390012	2164.8	60.9	182.3	9.8	16.5	468.3
CA1390016	1719.1	61.1	180.0	8.5	15.3	510.5
CA0790B00	1662.2	60.8	179.8	10	17.8	506.0
CA0890B04	1414.6	60.1	180.8	7.3	16.3	561.3
CA0790B05	1305.8	60.7	180.8	8	16.0	453.7
Mean	1782.0	60.9	180.9	8.6	16.7	487.0
LSD(0.05)	687.8	1.3	1.1	2.5	2.2	44.0
C.V.(s/mean)*100	21.9	1.2	0.3	19.1	8.7	5.1
P-value(0.05)	0.0646	0.2133	0.0003	0.2084	0.0596	0.0002

Seeding Date: 05/08/2018
Harvest Date: 09/7/2018
Fertilizer (actual): 11-22.5-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 5.19 inches
Herbicide: Pre-plant sprayed with Roundup RT3 at 40 oz/ac on 05/03/2018.
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Table 4. Soil test values for off-station and on-station plots, 2018.

Location	N (lbs/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	19.1	13	449	7.9	2.7	0.55
Devon	5.1	21	400	6.4	1.2	0.19
Knees	23.8	19	568	7.4	3.4	0.55
Choteau	57.8	10	556	8.1	2.7	0.75
WTARC-Var Fall	21.1	17	257	8.1	2.8	0.29
WTARC-N Fall	15.5	30	421	7.5	2.6	0.57
WTARC Spring	15.9	30	528	7.4	2.6	0.36

[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

<u>Project Title</u>: Canola variety evaluations at Western Triangle Ag. Research Center.

<u>Principal Investigators</u>: John H. Miller, Research Scientist and Gadi V.P. Reddy, Professor of Entomology/Ecology, Western Triangle Ag Research Center.

<u>Personnel</u>: Julie Prewett, Research Assistant and Alysha Miller, Research Assistant, WTARC, Conrad, MT, and Simon Fordyce and Pat Carr, MSU/MAES, Central Ag. Research Center, Moccasin, MT.

<u>Objectives</u>: To evaluate canola varieties grown at Western Triangle Ag. Research Center.

<u>Methods</u>: All plots were planted into no-till chemical fallow barley stubble using a 4-row plot drill with spacing set to one foot. Plots were trimmed, measured for length, and then harvested with a Wintersteiger Classic plot combine. Canola seed was cleaned prior to collecting data.

<u>Results</u>: The canola nursery averaged 24.5 bu/ac (Table 1). Test weight averaged 48.9 lbs/bu with mean seed oil content of 44.7%. There was no lodging or shatter to report in the canola nurseries. Highest yields in lb/ac were HyClass 730 having 1656.2, HyClass 930 at 1573.3, DKL70-10R with 1569.5, 4187 RR at 1569.4, and HyClass 955 in the amount of 1530.5, respectfully. Table 2 are the soil test results for the 2018 cropping year.

Overall, the crop year temperatures where cooler than 32 year average at the research center, May, when we could have used some cooler temperatures, was 5.2 degrees warmer than the average. But the overall average temperature for the year from September to August was 3.8 degrees cooler than the 32 year average. The winter temperature, from September to March was well below average, with February being 15.5 degrees colder than the 32 year average. March and April were 9.6 and 7.1 degrees colder than the 32 year average. May was the only month that had a temperature that was above the average with a temperature 5.2 degrees. September through March were at or above the average precipitation for those months. Then May through August were drier than the 32 year average. Overall, precipitation was average for the year with respect to the 32 year average.

The spring canola plots were seeded into soil that had good soil moisture storage from the summer, fall and winter of 2016-17.

A similar project will be proposed for FY 2018. 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. 2018.

Variety	Herbicide System	Seed Yield[1] (lb/ac)	Test Weight[1] (lb/bu)	Seed Oil (%)	Flowering Date (Julian)	Plant Height (in)
HyClass 730	RR	1656.2	48.7	46.8	176.3	37.0
HyClass 930	RR	1573.3	49.0	45.5	175.0	36.8
DKL70-10R	RR	1569.5	49.3	44.6	176.0	38.3
4187 RR	RR	1569.4	49.0	45.4	180.3	42.5
HyClass 955	RR	1530.5	49.0	46.4	175.8	37.0
6074 RR	RR	1460.9	48.5	44.2	178.5	42.8
5545 CL	CL	1457.9	49.8	44.3	176.3	42.0
DKL35-23R	RR	1395.2	48.7	43.8	176.5	35.5
11H4030	RR	1333.7	49.0	44.1	175.5	31.3
C5507	SU	1332.9	48.1	46.8	176.8	44.0
6090 RR	RR	1304.4	48.6	42.8	177.3	47.5
Exp201801		1271.1	48.4	44.6	178.5	40.0
InVigor L140P	LL	1258.8	49.4	43.1	178.5	41.3
InVigor L233P	LL	1140.0	48.8	44.0	176.5	39.8
Exp201803		982.2	48.7	44.4	175.8	42.3
Mean		1389.1	48.9	44.7	176.9	39.9
LSD (α = 0.05)		219.9	0.7	2.0	2.5	3.2
CV (%)		11.1	1.0	3.1	1.0	5.6
P-value (0.05)		0.0000	0.0012	0.0021	0.0054	0.0000

RR: Roundup ready, LL: Liberty link, SU: sulfonylurea, CL: Clearfield
Grain yield and test weight is adjusted to a uniform moisture content of 8%.
Grain protein, grain oil, and oil yield are reported on a dry matter basis.
Seeding date: 5/1/18 Swathed: 8/14/18 Thrashed: 8/21/18
Fertilizer (actual lb/ac): 120-20-20-20
Post-plant sprayed 2 days after seeding with Roundup RT3 at 40 oz/ac on 5/3 /2018.
Previous crop: Chemical fallow barley stubble.
Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Table 2. Soil test values for off-station and on-station plots, 2018.

Location	N (lbs/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	19.1	13	449	7.9	2.7	0.55
Devon	5.1	21	400	6.4	1.2	0.19
Knees	23.8	19	568	7.4	3.4	0.55
Choteau	57.8	10	556	8.1	2.7	0.75
WTARC-Var Fall	21.1	17	257	8.1	2.8	0.29
WTARC-N Fall	15.5	30	421	7.5	2.6	0.57
WTARC Spring	15.9	30	528	7.4	2.6	0.36

[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

Agronomy and Soil Nutrient Management Program

Low Energy Sprinkler Application Effect on Montana Malt Barley

Principal investigator: Gadi V.P. Reddy, Professor of Entomology/Ecology

Personnel: John Miller, Research Scientist, Western Triangle Agricultural Research Center, Montana State University**.**

Background

Barley has been grown in North America over the years as a forage crop, feed crop and malt crop adapting to dry land and irrigated ecosystems, and it works well in rotation with sugar beets serving as a valuable source of malt in Montana. In spite of vast variation in response of barley varieties to soil types, rainfall, nutrient content and other environmental factors, Montana is second in barley production, producing 22% of the U.S. barley, with an average yield of 60 bu/ac. (USDA, 2015).

Providing water requirements by choosing acceptable irrigation methods to have the proper moisture distribution, leads to maximized grain yield, malt quality and decreases weed growth and disease. Depending on the irrigation method, optimum yield that might be expected to happen when available soil moisture (ASM) is to retain above 50% of ASM. The center pivot system is a dominant irrigation method in Montana barley fields, and was designed to conserve water. The pivot should be correctly installed and managed to achieve high water conservation. It has been reported that a pivot system is the most common irrigation method in Montana, and applies water in a uniform distribution and efficient manner, but is not the best method to keep the soil moisture at proper levels during the barley reproductive period (Rogers et al., 2008).

Water limitation or inappropriate distribution leads to abundant morpho-physiological and biochemical changes in plants. There are not too many studies on plant physiology responses to using different irrigation methods in terms of seed quality, yield and water conservation. Therefore, the present study aim to investigate on:

- Compare Low Energy Sprinkler Application (LESA) irrigation system with regular or traditional irrigation method in one barley field.
- Study the effect of irrigation methods on dry matter pattern and leaf area during the season.
- Compare the differences in yield components, plant height and physiological traits related to yield under different irrigation application methods.

Material and methods

In order to test LESA methods and compare their effect on malt barley in Montana, experiments were conducted in three different locations, Fairfield, Conrad and Valier, to evaluate some phenological events, agronomic traits and physiological responses under center pivot system with a single drop tube (Regular), 2-drop tubes sprinklers with and 3-drop tubes for LESA pressure reducers and spreader plates. The two and three drop tubes were installed at the outlet for the single drop tube, the multiple drop tubes were split off the single outlet to create two or three drop tubes.

Two data loggers and eight soil moisture sensors were installed at Conrad and Valier locations and three data loggers and 12 soil moisture sensors were installed and the Fairfield location. The soil moisture sensors were installed at four depths including, 24 inch, 18 inch, 12 inch and 6 inch below the soil surface after planting and removed from the fields when the plots were harvested. Soil moisture probes and data loggers were installed as soon after seeding as practical, they were installed at the Conrad location on June 8th, 2018, Fairfield location on June 12th and the Valier location on June 11th. Soil moisture samples were taken at harvest time, to a depth of two feet. Samples were broken into six-inch increments for all depths. Water usage was measured throughout the cropping season to see if there is a difference in efficiency between the irrigation methods.

Seeds were planted on April 27th in Fairfield, April 30thin Valier and May 15thin Conrad, at the rate of 110 lb/ac. Nitrogen fertilizer was applied as Urea at 120 lb/ac while seeding. Plant sampling plots were along both sides of field transects in parallel with installed soil sensors. Plot size was measured at 5 ft x 20 ft. Row spacing was considered about 7.5 inches.

For measuring leaf area index, leaf area meter (LAI C2200) was used to record plants leaf area at intervals of seven days between tillering and physiological maturity stage, during the time period of 10 a.m. to 2 p.m.

Plant samples were cut at ground level, oven dried at 70˚C for 72 hours to reach constant weight. Biomass dry weight was recorded.

In addition, grain yield, test weight, seed protein, plump and thin kernels were collected after harvest. Plant height was measured using a ruler. A Wintersteiger Classic plot combine was used to collect harvest data for each sampling block along the transect.

After harvesting, kernel plumpness was assessed by sieving over a 6/64” slotted screen. Grain protein content and test weight were obtained at Western Triangle Agricultural Research Center, Conrad using the Near-Infrared Inframatic 9500 SW- Whole Grain Analyzer (Perten).

Statistical Analysis

Data were analyzed using CoStat Ver 6.400, CoHort Software and graphed using CoPlot Ver 6.400.

Results

Due to plant material getting over the rain gauges, the precipitation and irrigation water amounts are unreliable. With that said, Fairfield regular received 10.8 inches, 2 drop (2D) LESA system received 8.4 inches and 3 drop (3D) collected 10.2 inches. At the Valier location there was the most trouble with plants interfering with water collection. Valier 2D had 2.2 inches and the 3D was 2.6 inches, with the Conrad location receiving 4.3 inches for the 2D treatment and 4.1 inches for the 3D irrigation system.

Plant dry matter accumulation increased by leaf number and tiller development until anthesis, and then started to decline as the plant began to ripen, with a noted increase just before harvest at each location (Figure 1 thru 3). The greatest accumulation of plant was under the 2D LESA system of irrigation with the least accumulation under the 3D system.

Maximum leaf area index (LAI) did not respond significantly to irrigation methods. But the slightly higher LAI across sites under the 2D LESA system. In general the greater the LAI is an indication of higher yields. Conrad and Fairfield locations had LAI’s greater than 4 and had better yields than the Valier location where the LAI did not 3.5 (Figures 5 thru 7).

Maximum of grain protein content was observed in Fairfield (13.7 % under 2-Drops sprinkler system). Results showed grain protein content under three-Drops sprinkler systems was higher compared to 2D LESA irrigation method in Conrad and Valier location while in Fairfield grain protein content respond to 2D LESA irrigation method more than other methods (Table 1).

In Fairfield location, maximum and minimum grain yield were gained from One drop (1D) sprinkler system, 2D LESA sprinkler methods with123.2 bu/ac, and 118.2 bu/ac, there was no significant difference between using Regular and LESA methods. In Valier location, maximum grain yield was observed in 2D sprinkler system (78.7 bu/ac) and at the Conrad location; 2D LESA center pivot system with 141.9 bu/ac had the maximum grain yield when compared to 3D LESA irrigation system (Table 1).

In general results show that irrigation methods of application did not have any significant effect on plant height, plumpness and thin.

Table 1 demonstrates that Conrad with 136 bu/ac had the maximum grain yield while minimum grain yield was obtained from Valier (93 bu/ac). Late planting dates may explain the variation in grain yield at the different sites. These variations are reflected by the effects of environmental parameters; such as temperature, rainfall pattern and soil characteristics on plant performance.

Table 1 shows the average of barley yield response to different irrigation application methods. However, 2D LESA sprinkler to have the better yields at the Conrad location with a yield of 141.9 bu/ac and 80.3 bu/ac at the Valier location, the exception was Fairfield with a yield of 118.2 bu/ac/. There was no significant yield difference between regular center pivot method and LESA application. Espinoza et al. (2004) well documented water pressure, nozzle height, and uniformity of sprinkler method, affect water productivity by indicating better distribution and water proportion. Without a proper uniform water release, and water use efficiency, grain yield will be significantly reduced.

Recommendation

Sprinkler height affects the wetted area, water distribution and water productivity especially in windy areas like Montana’s Western Golden Triangle region. Wind velocity also influenced water distribution and uniformity, once released from sprinkler irrigation systems. In the present study for most of parameters, there were no significant difference in using regular center pivot system and LESA application. Even though there are no significant differences in the grain data it appears that the 2D LESA irrigation system is equal to 1D and 3D irrigation methods. If a producer desires to make the change from regular pivot irrigation to the LESA irrigation system they should consider the 2D system over the 3D system. There are other factors to consider when changing the irrigation systems to LESA, such as lodging and keeping the barley heads dry to help with the prevention of disease.

Nozzle size, height and drop numbers to meet plants water requirements might increase regular pivot system efficiency. Testing different varieties of barley, various crops, using precision application based on crop needs and soil profile in consecutive multi location experiments would deliver scientists and farmers a better understanding of water- plant -soil relationships. In addition, assessing the effect of different water regimes on saved water amount and plant response would be useful.

Acknowledgment

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References

Espinoza, B., J. C. E. P. Velez, J. C. Morales and B. R. Martinez. 2004. Impact of pressurized irrigation systems performance on productivity of eight crops, in Guanajuato, Mexico. Agrociencia-Montecillo 38(5): 477-486.

Rogers, D.H., M. Alam, and L.K. Shaw. 2008. Considerations for Sprinkler Packages on Center Pivots. Kansas State, Research and Extension. Irrigation Management Series. L-908 rev.

USDA. 2015. United State Department of Agriculture, Natural Agricultural Statistic Service, Montana Annual Crop Summary 2014.

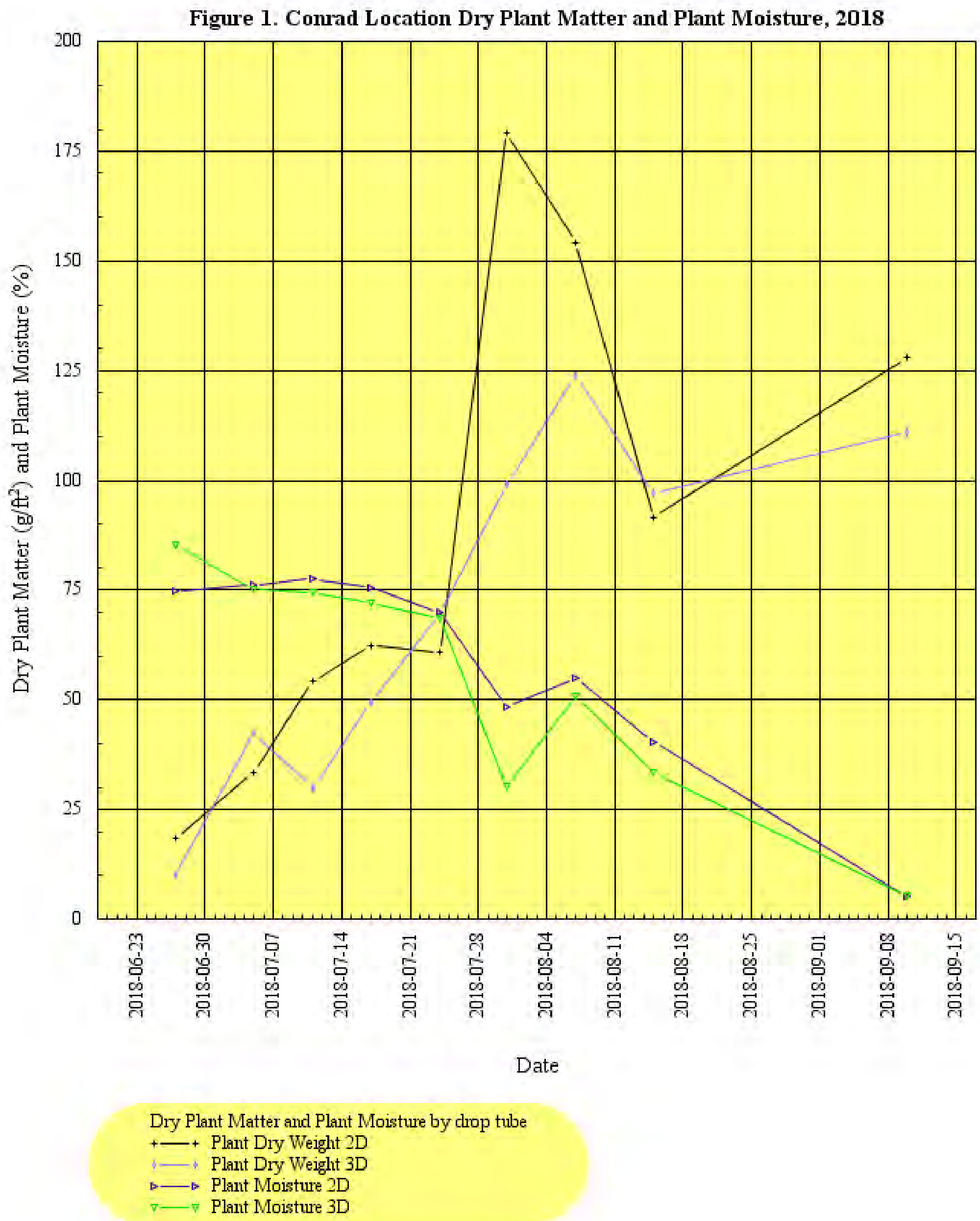


Figure 1. Conrad Location Dry Plant Matter and Plant Moisture, 2018
200
175
150
125
100
75
50
25
0
Dry Plant Matter (g/ft²) and Plant Moisture (%)
2018-06-23
2018-06-30
2018-07-07
2018-07-14
2018-07-21
2018-07-28
2018-08-04
2018-08-11
2018-08-18
2018-08-25
2018-09-01
2018-09-08
2018-09-15
Date
Dry Plant Matter and Plant Moisture by drop tube
Plant Dry Weight 2D
Plant Dry Weight 3D
Plant Moisture 2D
Plant Moisture 3D

Figure 2. Fairfield Location Dry Plant Matter and Plant Moisture, 2018

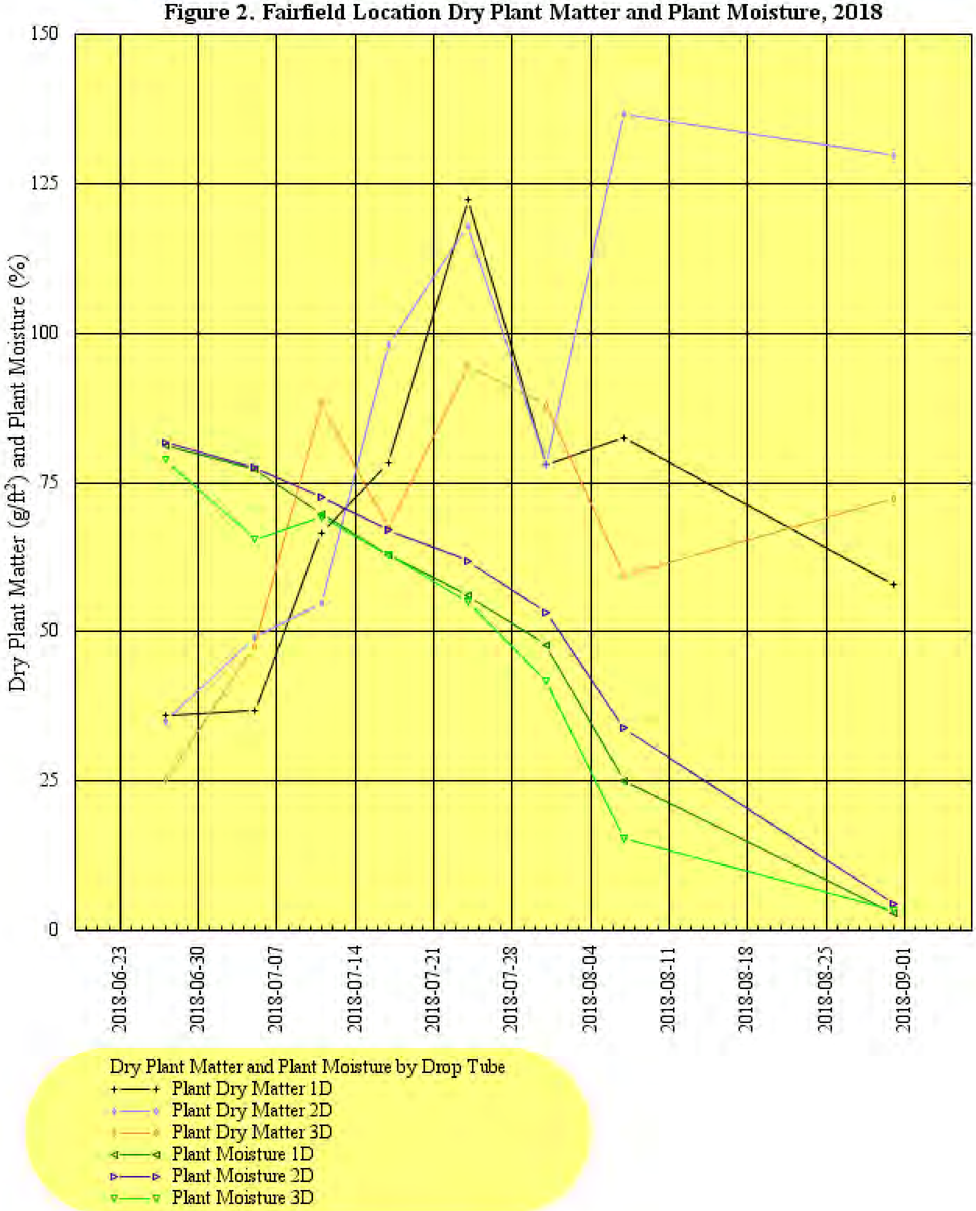


Figure 3. Valier Location Plant Dry Matter and Plant Moisture, 2018

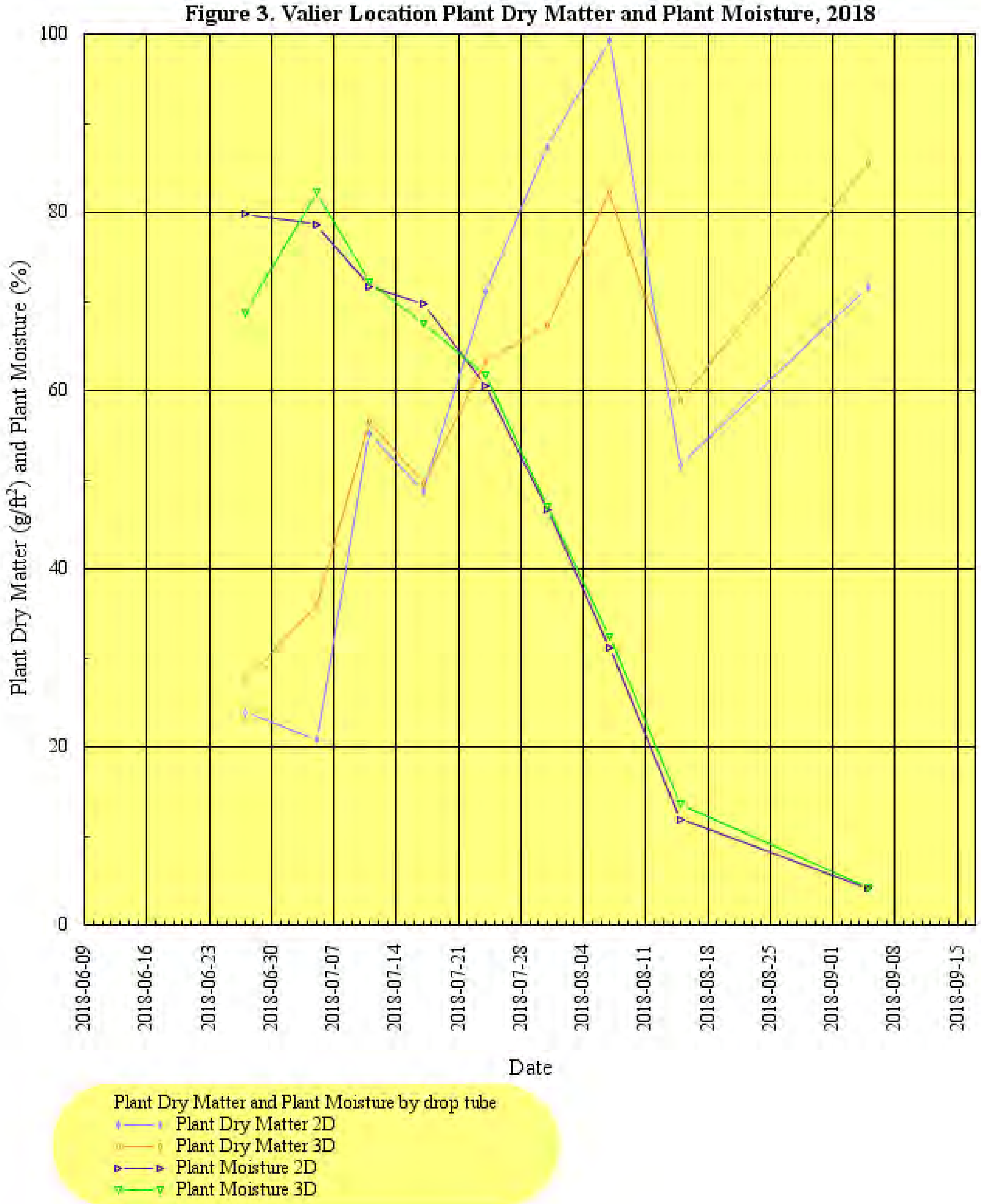


Figure 4. Conrad Location Leaf Area Index for 2 drop and 3 drop LESA, 2018

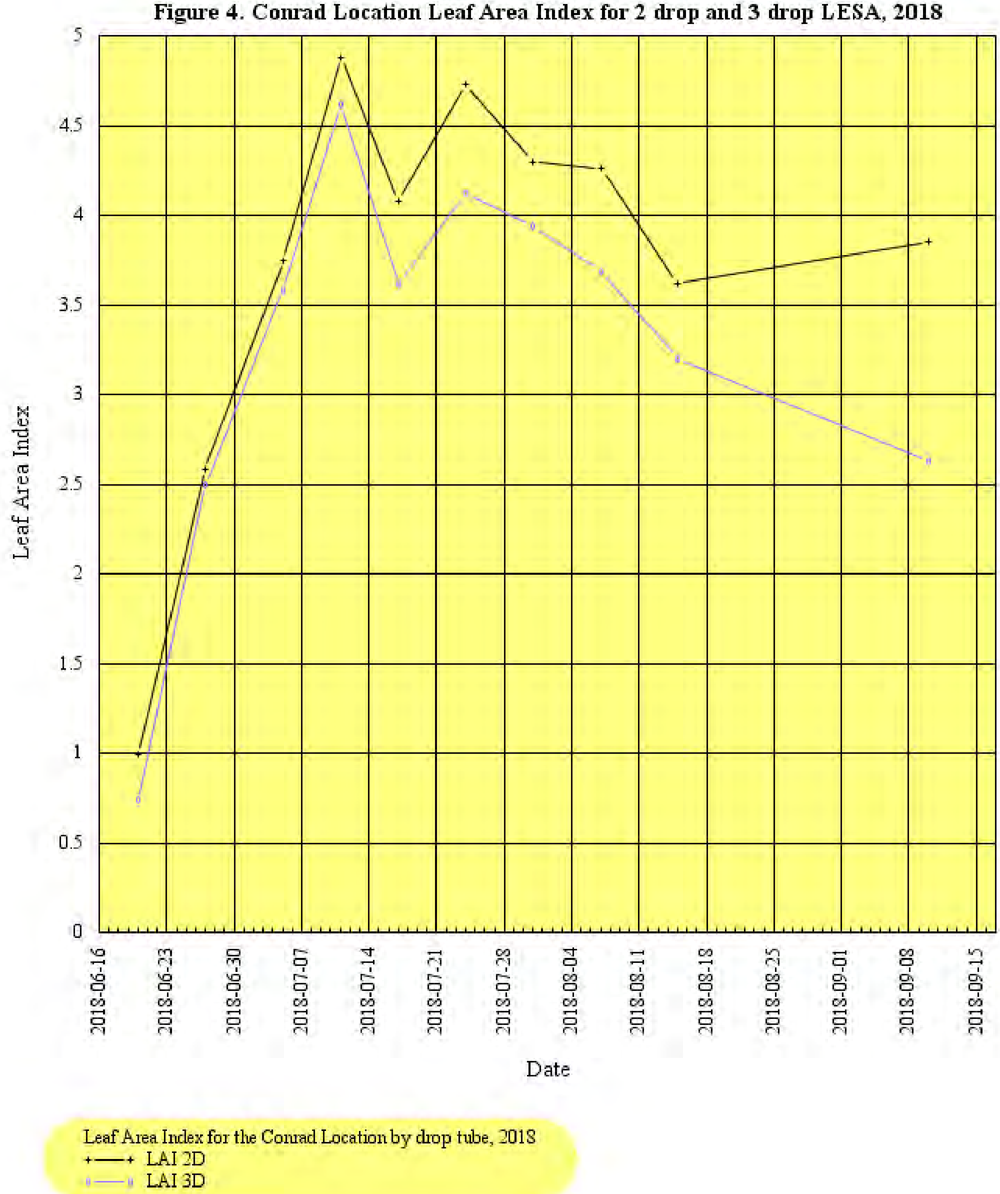
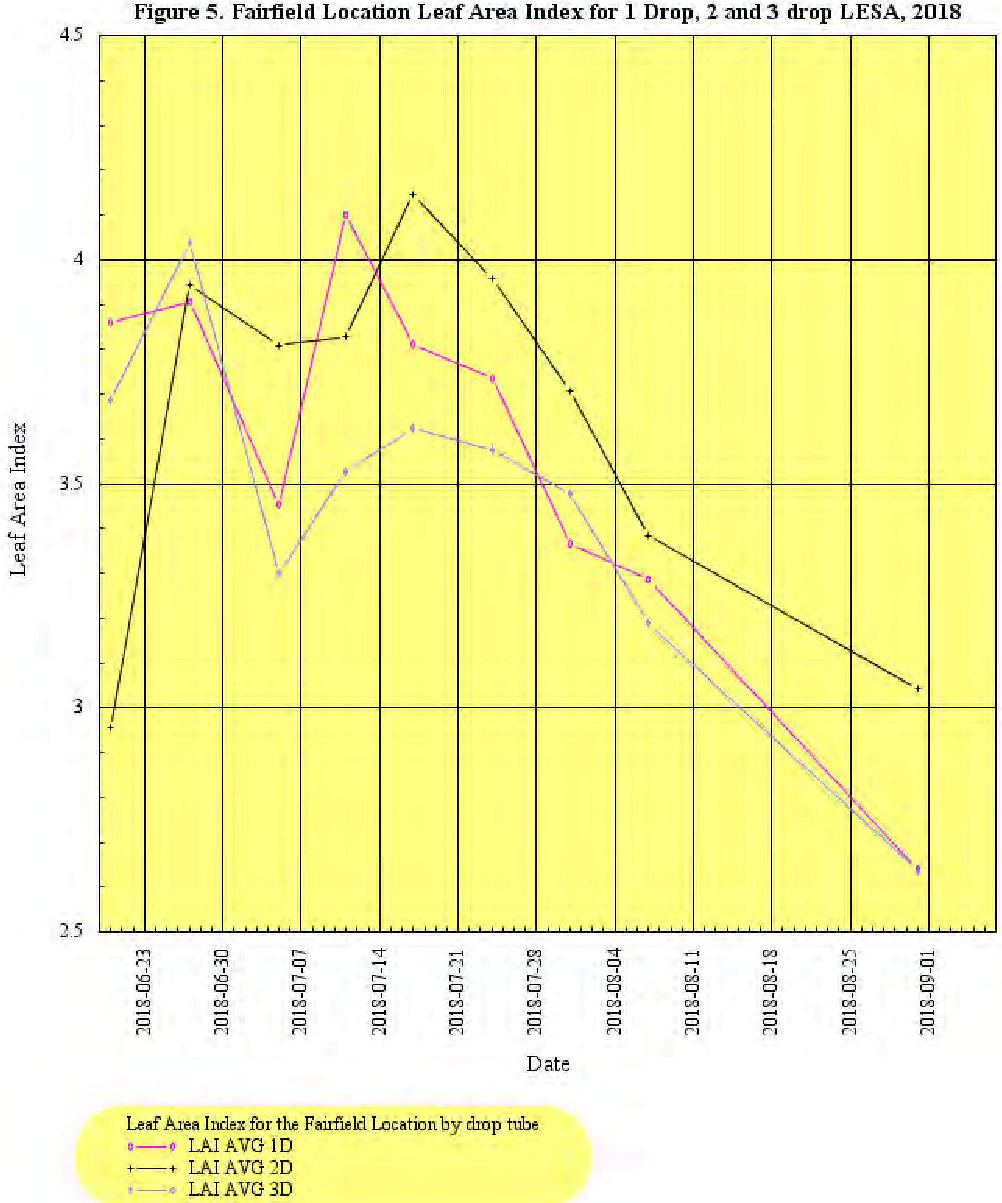


Figure 5. Fairfield Location Leaf Area Index for 1 Drop, 2 and 3 drop LESA, 2018



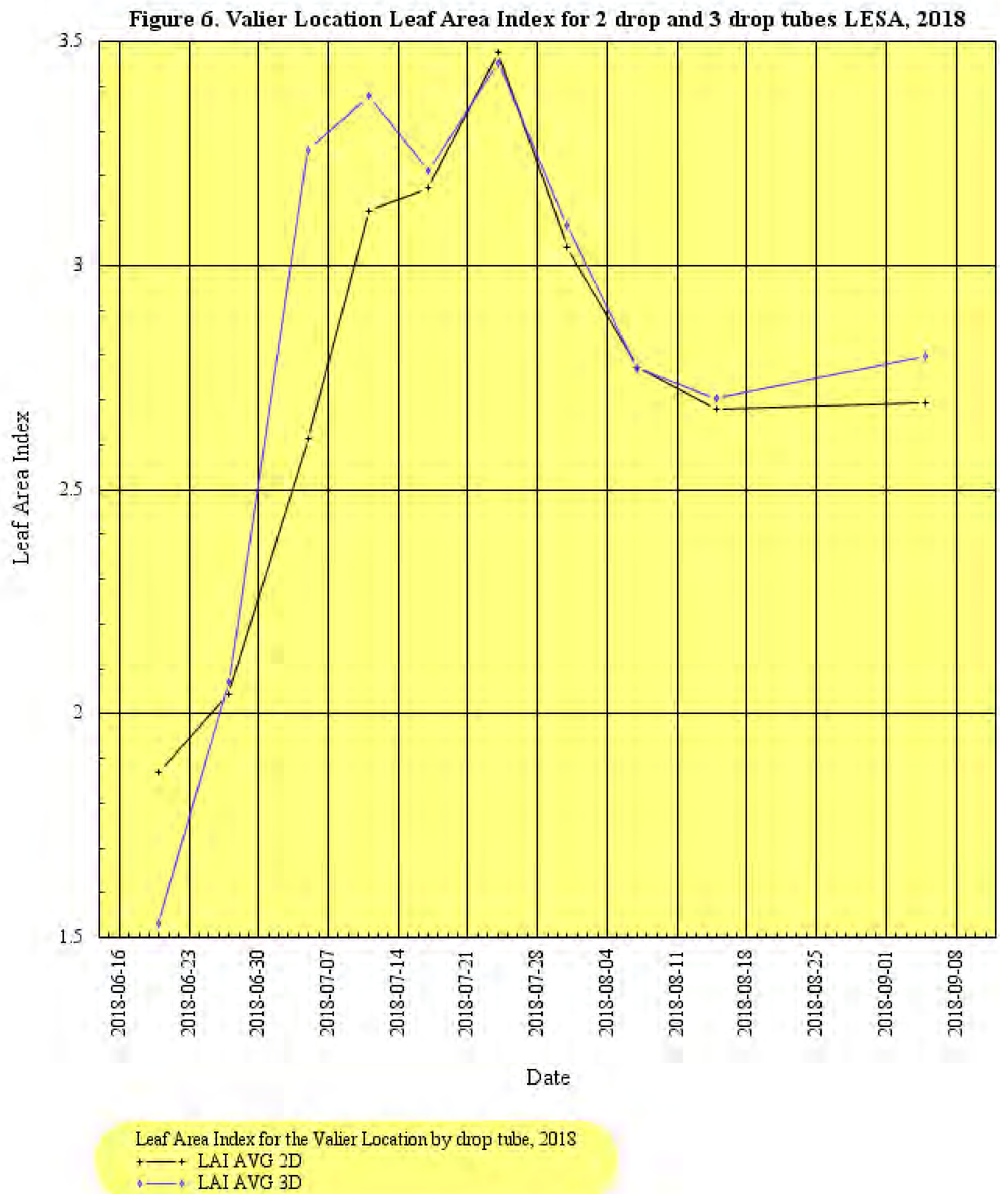


Figure 6. Valier Location Leaf Area Index for 2 drop and 3 drop tubes LESA, 2018
3.5
3
2.5
2
1.5
Leaf Area Index
2018-06-16
2018-06-23
2018-06-30
2018-07-07
2018-07-14
2018-07-21
2018-07-28
2018-08-04
2018-08-11
2018-08-18
2018-08-25
2018-09-01
2018-09-08
Date
Leaf Area Index for the Valier Location by drop tube, 2018
LAI AVG 2D
LAI AVG 3D

Table 1. 2018 LESA irrigation, grain data by location.

Location	Drop Tubes[2]	Yield (bu/ac[1])	Test Wt (lb/bu[1])	Height (inch)	Plump (%)	Thin (%)	Protein (%)
Conrad	2	141.9	51.5	27.8	99.1	0.33	11.3
	3	130.2	51.3	26.8	99.4	0.15	11.7
Mean		136.0	51.4	27.3	99.3	0.23	11.4
LSD (.05)		ns	ns	ns	ns	0.06	ns
C.V. (s/mean)*100		8.5	0.77	4.6	0.15	22.7	6.5
P-Value		0.2031	0.5271	0.3040	0.1008	0.0038	0.4467
Valier	2	80.3	45.5	29.8	85.8	3.5	11.3
	3	78.7	45.0	29.0	79.4	5.7	11.7
Mean		79.5	45.3	29.4	82.6	4.6	11.4
LSD (.05)		ns	ns	ns	ns	ns	ns
C.V. (s/mean)*100		16.4	3.1	3.6	10.7	62.9	6.5
P-Value		0.8671	0.5858	0.3559	0.3517	0.3297	0.4467
Fairfield	1	123.2	50.5	31.8	98.4	0.35	13.3
	2	118.2	50.8	34.0	97.7	0.33	13.7
	3	121.4	50.3	33.0	98.6	0.30	13.4
Mean		120.9	50.5	32.9	98.2	0.33	13.5
LSD (.05)		ns	ns	1.4	ns	ns	ns
C.V. (s/mean)*100		11.0	0.88	2.6	1.0	38.0	3.0
P-Value		0.8688	0.3118	0.016	0.4769	0.8515	0.3199

[1] Yield and test weight are adjusted to 13% seed moisture.

[2] One drop tube at Fairfield indicates normal irrigation.

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[2] One drop tube at Fairfield indicates normal irrigation.

Project Title: Evaluation of Crystal Green Based Fertilizer

Principal Investigators: John H. Miller, Research Scientist, and Gadi V.P. Reddy, Professor of Entomology/Ecology, Western Triangle Ag Research Center

Personnel: Julie Prewett, Research Assistant, and Alysha Miller, Research Assistant, WTARC, Conrad, MT.

Objectives: To this end the objective is to evaluate winter wheat fertilized with Crystal Green based products under the local conditions with respect to yield, test weight, lodging, and seed protein. The research center strives to provide growers of the western triangle area unbiased information of various fertilizer treatments.

Methods: The winter wheat plot was established with Yellowstone winter wheat with variations in fertilizer rates and products. All plots were seeded with a five row plot seeder on one foot spacing. All plots were planted on no-till chemical fallow. Phosphorus treatments were place in the furrow with the seed and part of the nitrogen and all of the potassium were side shot during seeding. The balance of the nitrogen was broadcast in the spring using a four foot Gandy fertilizer spreader. Plots were trimmed, measured for length, and then harvested with a Wintersteiger Classic plot combine. Winter wheat seed was cleaned prior to collecting data.

Results: Results are tabulated in Table 1. Table 2 contains product names and nutrient analysis. Table 3 are a presentation of soil test results. The soil test results pertinent to this experiment are WTARC-N fall.

Overall, the crop year temperatures where cooler than 32 year average at the research center, May, when we could have used some cooler temperatures, was 5.2 degrees warmer than the average. But the overall average temperature for the year from September to August was 3.8 degrees cooler than the 32 year average. The winter temperature, from September to March was well below average, with February being 15.5 degrees colder than the 32 year average. March and April were 9.6 and 7.1 degrees colder than the 32 year average. May was the only month that had a temperature that was above the average with a temperature 5.2 degrees. September through March were at or above the average precipitation for those months. Then May through August were drier than the 32 year average. Overall, precipitation was average for the year with respect to the 32 year average.

The winter wheat fertility plots were seeded into soil that had good soil moisture storage from the late summer and fall moisture in 2017. A warmer and dryer May and lack of summer moisture probably affected yield, test weight, and seed protein.

Grain yields averaged 71.3 bu/ac with no statistical difference in yield across treatments. There were no statistical differences for the measured agronomic factors of test weight or protein. The plots suffered from a sawfly infestation as the variety was Yellowstone.

Summary: It is planned to continue the Crystal Green based products for the 2018-2019 winter wheat growing season.

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 probability 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.

Table 1. Winter Wheat Crystal Green based product as a phosphorus source. Western Triangle Ag. Research Center, Conrad, MT.2018

Variety	Yield[1] (bu/ac)	Test Weight[1] (lb/bu)	Lodging (%)	Protein (%)
0	74.3	59.9	82.0	12.5
MAP 75 CGO 25	73.9	60.2	83.8	12.3
MAP 100	73.4	60.6	81.3	12.4
CG1783 100	70.5	59.9	78.8	12.6
MAP 65 CGNXT 35	69.8	59.0	77.0	12.7
MAP 75 CGNXT 25	69.2	59.3	83.8	12.8
MAP 85 CGNXT 15	69.0	60.0	83.8	12.7
Mean	71.3	59.8	81.5	12.6
LSD (0.05)	8.7	1.5	12.9	0.4
C.V. (s/mean)*100	7.1	1.7	10.6	2.2
P-value (0.05)	0.7356	0.3977	0.8793	0.1384

Planted: 10/16/2017 on chemical fallow and harvested on 8/21/2018
Fertilizer: 140 lbs N/ac as urea was broadcast on 4/30/2018. For nitrogen fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: Huskie at 11.0 oz/ac and Axial XL at 16.4 oz/ac applied on 6/3/2018.
[1] Yield and test weight are adjusted to 13% seed moisture.

Table 2. Crystal Green product and nutrient analysis.

Trt #	Treatment Description	Total P Rate %	% of P_2O_5 from each source			
			MAP	CGO	CGNXT	CG1783
1	Zero P Control	0%	0	0	0	0
2	100% MAP	100%	100	0	0	0
3	CGO25-MAP75	100%	75	25	0	0
4	CGNXT15-MAP85	100%	85	0	15	0
5	CGNXT25-MAP75	100%	75	0	25	0
6	CGNXT35-MAP65	100%	65	0	35	0
7	CG1783	100%	0	0	0	100

MAP = monoammonium phosphate
CGO = Crystal Green Original
CGNXT = Crystal Green NXT
CG1783 = Experimental

MAP = 11-52-0
CGO = 5-28-0-10Mg
CGNXT = 5-28-0-10Mg
CG1783 = 9-45-0-3

Table 3. Soil test values for off-station and on-station plots, 2018.

Location	N (lbs/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	19.1	13	449	7.9	2.7	0.55
Devon	5.1	21	400	6.4	1.2	0.19
Knees	23.8	19	568	7.4	3.4	0.55
Choteau	57.8	10	556	8.1	2.7	0.75
WTARC-Var Fall	21.1	17	257	8.1	2.8	0.29
WTARC-N Fall	15.5	30	421	7.5	2.6	0.57
WTARC Spring	15.9	30	528	7.4	2.6	0.36

[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

Entomology/Ecology Program

Field Testing the Effect of Biopesticides against Wheat Stem Sawfly Management: Dose Response

Principal Investigator: Gadi V.P. Reddy

Project Personnel: Govinda Shrestha, Rama Devi Gadi, Debra Miller, John H. Miller and Julie Prewitt

Western Triangle Agricultural Research Center, Montana State University, 9546 Old Shelby

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Aim of the Study

The aim of this study was: 1) to determine the effects of three biopesticides (Actigard, Xpectro and Neem) treatment application on wheat stem sawfly (WSS) management, using two doses (low and high concentration) of each product.

Materials and Methods

Locations of winter wheat fields used in field trials

The field experiments were performed at four locations: Knees (N 48°00'08.5 W 111°21'51.8), Conrad (N 48°18'29.0 W 111°55'23.1), Devon (N 48°55' 31.1W 111°39' 64.4), and Choteau (N 47°59'36.0 W 112°06'49.9), in the Golden Triangle, Montana, USA. All experimental locations had moderate to high WSS infestations for several years. The experimental plots were seeded in September 2017 at a rate of 194 live seeds per m^2. The seeds were planted in four rows, with 30 cm between rows. Glyphosate (Roundup Powermax®) was applied at the rate of 2.5 L/ ha (the active ingredient of 540 g/L of acid glyphosate) prior seeding to control weed growth. Fertilizers N, P, and K at 224.2, 0, and 22.4 kg/ha were broadcasted while planting, and an additional application of 12.3, 25.2, and 0 kg/ha of these three nutrients were applied through the seed plot drill.

At each field location, treatments were arranged in a randomized complete block design (RCBD) with nine replicates per treatment. Plots for treatments were 3.6 × 1.2 m separated by 0.60 m buffer zones to avoid cross contamination of treatments.

Monitoring of wheat stem sawfly adults

Considering the ideal application time for biopesticides can be one of the important factors for WSS management. Currently, there is no established degree-day model for determining the precise timing of adult emergence. Two methods were used for monitoring the emergence of adults: 1) dissection of WSS-infested stubble to determine the stage of immature development and 2) sweep net sampling in the winter wheat fields to detect adults. Experimental plots and their adjacent winter wheat fields were scouted weekly from the last week of April – first week of June, 2018.

Application of chemicals

From 2017 WSS lab and field trials, we found that two-time application of two biopesticide products (Actigard and Neem) had some impacts on WSS management (Shrestha et al., 2018). In addition, 2016 WSS field trial study showed that two-time application of Xpectro biopesticide product had also some impact especially WSS larval mortality. The two-time applications refer to applications of chemicals when WSS eggs and larvae are expected to be present, respectively, inside stems. Therefore, these three chemicals were used for the study (Table 1). Since these chemicals are relatively expensive than synthetic insecticides, it is important to test whether the repeated lower doses of potential biopesticide product may work for WSS management and thereby reducing costs for winter wheat producers. The rate of each chemical is presented in Table 1.

Treatment application were based on sawfly adult's emergence timing. First application were done on June 5 (Knees and Choteau locations) and June 6 (Devon and Conrad locations), 2018. The second application was made on June 12(Knees and Choteau locations) and June 13 (Devon and Conrad locations), 2018. Treatments were applied using a SOLO backpack sprayer (SOLO, Newport News, VA) calibrated to deliver about 400 L of spray solution/ha based on nozzle flow and walking speed. Plants treated with water served as untreated control plots. At all field trial locations, chemicals were applied at the wheat stage with 4-6 nodes.

Table 1. Biopesticide products and rate of application in each treatment

Treatment	**Concentration**
T1: Water	-
T2: Actigard® High dose	1.50 g/L
T3: Xpectro® High dose	5.0 ml/L
T4: Azadirachtin® (Neem) High dose	5.76 ml/L
T5: Actigard® Low dose	0.75 g/L
T6: Xpectro® Low dose	2.5 ml/L
T7: Azadirachtin® (Neem) Low dose	2.88 ml/L

Collection of wheat stems

Wheat stems were sampled in all plots to determine the treatment effects during the growing season. Sampling was conducted 3 days before to treatment application (PT), and 10 and 50 days after treatments. Three random samples were collected from two central rows of each treatment plot, with five stems/sample. Wheat stems were cut from the base of plants with help of scissors, placed into one zipper-lock bag, and kept in picnic cooler. During the final sampling time, however, clumps of stems were pulled randomly from three sampling points of two middle rows of each plot with the help of shovel to collect entire matured plants. This technique was used mainly because the WSS diapausing larvae usually prefer to remain at the base of the wheat stem.

Samples were brought to the laboratory, where stems were dissected lengthwise with a fine bladed scalpel to determine the following parameters: 1) WSS stem infestation level; the presence of WSS immatures, parasitoid immature or frass inside dissected wheat stems, 2) WSS immatures population; the presence of eggs and larvae inside dissected wheat stems at each sampling time, 3)

WSS larval mortality; the presence of dead larvae inside dissected wheat stems, 4) WSS larval body weight; body weight of diapausing larvae and 5) parasitism rate; presence of parasitoid cocoons inside stems parasitoid holes in stems.

Host and parasitoid adult populations: WSS and *Bracon* spp.

Three biopesticide products were also tested to examine whether they can repel WSS adults and their impact on WSS parasitoid adult population levels. A sweep net was used to assess insect population (WSS and parasitoid adults). Sweeping was done with a standard sweep net (180^{o} arc), collecting 15 sweeps from each treatment plot. Sampling was done one to two days before treatment application (PT) and, 10, 20 and 30 days after treatment application. Samples were stored in a freezer until examined in the laboratory and insects counted.

Stem lodging level at harvest

WSS larval feeding inside stems caused wheat stands fall into ground and thereby cause difficulty during harvesting. We examined that whether tested chemicals had any effects on plant stand levels during the wheat grain harvest. Wheat stems lodging measurements were made by visual classification rating scale of 1 to 10. The rating of 1 indicates that all plants in a plot were vertical and 10 for all plants in a plot were horizontal.

Yield and quality

To harvest the wheat grains from treatment plots, Hege 140 plot combine was used. The precaution was used to minimize the borders and any overlap of treatment effects on wheat yield and quality. Each plot length was measured, and the wheat grain threshed from each plot. Wheat grains were cleaned with a seed processor (Almaco, Nevada, IA) and weighed on a scale to determine yield. Test weight was measured on a Seedburo test weight scale. The protein and moisture percentages of seed were determined with NIR grain analyzer IM 9500 (Perten Instruments, Springfield, IL).

Statistical analysis

One-way-ANOVA was performed to determine the effects of treatments on WSS infestation level, WSS diapausing larval body weight, WSS diapausing larval mortality, parasitism level, stem lodging, and yield and quality parameters of winter wheat fields infested with WSS. Tukey test was used as a post hoc test for multiple comparisons between the means at probability (α = 0.05). A non-parametric one-way ANOVA was used to examine the effect of treatment on WSS and parasitoid adults' population at each sampling time. Mann-Whitney U-tests were used as post hoc for multiple comparisons between treatment means. The data was analyzed using the software statistical package R 2.15.1 (R Development Core Team, 2011).

Results

WSS infestation level

WSS infestation levels at different sampling time are presented at Table 2. This study showed that treatments had no significant impacts on WSS infestation levels (see Table 2 for statistical output). Overall, there was high variation in infestation levels at different time of sampling. However, Actigard or Xpectro treatments had numerically lower infestation levels compared with untreated control at 10 days after the treatments application, irrespective of location (Table 2).

Table 2. Effects of Neem, Xpectro and Actigard applications on wheat stem sawfly (WSS) infested stem % level (mean ± SE) in winter wheat fields at the four study location of Montana.

	WSS Infested Stem Percentage		
Treatment	**PT**	**10 DAT**	**50 DAT**
Choteau			
Control	3.94 ± 2.30	54.82 ± 7.25	88.87 ± 1.78
Neem Low	9.17 ± 3.13	48.99 ± 8.47	88.49 ± 2.38
Neem High	1.97 ± 1.23	57.61 ± 7.97	88.01 ± 3.46
Xpectro Low	6.46 ± 2.98	48.37 ± 4.42	89.88 ± 2.56
Xpectro High	6.01 ± 1.51	42.16 ± 6.71	90.67 ± 2.37
Actigard Low	11.73 ± 6.85	41.69 ± 5.58	87.00 ± 3.58
Actigard High	3.89 ± 1.47	56.24 ± 7.76	88.84 ± 2.64
Stat. output	$F_{6, 49} = 0.91; P = 0.49$	$F_{6, 56} = 0.84; P = 0.54$	$F_{6, 56} = 0.17; P = 0.98$
Knees			
Control	12.29 ± 3.60	69.83 ± 5.13	90.47 ± 3.33
Neem Low	14.12 ± 5.95	65.30 ± 5.68	90.19 ± 4.45
Neem High	12.86 ± 4.76	71.00 ± 9.25	94.79 ± 2.48
Xpectro Low	16.65 ± 3.60	55.14 ± 7.10	82.85 ± 4.81
Xpectro High	14.82 ± 2.03	52.03 ± 8.54	89.76 ± 3.60
Actigard Low	17.07 ± 3.80	67.74 ± 7.28	85.61 ± 5.11
Actigard High	16.68 ± 3.52	65.01 ± 6.63	84.27 ± 3.23
Stat. output	$F_{6, 49} = 0.21; P = 0.97$	$F_{6, 56} = 1.16; P = 0.34$	$F_{6, 56} = 0.42; P = 0.42$
Devon			
Control	9.58 ± 4.33	44.85 ± 8.36	51.78 ± 5.42
Neem Low	4.84 ± 2.31	41.03 ± 4.94	47.77 ± 7.72
Neem High	7.98 ± 3.93	37.57 ± 8.25	54.96 ± 7.98
Xpectro Low	5.06 ± 2.76	34.64 ± 7.05	51.03 ± 4.92
Xpectro High	1.85 ± 1.15	35.13 ± 4.78	53.86 ± 6.46
Actigard Low	5.12 ± 1.95	34.95 ± 9.18	51.03 ± 4.21
Actigard High	4.03 ± 2.71	29.63 ± 6.24	46.90 ± 2.81
Stat. output	$F_{6, 49} = 0.72; P = 0.64$	$F_{6, 56} = 1.16; P = 0.33$	$F_{6, 56} = 0.25; P = 0.95$
Conrad			
Control	13.47 ± 4.44	32.32 ± 7.85	75.99 ± 4.41
Neem Low	11.59 ± 3.29	30.79 ± 6.20	80.31 ± 4.46
Neem High	16.27 ± 5.09	38.57 ± 3.85	81.21 ± 2.91
Xpectro Low	19.90 ± 6.04	31.81 ± 3.67	74.15 ± 4.25
Xpectro High	8.80 ± 3.31	33.26 ± 7.00	80.99 ± 2.69
Actigard Low	9.51 ± 2.62	28.07 ± 6.62	78.25 ± 3.68
Actigard High	16.00 ± 2.32	14.14 ± 3.03	75.48 ± 3.21
Stat. output	$F_{6, 49} = 0.88; P = 0.51$	$F_{6, 56} = 1.78; P = 0.12$	$F_{6, 56} = 0.59; P = 0.73$

PT, Pre Treatment; DAT, Days After Treatment Application

Wheat stem sawfly adults, and parasitoid adults and their parasitism level

In general, WSS adult populations were found higher at the Knees location followed by the Choteau, Conrad and Devon locations (Table 3). Regardless of location, treatments did not have a significant impact on WSS adult population, at any sampling time (see Table 3 for statistical output). Except, at the Knees location, the wheat plots treated with lower dose of Xpectro had significantly lower WSS adult population compared with the untreated control plots at 10 days after treatment application (Table 3).

Regarding *Bracon* spp. adult, there were no significant differences in parasitoid adult population levels between treatments at each sampling time at the Choteau, Knees, Devon and Conrad locations (Table 3). In addition, the study did not depict any significant difference on parasitism levels between treatments either of study locations (Choteau; $df = 6, 56$; $F = 1.13$; $P = 0.36$; Conrad: $df = 6, 56$; $F = 0.67$; $P = 0.68$, Knees; $df = 6, 56$; $F = 0.89$; $P = 0.50$ and Devon; $df = 6, 56$; $F = 1.48$; $P = 0.20$). (Figure 1). The overall average parasitism at the Choteau, Knees, Devon and Conrad locations varied from 3.61-8.62 %, 11.50 -12.81 %, 10.69-12.28 and 14.39-15.61 %, respectively (Figure 1).

WSS diapausing larval mortality

In overall, higher diapausing WSS larval mortality was observed at the Knees followed by Devon, Conrad and Choteau locations, irrespective of treatment. Total mean larval mortality percentage varied from 26-45, 20-40, 20-40 and 19-27 for Knees, Devon, Conrad, and Choteau locations, respectively (Figure 1). In Knees and Conrad locations, wheat plots treated with Actigard lower dose inflicted noticeably higher percentage of mortality compared to plots treated with Xpectro, Neem and control, while with higher Actigard dose application at the Devon location. However, no significant differences were found between treatments either of these locations (Knees; $df = 6, 56$; $F = 0.98$; $P = 0.45$; Conrad: $df = 6, 56$; $F = 0.67$; $P = 0.67$ and Devon; $df = 6, 56$; $F = 1.00$; $P = 0.43$). Similarly, the treatments had no significant impact on larval mortality at the Choteau location ($df = 6, 56$; $F = 0.63$; $P = 0.70$).

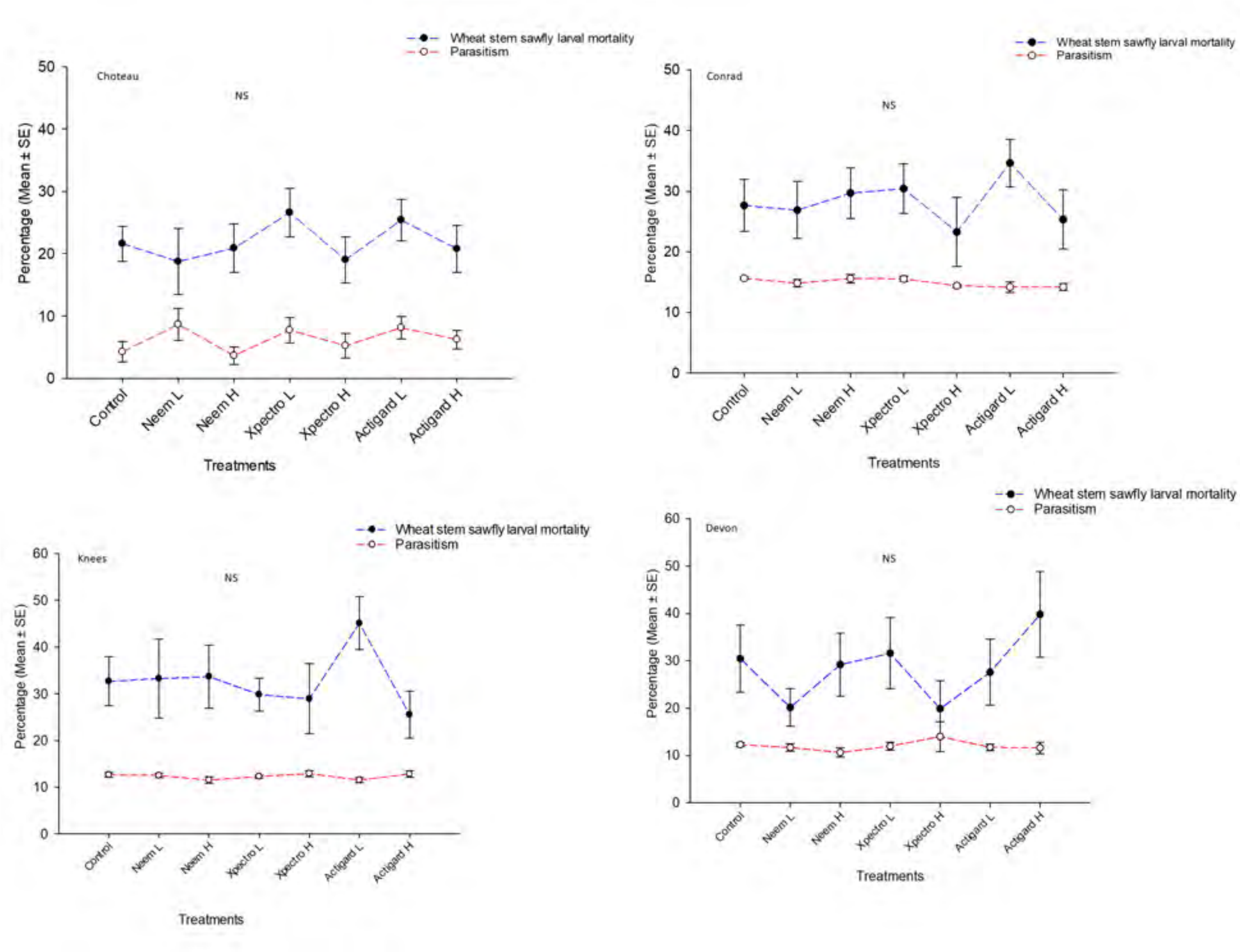

Figure 1. Effect of Neem, Xpectro and Actigard applications on total mortality of diapausing larvae (mean ± SE) and parasitism levels, recorded in dissected stems and emergence holes in stems at final harvest in winter wheat at the four study locations of Montana. NS refers to non-significant.

Body weight of diapausing WSS larvae

Higher body weight of diapausing larvae were generally found at the Conrad followed by Choteau Knees and Devon locations (Figure 2). Mean larval body weight recorded for treatments including control plots ranged from 14.16-15.62 mg, 13.31-14.32 mg, 11.51-14.17 mg and 10.63-14.00 mg for Conrad, Choteau, Knees and Devon locations, respectively (Figure 2). This study reported that treatments had no significant impact on larval body weight either of the study location: Conrad (df = 6, 56; F = 1.16; P = 0.34), Choteau (df = 6, 56; F = 1.52; P = 0.19), Knees (df = 6, 56; F = 0.98; P = 0.45) and Devon (df = 6, 56; F = 0.57; P = 0.75) locations (Figure 2).

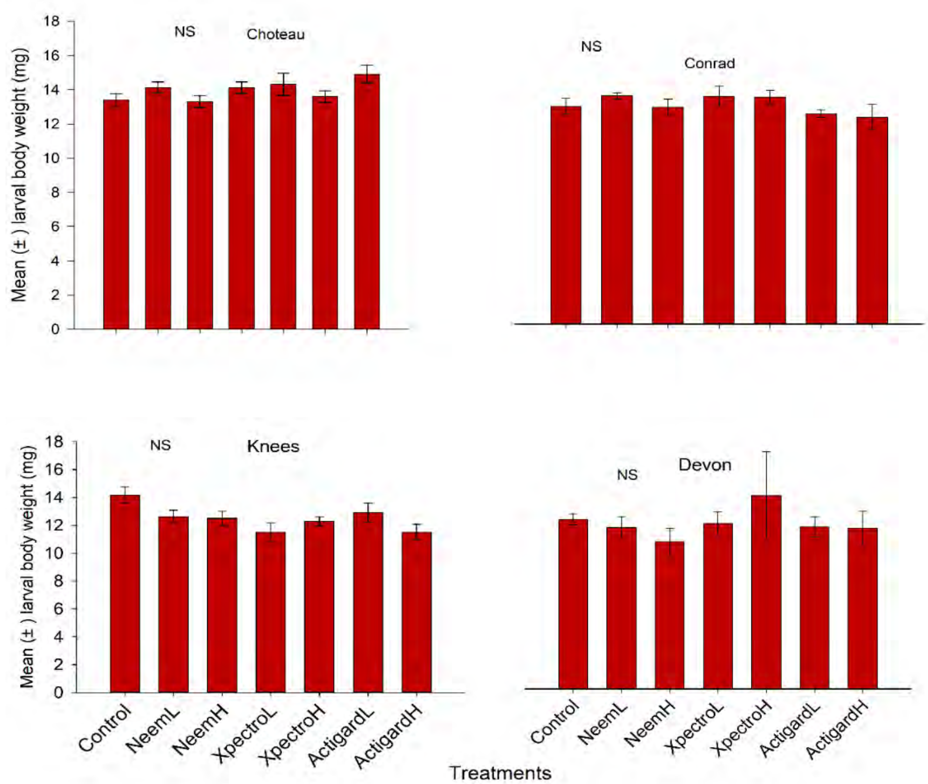

Figure 2. Effect of Neem, Xpectro and Actigard applications on diapausing larvae (mean ± SE) body weight, recorded in dissected stems at final harvest in winter wheat at the four study locations of Montana. NS refers to non-significant.

Wheat stem lodging

This study demonstrated main significant effect of treatment on wheat stem lodging at two of the study locations: Conrad (*df* = 11, 36; *F* = 3.02; *P* = 0.006) and Devon (*df* = 11, 36; *F* = 3.02; *P* = 0.006) (Figure 3). In contrast, treatments had not shown any significant effects on other two locations: Choteau (*df* = 11, 36; *F* = 0.40; *P* = 0.88) and Knees (*df* = 11, 36; *F* = 1.22; *P* = 0.31). At Conrad location, significantly lower mean stem lodging (± SE) occurred when wheat plots were treated with Actigard lower dose (2.78 ± 0.79), and Neem low (2.89 ± 0.20) and high (2.82 ± 0.36) doses compared with untreated control plots (4.33 ± 0.33) (Figure 3). In contrast, the remaining treatments showed no significant differences from the untreated control. At the Devon location, Neem applied with higher dose had only significantly lower mean stem lodging (1.89 ± 0.31) compared with untreated control plots (3.56 ± 0.44) (Figure 3).

Yield

In overall, higher average winter wheat yield was found in Choteau (64-75 bushel/acre) followed by Knees (54-64 bushel/acre), Conrad (52-64 bushel/acre) and Devon (40-46 bushel/acre) locations. This study reported that treatments had significant impacts on winter wheat grain yield at the Choteau and Conrad locations, but without effects at the Knees and Devon locations (see

Table 3 for statistical outputs). At the both Choteau and Conrad locations, wheat plots treated with higher dose of Actigard had significantly or numerically lower grain yield compared with other treatments including water (Table 4). Similar patterns were also observed at the Knees and Devon locations.

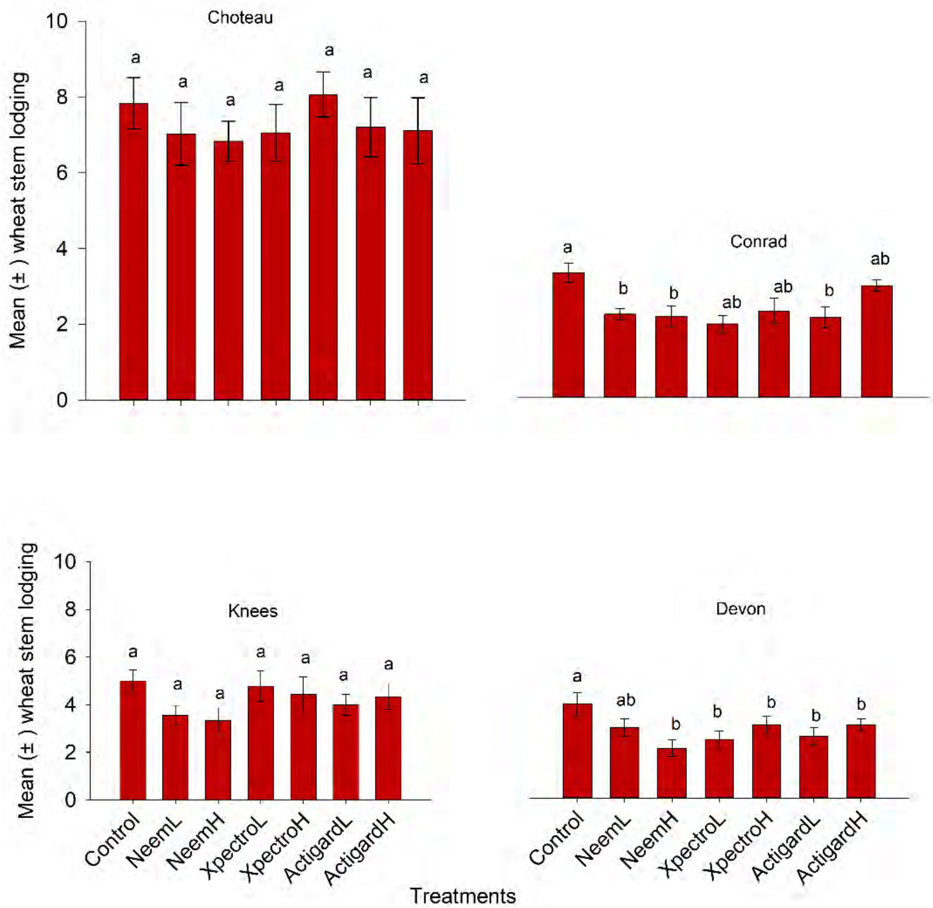

Figure 3. Effect of Neem, Xpectro and Actigard applications on On the wheat stem lodging (mean ± SE) recorded at the harvesting time at the four study location of Montana. In y-axis scale, 1 demonstrates that all plants in a plot were vertical and 10 for all plants in a plots were horizontal during harvest. Mean values within bars bearing the different letters are significantly different (Tukey test, P<0.05)

Quality

The treatments had no significant impact on a test weight at any study locations (see Table 3 for statistical output). The overall test weight was numerically higher at the Conrad (61-62 lbs/bushel) followed by Knees (60-61 lbs/bushel), Devon (59-60 lbs/bushel) and Choteau (58-59 lbs/bushel) (Table 4). Similarly, there were no significant differences in moisture percentage and 1000 kernels weight among treatments (Table 4). However, regarding to protein levels, they were significantly higher when wheat plots were treated with higher dose of Actigard compared with plots treated with water, Neem or Xpectro at the Choteau and Devon locations, but without significant effects at the Knees and Conrad locations (Table 4).

Acknowledgements

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References

R Development Core Team. 2011. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna.

Shrestha, G, Briar, S.S., Reddy, G.V.R., 2018. Plant defense elicitors: Plant fitness versus wheat stem sawfly. PeerJ, DOI 10.7717/peer.5892.

Table 3. Effect of Neem, Xpectro and Actigard applications on wheat stem sawfly and Bran spp. adult individuals (15 sweeps/plot) at the four study location of Montana.

	WSS adult number				Parasitoid adult number			
Treatment	**PT**	**10 DAT**	**20 DAT**	**30 DAT**	**PT**	**10 DAT**	**20 DAT**	**30 DAT**
Choteau								
Control	15.00 ± 2.11	9.22 ± 2.28	1.333 ± 0.50	-	-	-	0.56 ± 0.24	0.11 ± 0.11
Neem Low	15.63 ± 2.26	9.67 ± 1.85	1.444 ± 0.44	-	-	-	0.89 ± 0.26	0.44 ± 0.34
Neem High	15.38 ± 1.49	8.00 ± 1.40	1.125 ± 0.52	-	-	-	0.38 ± 0.25	0.11 ± 0.11
Xpectro Low	16.63 ± 2.03	8.44 ± 1.76	1.222 ± 0.58	-	-	-	0.11 ± 0.11	0.33 ± 0.17
Xpectro High	16.38 ± 1.69	8.56 ± 1.36	2.00 ± 0.43	-	-	-	0.44 ± 0.18	0.22 ± 0.15
Actigard Low	15.63 ± 1.94	9.22 ± 1.76	2.00 ± 0.64	-	-	-	0.33 ± 0.24	0.22 ± 0.15
Actigard High	17.00 ± 2.66	9.67 ± 1.41	1.5 ± 0.60	-	-	-	0.75 ± 0.15	0.11 ± 0.11
Stat. output	*$\chi2_{6}$=0.64; P=0.10*	*$\chi2_{6}$=1.38; P=0.97*	*$\chi2_{6}$=3.96; P=0.68*				*$\chi2_{6}$=10.32; P=0.12*	*$\chi2_{6}$=2.44; P=0.87*
Knees								
Control	40.13 ± 5.34	7.67 ± 0.94ab	0.11 ± 0.12	-	-	0.44 ± 0.24	0.22 ± 0.15	0.22 ± 0.15
Neem Low	48.13 ± 7.07	9.11 ± 1.46a	0.11 ± 0.12	-	-	0.00 ± 0.00	0.33 ± 0.17	0.22 ± 0.15
Neem High	46.25 ± 4.98	9.78 ± 0.96a	0.11 ± 0.12	-	-	0.33 ± 0.17	0.56 ± 0.29	0.11 ± 0.11
Xpectro Low	42.75 ± 6.34	3.56 ± 0.56bc	0.11 ± 0.12	-	-	0.00 ± 0.00	0.44 ± 0.24	0.44 ± 0.24
Xpectro High	51.88 ± 7.67	8.22 ± 1.89ab	0.11 ± 0.12	-	-	0.11 ± 0.11	0.44 ± 0.34	0.33 ± 0.17
Actigard Low	45.88 ± 9.50	6.67 ± 1.83bc	0.56 ± 0.36	-	-	0.22 ± 0.15	0.56 ± 0.34	0.33 ± 0.17
Actigard High	52.75 ± 7.54	6.78 ± 0.93bc	0.11 ± 0.12	-	-	0.33 ± 0.24	0.22 ± 0.15	0.22 ± 0.15
Stat. output	*$\chi2_{6}$=2.38; P=0.88*	*$\chi2_{6}$=18.09;* ***P=0.001***	*$\chi2_{6}$=3.40; P=0.76*	-	-	*$\chi2_{6}$=7.37; P=0.28*	*$\chi2_{6}$=1.16; P=0.97*	*$\chi2_{11}$=2.14; P=0.91*
Devon								
Control	10.63 ± 1.45	1.22 ± 0.49	-	-	-	0 .00 ± 0.00	0 .00 ± 0.00	0 .00 ± 0.00
Neem Low	10.13 ± 1.54	1.13 ± 0.48	-	-	-	0.11 ± 0.11	0.11 ± 0.11	0 .00 ± 0.00
Neem High	10.50 ± 2.01	1.56 ± 0.50	-	-	-	0 .00 ± 0.00	0.22 ± 0.15	0 .00 ± 0.00
Xpectro Low	11.50 ± 1.2	1.33 ± 0.35	-	-	-	0 .00 ± 0.00	0 .00 ± 0.00	0.11 ± 0.11
Xpectro High	12.00 ± 1.98	1.11 ± 0.57	-	-	-	0 .00 ± 0.00	0 .00 ± 0.00	0.00 ± 0.00
Actigard Low	12.88 ± 1.91	1.78 ± 0.42	-	-	-	0 .00 ± 0.00	0 .00 ± 0.00	0.22 ± 0.15
Actigard High	8.00 ± 1.25	1.44 ± 0.53	-	-	-	0 .00 ± 0.00	0 .00 ± 0.00	0.00 ± 0.00
Stat. output	*$\chi2_{6}$=4.09; P=0.54*	*$\chi2_{6}$=3.04; P=0.80*	-	-	-	*$\chi2_{6}$=6; P=0.42*	*$\chi2_{6}$=8.96; P=0.18*	*$\chi2_{11}$=8.96; P=0.17*
Conrad								
Control	15.63 ± 2.21	4.56 ± 0.83	0.00 ± 0.00	-	-	0.11 ± 0.11	0.00 ± 0.00	0.78 ± 0.36
Neem Low	10.25 ± 2.12	4.33 ± 1.44	0.00 ± 0.00	-	-	0.11 ± 0.11	0.00 ± 0.00	0.78 ± 0.36
Neem High	15.50 ± 2.46	4.00 ± 1.05	0.00 ± 0.00	-	-	0.00 ± 0.00	0.22 ± 0.22	0.33 ± 0.17
Xpectro Low	10.63 ± 1.64	3.11 ± 0.60	0.00 ± 0.00	-	-	0.00 ± 0.00	0.33 ± 0.17	0.22 ± 0.15
Xpectro High	10.38 ± 1.32	3.78 ± 0.75	0.11 ± 0.12	-	-	0.11 ± 0.11	0.00 ± 0.00	0.44 ± 0.18
Actigard Low	11.38 ± 1.49	4.67 ± 1.16	0.00 ± 0.00	-	-	0.00 ± 0.00	0.22 0.15	0.44 ± 0.18
Actigard High	9.00 ± 2.06	4.22 ± 0.61	0.00 ± 0.00	-	-	0.00 ± 0.00	0.33 ± 0.17	0.33 ± 0.24
Stat. output	*$\chi2_{6}$=7.93; P=0.24*	*$\chi2_{6}$=3.06; P=0.80*	*$\chi2_{6}$=6; P=0.42*	-	-	*$\chi2_{6}$=6; P=0.42*	*$\chi2_{6}$=9.80; P=0.13*	*$\chi2_{6}$=2.96; P=0.81*

PT, Pre Treatment; DAT, Days After Treatment Application. Mean values within columns bearing the different letters are significantly differetn (Mann-Whitney test, P<0.05)

Table 4. Effect of Neem, Xpectro and Actigard on average yield and quality (± SE) parameter of winter wheat fields infested at the four study location of Montana

Treatment	Yield (bushel/acre)	Test weight (lbs/bushel)	Protein (%)	Moisture (%)	Thousand Kernel Weight (gram)
Knees					
Water	53.80 ± 1.51	60.99 ± 0.13	13.89 ± 0.10	10.42 ± 0.04	29.77 ± 0.58
Neem L	61.55 ± 2.30	61.06 ± 0.12	13.65 ± 0.11	10.37 ± 0.02	30.52 ± 0.47
Neem H	59.27 ± 1.77	60.81 ± 0.15	13.69 ± 0.09	10.43 ± 0.05	30.98 ± 0.54
Xpectro L	62.95 ± 2.43	60.70 ± 0.18	13.70 ± 0.10	10.45 ± 0.07	29.74 ± 0.60
Xpectro H	59.40 ± 2.66	60.71 ± 0.15	13.74 ± 0.08	10.40 ± 0.06	30.24 ± 0.35
Actigard L	55.59 ± 2.08	61.27 ± 0.12	14.02 ± 0.09	10.40 ± 0.04	30.48 ± 0.55
Actigard H	54.65 ± 2.36	61.16 ± 0.16	14.15 ± 0.09	10.37 ± 0.04	29.38 ± 0.44
Stat. output	$F_{6, 50} = 2.27; P = 0.06$	$F_{6, 56} = 1.74; P = 0.128$	$F_{6, 56} = 1.85; P = 0.106$	$F_{6, 56} = 0.40; P = 0.878$	$F_{6, 56} = 1.59; P = 0.169$
Choteau					
Water	73.28 ± 1.30*a*	59.37 ± 0.24	14.54 ± 0.08*b*	9.66 ± 0.05	26.97 ± 0.47
Neem L	73.29 ± 1.56*a*	59.26 ± 0.14	14.55 ± 0.06*ab*	9.85 ± 0.04	26.86 ± 0.36
Neem H	69.37 ± 2.16*a*	58.87 ± 0.18	14.69 ± 0.11*ab*	9.79 ± 0.09	25.97 ± 0.33
Xpectro L	71.47 ± 1.48*a*	58.93 ± 0.27	14.58 ± 0.07*ab*	9.72 ± 0.04	26.63 ± 0.39
Xpectro H	74.99 ± 1.89*a*	59.47 ± 0.14	14.50 ± 0.08*b*	9.74 ± 0.03	26.56 ± 0.31
Actigard L	66.67 ± 1.12*ab*	59.34 ± 0.13	14.96 ± 0.10*a*	9.81 ± 0.07	25.96 ± 0.20
Actigard H	63.71 ± 1.76*bc*	59.81 ± 0.15	14.98 ± 0.10*a*	9.76 ± 0.04	26.80 ± 0.34
Stat. output	$F_{6, 49} = 5.44; P = \mathbf{0.0002}$	$F_{6, 56} = 1.83; P = 0.109$	$F_{6, 56} = 4.40; P = \mathbf{0.001}$	$F_{6, 56} = 1.0; P = 0.435$	$F_{6, 56} = 1.86; P = 0.104$
Devon					
Water	40.11 ± 3.21	59.98 ± 0.34	11.78 ± 0.27*c*	10.56 ± 0.10	26.41 ± 0.65
Neem L	45.90 ± 2.35	59.58 ± 0.21	12.02 ± 0.24*abc*	10.56 ± 0.13	25.93 ± 0.52
Neem H	41.85 ± 3.18	59.88 ± 0.33	11.97 ± 0.32*abc*	10.57 ± 0.15	26.27 ± 0.79
Xpectro L	46.31 ± 1.94	59.93 ± 0.31	11.59 ± 0.27*c*	10.60 ± 0.17	26.27 ± 0.76
Xpectro H	43.08 ± 1.01	59.61 ± 0.36	11.75 ± 0.31*c*	10.46 ± 0.09	25.97 ± 0.69
Actigard L	41.67 ± 1.93	60.30 ± 0.28	12.44 ± 0.27*ab*	10.65 ± 0.20	26.87 ± 0.66
Actigard H	40.00 ± 2.80	60.38 ± 0.24	12.75 ± 0.24*ab*	10.75 ± 0.21	26.67 ± 0.50
Stat. output	$F_{6, 49} = 0.95; P = 0.468$	$F_{6, 56} = 0.9; P = 0.502$	$F_{6, 56} = 2.58; P = \mathbf{0.028}$	$F_{6, 56} = 0.43; P = 0.855$	$F_{6, 56} = 0.43; P = 0.966$
Conrad					
Water	60.62 ± 2.38*abc*	61.93 ± 0.18	14.00 ± 0.19	9.38 ± 0.10	34.17 ± 0.47
Neem L	63.90 ± 2.23*ab*	61.93 ± 0.18	13.88 ± 0.20	9.36 ± 0.10	34.41 ± 0.52
Neem H	61.63 ± 2.59*abc*	61.80 ± 0.15	14.11 ± 0.20	9.41 ± 0.10	33.00 ± 0.90
Xpectro L	64.35 ± 3.30*ab*	61.42 ± 0.28	13.97 ± 0.15	9.22 ± 0.12	33.93 ± 0.55
Xpectro H	56.27 ± 2.60*abc*	61.69 ± 0.24	14.10 ± 0.16	9.20 ± 0.10	33.83 ± 0.59
Actigard L	56.62 ± 2.74*abc*	61.87 ± 0.18	14.16 ± 0.21	9.06 ± 0.09	33.46 ± 0.37
Actigard H	51.71 ± 1.77*c*	61.71 ± 0.19	14.52 ± 0.19	9.21 ± 0.15	33.52 ± 0.41
Stat. output	$F_{6, 49} = 2.88; P = \mathbf{0.017}$	$F_{6, 56} = 0.77; P = 0.595$	$F_{6, 56} = 0.99; P = 0.437$	$F_{6, 56} = 1.05; P = 0.403$	$F_{6, 56} = 0.64; P = 0.695$

Mean values within columns bearing the different letters are significantly differetn (Tukey test, P<0.05)

Evaluation of the effectiveness of entomopathogenic fungus and trap crops for the management of wireworms on spring wheat

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Aim of the study

The aims of this study were: 1) to evaluate the effectiveness of trap crops for the management of wireworms and 2) to evaluate efficacy of entomopathogenic fungi for wireworm management under lab and field conditions.

Figure 1. Wireworms feeding on spring wheat and pupa of wireworm in the soil.

Material and Methods

Study sites

In 2018, six sites were selected for evaluating entomopathogenic fungus and trap crops. All the sites were pre analyzed for presence of wireworms before commencing the experiments. Three irrigated and two non-irrigated sites were selected in Pondera and Teton counties. Three irrigated sites were at Ledger (N48° 16.334' W111° 53.175'), Valier (N48° 18.454' W111° 55.524'), and Choteau (N47° 90.238' W112° 23.802') and two non-irrigated sites were at Pendroy (N48° 56.009'

W111° 40.565’; hereafter named as Pendroy-1) and (N48° 04.206’ W112° 20.099’; hereafter named as Pendroy-2). The wireworm pressure was moderate to high in the selected sites.

Experimental design

The experiment used a Randomized Complete Block Design (for EPF experiment) and Split Plot Design (for trap crop experiment) with a total of 48 plots [including four replications. Each plot was 3.6 ×1.2 m. Buffer zones of 0.6 m were maintained between plots. Before seeding, the herbicide glyphosate (RT3®, Monsanto Company, St. Louis, MO) was applied at 2.5 L/ha for weed control, following regional farming practices. Before planting, fertilizer (N, P, and K) was applied at a ratio of 224.2, 0, and 22.4 kg/ha in a band about an inch away from the seed using Morris® double shoot no-till openers during planting, and an additional fertilizer application (N, P, and K at a ratio of 12.3, 25.2, and 0 kg/ha) was applied with the seed through the seeding cone of the plot drill. The experimental plots at irrigated sites received 5 cm of water via overhead irrigation once a week. Non-irrigated sites did not receive any water. For trap crop experiment, Duclair spring wheat were seeded at 22 seeds/sq.ft and Montech pea at 12 seeds/sq.ft. Each plot had four rows. Peas and wheat at every site were seeded in 48 plots, outer 12 plots on each side were seeded with peas and inner 24 plots were seeded with wheat. In each plot four rows were planted. Peas in outer rows are named as Pea1 and inner rows are named as Pea 2. Inner most wheat rows are named as Wheat 2 and outer rows of wheat are named as Wheat 1 (Figure 2). For entomopathogenic fungus (EPF) experiment, spring wheat cultivar, Duclair was seeded at the rate of 22 seeds/sq. feet. Imidacloprid (Gaucho® 600, Bayer Crop Science), seed treatment commonly used by growers, was used as a chemical control. EPFs used in 2018 were on two carrier, millet and couscous. The treatments applied in field were in granules on millet and couscous. The treatments were, millet, couscous, *Beauveria bassiana* GHA millet, *Beauveria bassiana* GHA couscous, *Beauveria bassiana* ERL836 millet, *Beauveria bassiana* ERL836 couscous, *Metarhizium brunneum* F52 millet, *Metarhizium brunneum* F52 couscous, *Metarhizium robertsii* DWR2009 millet, and *Metarhizium robertsii* DWR2009 couscous. All EPF treatments were applied with seeds in furrows (at the rate of 5gms/plot Table 1). The fungus formulations were prepared by USDA ARS, Sidney MT. The fields were seeded at Pendroy (14 May and 16 May), Choteau and Valier (24 May) and Ledger (29 May 2018). The first irrigation took place within 30 days of planting in irrigated fields, and crops were harvested in August and October 2018.

Sampling for plant damage

To determine the level of crop damage from wireworms, the number of seedlings in each plot was measured randomly using the 1 m line intercept method. Two counts were taken from each plot, from the two middle rows. The first count was taken two weeks after planting. The starting and ending points of the sample areas (n = 2; each 1 m in length) were labeled with wooden stakes, so that the same group of seedlings could be recounted each time. Subsequent counts were taken at two-week intervals at both sites. At harvest, the height of these same marked plants was recorded using a wooden meter scale (Washington, USA).

Sampling for wireworms density

To determine the density of wireworms larvae, traps were established in each plot areas following the soil sampling bait-trap method of Reddy *et al.* (2014), which consisted of stockings filled with a mixture of wheat and barley.

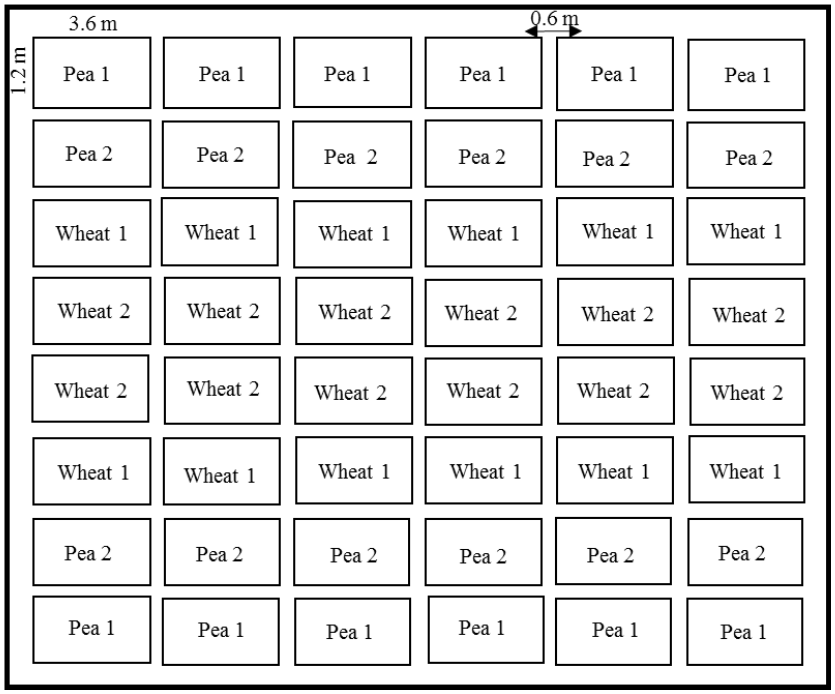

Figure 2: The schematic representation of the split plot design of experiment at five sites in 2018. Spring wheat as a main crop, was planted inside and rows of pea were planted as border.

The traps were soaked for 24 hours to make the seeds sprout which is attractive to wireworms due to CO_2 release. The traps were buried in 8–15 cm deep hole and were covered with black plastic to provide an amenable environment to wireworms. Traps were then collected at 15 days and 30 days post-deployment for assessment of larval numbers. Traps with wireworms were brought to the Western Triangle Agricultural Research Center (WTARC), Conrad, Montana. At WTARC, traps were processed in Berlese Funnels (Bioquip products, California, USA; wooden stands set up for Berlese Funnel were built at WTARC) and wireworms were separately collected from each plot and identified using keys described by Etzler (2013).

Post-harvest data collection

Before harvesting, the plot's surface areas were calculated. After harvesting, wheat and pea from each plot were brought to the WTARC facility and cleaned using a seed cleaning machine (Almaco, Allan Machine Company, Iowa, USA). The plot and test weight was measured using a laboratory balance (Ohaus, Adventure™ Pro model AV8101). Wheat samples were processed through a grain analyzer (Perten Instruments IM9500; Hägersten, Sweden) to determine grain moisture and protein, while peas and lentils were processed with another grain analyzer (Perten Instruments AM5200; Hägersten, Sweden). Protein in pea was analyzed using a Foss grain analyzer (Infratec™ 1241).

Statistical analysis

Analysis of variance (ANOVA) was carried out using the PROC Mixed procedure in SAS 9.4 (PROC Mixed, SAS Institute 2018). Data were pooled for each replicate, and treatments were considered as fixed effects while the block was considered a random effect. Normality of data was tested with a Univariate procedure (PROC Mixed). The effect of treatments, on the number of plants, seed test weight, seed yield, and the number of wireworms within wheat were analyzed in ANOVA. Estimates of least square means and differences of least square means were evaluated (Type 3 test of fixed effects F-test). Multiple comparisons among the treatments were made using Fisher's Least Significant Test (LSD) at $\alpha = 0.05$ by using the standard error generated in ANOVA. In trap crop experiment, dispersion of wireworms between the plots was evaluated by using Generalized Linear Model.

Results

Evaluation of efficacy of entomopathogenic fungus

Out of five selected sites, significant variation in yield was only found at one site (Pendroy-2; F=772; df=33; P<0.0001) (Figure 3, 4). Wireworm pressure at all the five sites varied and Pendroy-2 site had highest wireworm pressure (>5 per trap), followed by Ledger (<1.5 per trap), Choteau (<1 per trap), Pendroy-1 (0.5 per trap) and Valier site (<0.2 per trap) (Figure 5). Since at Valier site, the wireworm pressure was much lesser (Table 3), hence we do not consider the impact of treatments on yield at that site for both EPF and trap crop experiment. The yields were greater at irrigated sites but at Choteau site which is irrigated hail damage was incurred hence the yield was less (Table 2, 4; Figure 4). Nevertheless, among non-irrigated sites after post-hoc analysis (α=0.05), at Pendroy-1 site *Beauveria bassiana* ERL836 on millet carrier and *Metarhizium robertsii* DWR2009 on both millet and couscous carrier provided significantly greater yield compared to control (F=403; df=33; P<0.3947). At Pendroy-2 the greater wireworm pressure resulted in no yield with some treatments. Conventional seed treatment (imidacloprid) provided a significant yield and hence protection from wireworms. Treatments, *B. bassiana* ERL836 on millet carrier and millet carrier alone provided a significant protection against wireworm (Table 2; F=772; df=33; P<0.0001). These two treatments also had significantly greater test weight. At irrigated sites, at both sites, *Beauveria bassiana* GHA on millet and couscous carrier and couscous alone as carrier provided a significant yield compared to control (Table 2; F=205; df=33; P<0.33; F=933; df=33; P<0.19).

Evaluation of the effectiveness of trap crops

All the sites have the variances which are higher than the observed means indicated that dispersion of wireworms was high between the wheat and pea plots (Table 3). This dispersion also made the analysis complicated since Yield of wheat in both treatments (Wheat 1 and Wheat 2) did not differ significantly at any site but yield of peas differed significantly in both treatments (Pea 1 and Pea 2) at sites, Pendroy 2 and Choteau (Table 4; F=13; df=11; P<0.003). At site Pendroy 2 which has maximum average wireworm pressure pea yield was significantly less in inner rows compared to outer rows of peas (F=8.3; df=11; P<.0001) indicating greater damage to peas closer to wheat rows. At all the five sites there was no difference in the wheat yield in wheat 1 and wheat 2 rows indicating no effect of pea rows on wheat yield (Table 4). The wireworm population dispersion in 15 to 30 days' time, at Pendroy 2 site, indicated increase in wireworm number with the time but greater increase was observed in wheat rows. Only at Pendroy 1 site, reduction in wireworm population was observed in 30 days' time and otherwise rest all the sites had greater population of wireworms in 30 days' time. Overall, the impact of pea crop was not observed in wheat crops.

Conclusion

In 2017, *Metarhizium robertsii* DWR2009 on millet gave numerically high yield. This year we tested the efficacy of carrier (millet and couscous) and also new strain, *Beauveria bassiana* ERL836. In 2018, results indicated that in non-irrigated sites millet and *Beauveria bassiana* ERL836 on millet gave protection from wireworms and hence greater yield was observed in the plots treated with these two treatments. Whereas in irrigated sites, *Beauveria bassiana* GHA on millet and couscous carrier and couscous alone as carrier gave higher yield. The results indicate that both millet and couscous have impact on wireworms along with entomopathogenic fungus. In trap crop experiment, according to last results (Adhikari and Reddy 2017; Sharma et al. 2018), pulses especially peas attracted wireworms towards them and hence this year we have tested peas along with border in split plot design. This year, we have found that at the site where wireworm pressure was highest, pea rows closer to wheat had more damage and hence less yield was noticed. Nevertheless, due to high wireworm dispersion, no significant effect was noticed in wheat yield and further exploration is required.

Table 1 Materials, rates, and methods of application for treatments applied in study of wireworm control at non-irrigated (Pendroy-1 and Pendroy-2) and irrigated sites (Choteau and Ledger), Montana in 2018.

Treatment	Material	Rate	Source
T1:	Control (Water)		
T2:	Gaucho® (Imidacloprid)	0.157 ml/L (2.4 oz/45.352 kg/seed)	Bayer Crop Science
T3:	Millet	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T4:	Couscous	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T5:	*Beauveria bassiana* GHA Millet	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T6:	*Beauveria bassiana* GHA Couscous	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T7:	*Beauveria bassiana* ERL836 Millet	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T8:	*Beauveria bassiana* ERL836 Couscous	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T9:	*Metarhizium brunneum* F52 Millet	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T10:	*Metarhizium brunneum* F52 Couscous	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T11:	*Metarhizium robertsii* DWR2009 Millet	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T12:	*Metarhizium robertsii* DWR2009 Couscous	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS

Table 2 Impact of Entomopathogenic fungus treatments on spring wheat 'Duclair' performance in 2018 in terms of plant count, yield, and test weight. Wireworm population collected from each treated plot is also analyzed. Standard error and least significant differences are calculated with the means generated by PROC MIXED analysis (α=0.05). The treatments were applied in Randomized Block Design (n=4); water was used as control (T1) and imidacloprid was used as chemical control (T2).

Non-irrigated sites					Irrigated sites			
Pendroy site 1					Choteau			
Treatments	Plant Count	Yield (kg/ha)	Test Weight (gms)	No. of wireworms	Plant Count	Yield (kg/ha)	Test Weight (gms)	No. of wireworms
T1:	8.37±0.7a	1805±142c	74.5±0.35a	0±0.58a	7.5±0.7a	311±73b	72±0.8ab	2.5±0.76ab
T2:	9±0.7a	2194±142abc	73.4±0.35b	2.75±0.58a	7.7±0.7a	**629±73a**	74±0.8a	2.5±0.76ab
T3:	8.37±0.7a	2041±142abc	74.2±0.35ab	1±0.58a	8.5±0.7a	515±73ab	73±0.8ab	0.75±0.76b
T4:	9±0.7a	2190±142abc	74.4±0.35a	1±0.58a	8.5±0.7a	476±73ab	72±0.8ab	1.75±0.76b
T5:	9.37±0.7a	2114±142abc	74.25±0.35ab	1±0.58a	8±0.7a	**541±73a**	73±0.8ab	1.5±0.76b
T6:	9.25±0.7a	2162±142abc	74.26±0.35ab	0.5±0.58a	8.2±0.7a	**553±73a**	72±0.8ab	2.3±0.76ab
T7:	8.87±0.7a	**2226±142ab**	74.91±0.35a	1.25±0.58a	9.2±0.7a	440±73ab	73±0.8ab	3.75±0.76a
T8:	8.75±0.7a	2038±142abc	74.51±0.35a	1±0.58a	7.6±0.7a	507±73ab	72±0.8ab	1.75±0.76b
T9:	8.87±0.7a	2081±142abc	74.37±0.35a	1.5±0.58a	8.7±0.7a	465±73ab	71±0.8b	1.5±0.76b
T10:	8.87±0.7a	1877±142bc	74.52±0.35a	0.5±0.58a	8.5±0.7a	492±73ab	73±0.8ab	0.75±0.76b
T11:	8±0.7a	**2236±142ab**	74.46±0.35a	1±0.58a	8.8±0.7a	430±73ab	73±0.8ab	1±0.76b
T12:	9.12±0.7a	**2293±142a**	74.42±0.35a	0.75±0.58a	8.8±0.7a	455±73ab	74±0.8a	1.2±0.76b
F (P)	1.9 (0.97)	403.53 (0.3947)	0.88 (0.29)	1.6 (0.23)	1.78 (0.66)	205 (0.33)	2.3 (0.53)	2 (0.19)
Pendroy site 2								
Treatments	Plant Count	Yield (kg/ha)	Test Weight (gms)	No. of wireworms	Plant Count	Yield (kg/ha)	Test Weight (gms)	No. of wireworms
T1:	2±0.88b	0±277d	0±13d	9±3abc	13.5±1.4b	3710±348b	74±0.5bc	1.5±1.5a
T2:	**9±0.88a**	**2194±277a**	**72±13a**	10±3abc	16.8±1.4ab	**4857±348a**	75±0.5a	2.75±1.5a
T3:	2±0.88b	**1103±277b**	**52±13ab**	7±3abc	14.8±1.4ab	4457±348ab	74±0.5abc	3±1.5a
T4:	2±0.88b	606±277bcd	35±13bcd	9±3abc	13±1.4b	**4742±348a**	74.6±0.5abc	2±1.5a
T5:	2±0.88b	244±277cd	16±13cd	11±3abc	14.9±1.4ab	**4819±348a**	74.8±0.5ab	3±1.5a
T6:	1±0.88b	0±277d	0±13d	**15±3a**	15±1.4ab	4497±348ab	74.4±0.5abc	2.5±1.5a
T7:	3±0.88b	**898±277bc**	50±13abc	6±3bc	13.2±1.4b	4048±348ab	74±0.5abc	2.75±1.5a
T8:	1±0.88b	0±277d	0±13d	7±3abc	15.3±1.4ab	3707±348b	73.6±0.5c	4.75±1.5a
T9:	2±0.88b	330±277cd	16±13cd	5±3c	15.6±1.4ab	4112±348ab	74±0.5abc	2.5±1.5a
T10:	2±0.88b	284±277cd	17±13d	6±3bc	17.8±1.4a	4175±348ab	74±0.5abc	5.5±1.5a
T11:	1±0.88b	0±277d	0±13d	12±3abc	15.2±1.4ab	4157±348ab	74±0.5abc	3±1.5a
T12:	1±0.88b	213±277cd	16±13cd	14±3ab	13.6±1.4b	4163±348ab	73.9±0.5bc	2.5±1.5a
F (P)	**2.5 (<.0001)**	**772 (<.0001)**	36 (0.0018)	8.4 (0.3)	4 (0.43)	933 (0.19)	1 (0.29)	4.2 (0.85)

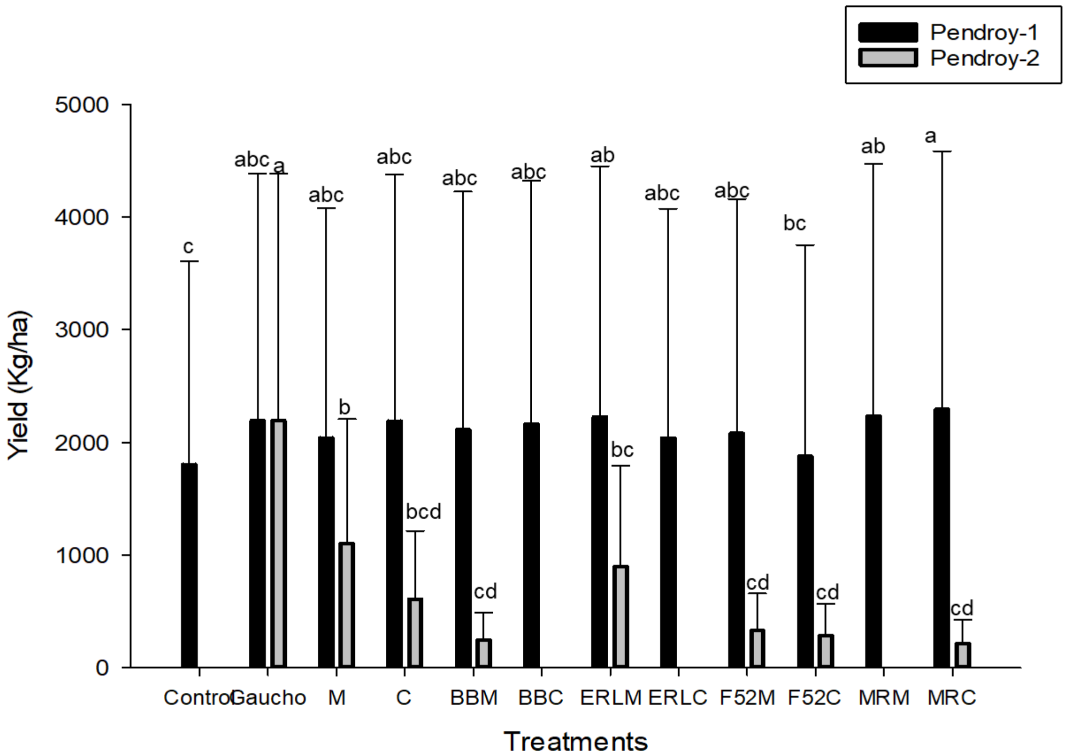

Figure 3. Mean yield (kg/ha) of wheat at two non-irrigated sites, Pendroy-1 (■) and Pendroy-2 (□) in 2018. [n = 4]. Different letters above the bars indicate significant differences (α= 0.05). y-axis shows mean yield (mean yield+ SE) and x-axis indicates twelve treatments.

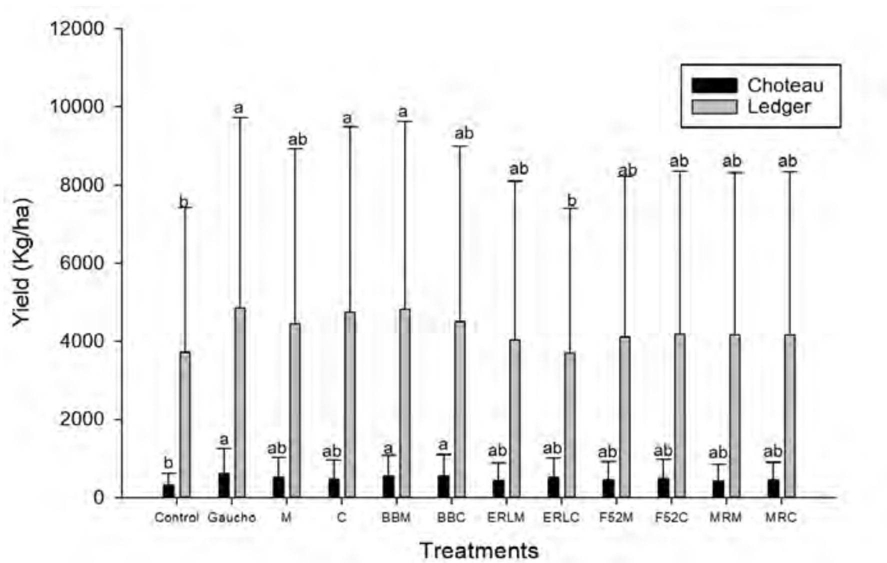

Figure 4. Mean yield (kg/ha) of wheat at two non-irrigated sites, Choteau (■) and Ledger (□) in 2018. [n = 4]. Different letters above the bars indicate significant differences (α= 0.05). y-axis shows mean yield (mean yield+ SE) and x-axis indicates twelve treatments.

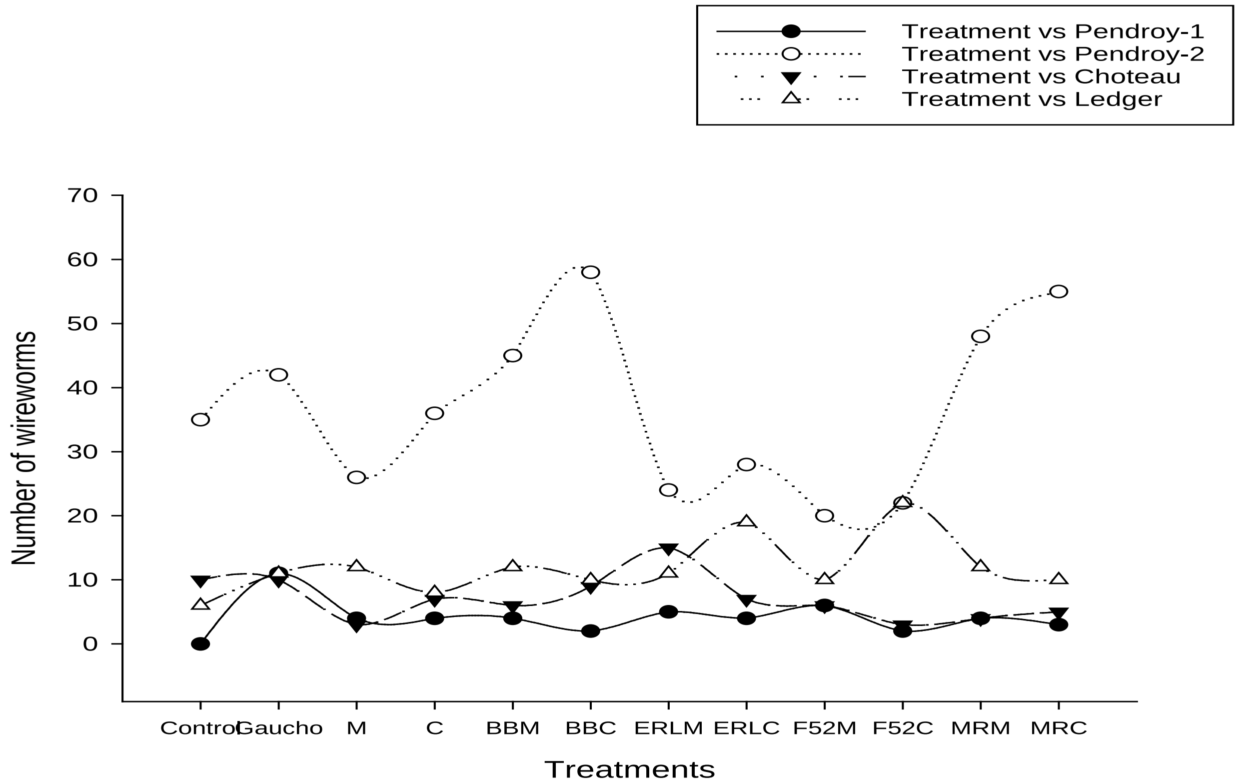

Figure 5. Total numbers of wireworms collected in bait traps associated with the wheat at different treatments at Pendroy-1 (●), Pendroy-2 (○), Choteau (▲), and Ledger (△) in 2018. [n = 4]. Difference were analyzed between treatments at α= 0.05. y-axis shows number of wireworms (mean+ SE) and x-axis indicates twelve treatments.

Table 3: The average counts are small (less than 3), except for site JS, which shows much higher average counts, especially for wheat. Some of the variances are (much) higher than the observed means, indicating that over dispersion of wireworms is found throughout all the sites. The variances are calculated by using Generalized Linear Model (GLM).

Site	Day	Crop	Mean	Variances
Pendroy 1	15	pea	0.9	2.2
Pendroy 1	15	wheat	0.6	0.9
Pendroy 1	30	pea	0.3	0.4
Pendroy 1	30	wheat	0.3	0.6
Pendroy 2	15	pea	3.0	5.9
Pendroy 2	15	wheat	6.4	49.2
Pendroy 2	30	pea	4.7	30.2
Pendroy 2	30	wheat	15.3	318.4
Choteau	15	pea	0.5	0.5
Choteau	15	wheat	1.1	1.2
Choteau	30	pea	1.2	2.3
Choteau	30	wheat	1.3	4.0
Ledger	15	pea	2.0	8.4
Ledger	15	wheat	1.1	1.6
Ledger	30	pea	2.9	9.4
Ledger	30	wheat	1.5	3.9
Valier	15	wheat	0.1	0.1
Valier	15	wheat	0.1	0.1
Valier	30	pea	0.0	0.0
Valier	30	pea	0.0	0.0

Table 4: Yield of spring wheat 'Duclair' and 'Montech' pea in 2018. Standard error and least significant differences are calculated with the means generated by PROC MIXED analysis (α=0.05). The treatments were applied in Split Plot Design.

	Pendroy 1	Pendroy 2	Choteau	Ledger
Pea 1	2118±88a	163±5a	228±32b	2996±177a
Pea 2	2058±88a	130±5b	259±32a	3120±177a
F (P)	226 (0.5)	8.3 (<.0001)	13 (0.003)	324 (0.4)
Wheat 1	2100±82a	256±250a	1295±125a	4093±237a
Wheat 2	2144±82a	387±250a	1212±125a	4027±237a
F (P)	154 (0.5)	486 (0.5652)	308 (0.5)	420 (0.7)

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References

Adhikari A, and Reddy GVP. 2017. Evaluation of trap crops for the management of wireworms in spring wheat in Montana. Arthropod Plant Interact. 11: 755–766. DOI 10.1007/s11829-017-9533-5.

Etzler FE. 2013. Identification of economic wireworms using traditional and molecular methods. M.S. thesis dissertation, Montana State University, Bozeman, Montana.

Reddy, GVP, Tangtrakulwanich K, Wu, Miller JH, Ophus VL, Prewett J, and Jaronski ST. 2014. Evaluation of the effectiveness of the entomopathogens for the management of wireworms (Coleoptera: Elateridae) on spring wheat. J. Invertebr. Pathol. 120: 43–49.

SAS Institute Inc. 2018. 9.4 In-Database Products, User's Guide, fifth ed. SAS Publishers, Cary, NC, USA.

Sharma A, Sandhi RK, Briar SS, Miller JH, and Reddy GVP. 2018. Assessing the performance of pea and lentil at different seeding densities as trap crops for the management of wireworms in spring wheat, *Journal of Applied Entomology, accepted.*

Role of entomopathogenic nematodes for the management of wireworms (Coleoptera: Elateridae)

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Aim of the study

The different aims of the study were: (1) To test the efficacy of available EPN strains against wireworms, (2) To extract and identify the native EPN strains in Golden Triangle Area of Montana, and (3) To test the efficacy of found native EPN strains against wireworms.

Materials and methods

Wireworm Collection: The larvae of different instars were collected from different locations (Conrad, Pendroy, and Kallispell fields). The wireworms were collected by using stocking traps. The stocking traps with soaked wheat seeds were put in the different spots in soil and then covered with plastic sheets. After 15-20 days, the stocking traps were collected and brought back to the laboratory. These stocking traps were replaced every time we collected the old traps. The stocking traps with wireworms were put in the Berlese Funnels for 12 hours and the wireworms were collected and categorized into small, medium and large based on their size (Figure 1). We found mainly three wireworm species viz. *Limonius californicus, Hypnoides bicolor,* and *Aeolus mellillus.* However, the wireworm specie, *L. californicus* is the dominant specie in Golden Triangle Area of Montana, only this specie is being used in the experiments. These wireworms were stored in the incubator in the plastic cups with sterilized soil and wheat seeds as their food. These plastic cups were put in the incubator at 8° C. The wireworms were also collected manually by collecting the soil from fields infested with wireworms.

1. Efficacy of available EPN strains against wireworms:

EPN's species: Ten nematode strains were obtained from Dr. David Shapiro (USDA ARS, Georgia). The list is given in Table 1as follows:

Table 1. List of EPN strains (Source: Dr. David Shapiro, USDA-ARS, Georgia)

Entomopathogenic nematode species	Strain
Steinernema carpocapsae	All strain
	Cxrd strain
Steinernema feltiae	SN strain
Heterorhabditis bacteriophora	HP88 strain
	VS strain
Steinernema riobrave	355 strain
	7-12 strain
Heterorhabditis floridensis	K22 strain
Heterorhabditis georgiana	Kesha strain
Steinernema rarum	17 c + e strain

Nematodes rearing: The nematodes received were reared on waxworm larvae. Ten waxworm larvae were placed on the filter paper in the petri dishes. 500-1000 Infective Juveniles (IJ)/ml were inoculated in the petri dishes with 100-200 IJ/larva. Petri dishes were left at room temperature for nematode infection. After 3-5 days, nematodes infected larvae were placed on the white traps for rearing (Figure 1). After 7 to 10 days, nematodes were collected from the white traps and stored in the tissue culture flasks.

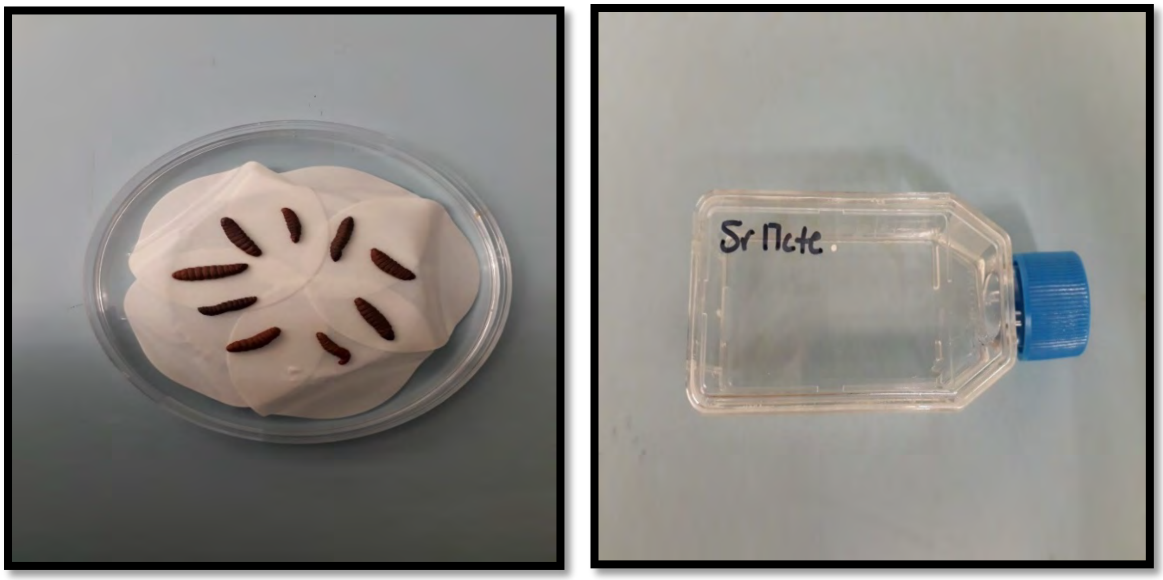

Figure 1. Infected waxworm larvae on white trap and collected IJs stored in tissue culture flasks

Nematode doses: For preparing the different nematode doses, the nematode were dissolved in distilled water (100-1000 ml). After making the solution, 1 ml of the nematode suspension was taken in the nematode counting slide and the number of nematodes were counted under the microscope. This was repeated 5 times for avoiding the errors in the counting. Then the number of IJ/ml were characterized. First, the higher dose i.e. 5600 IJ/ml was prepared and on the basis of this dose, further dilutions like 2800, 1400, and 700 IJ/ml were made. This procedure was followed for the all the available nematode strains. These nematode doses were stored in the incubator with 8° C temperature and used within 10 days after collection. The nematodes were observed under microscope for their survival and nematodes with >95% survival rate were used in the experiment.

Laboratory bioassay: In the bioassay, medium sized larvae (10-20 mm) of *L. californicus* were used. 1 oz. plastic cups were filled with 20 g of sterilized sandy loam soil (sand-78 %, silt-12%, clay-10%, pH-7.7, and organic matter-1.4) and few soaked wheat seeds were provided as a food source for the larvae. One wireworm larva which had been held at 8° C were placed in the cups. The different nematode doses (i.e. 5600, 2800, 1400, and 700 IJ/ml) were inoculated onto the soil surface in 1 ml of water. The soil moisture was standardized to 15%. In the cups with control treatment, only 1 ml of water was applied. The cups were capped with some holes and then placed in the growth chamber at 22° C, 75 % RH in the dark (Figure 2). The larval mortality was observed at 24 hr intervals for 28 days. The dead larvae were dissected under the stereomicroscope to confirm that the infection was due to the nematodes. The same experiment was repeated 5 times with different cultures of nematodes.

Penetration Rate: The penetration rate of different EPNs was also observed. The dead wireworm larvae were placed on room temperature for 2 more days after their death to let infective juveniles grow to males and females and then number of nematodes inside the larval body were counted by dissecting the larva.

Figure 2. Inoculated cups in incubator

Shade house screening: Six promising strains found from the laboratory bioassay were screened in a shade house experiment. The plastic pots (18 cm height, 12 cm diameter; surface area 600 cm sq.) were filled with sterilized sandy loam field collected soil to 10 cm height. Approximately, 8-10 wheat seeds were sown in each plastic pot. The plants were watered twice a day because of the sandy soil (loose moisture quickly) and plants were allowed to grow for 3 weeks. After that, 5 wireworm larvae were released in the soil in each replicate. After 5 hours, 2 doses; 60000 IJs (100 IJs/cm^2) and 15000 IJs (25 IJs/cm^2) of promising EPN's from laboratory (Sr 355, Sr 17 c+e, ScA11, ScCxrd, HbVS, and Sr 7-12) were inoculated in the pots with a pipette. The pots were kept in the shade house with average temperature of 21°C (5°-30°C) and soil moisture 25±5%. There were 16 replications for each strain. The larval mortality was observed after 7, 14, 21, and 28 days. 4 out of 16 replications were observed destructively and observed for larval mortality every week. The alive wireworm larvae were kept for 3 more days to observe the mortality.

2. To extract and identify the native EPN strains in Golden Triangle Area of Montana

Collection of soil samples: The soil samples were collected from 30 different fields from Pendroy, Choteau, Valier, Conrad, Kallispell, Knees, Brady, Collins, Dutton, Shelby, Sunburst, and Tiber areas were collected in Golden Triangle Area of Montana in summer 2018. The fields surveyed were winter wheat, canola, peas, alfalfa, chickpea, flax, hemp, durum wheat, lentil, triticale, spring wheat, and fallow. From each field, 5 random plots (8-10 m^2) were chosen and, within each sample plot, 5 random 10-15 cm deep soil samples were taken with the help of hand shovel. Overall, there were 25 soil samples for each field site. The shovel was washed with water and sterilized with 75% ethanol in between the samples for avoiding the contamination. These collected soil samples were then placed into plastic bags brought back to laboratory in a cooler (8-10° C). The latitude, longitude, site, date, habitat, soil texture, pH, organic matter and electrical conductivity were recorded for each field soil.

Isolation of entomopathogenic nematodes; Insect Bait Method - Bedding and Akhurst (1975): Approximately 300 g soil sample was placed in 500 ml plastic cups with five *G. mellonella* larvae in each cup with some moisture. The plastic cups were incubated at room temperature for 7 days by observing them regularly after 2 days. If no larvae were dead after 7 days, we considered that entomopathogenic nematodes are absent from that sample. The dead *G. mellonella* larvae were removed and placed on the white traps. These white trap petri dishes were checked daily for nematodes. After 7 to 10 days, emerging nematodes from well infected cadavers were concentrated and checked again for *G. mellonella* larval mortality by inoculating with the emerged nematodes. These emerged nematodes were identified by using morphological and molecular techniques.

Morphological identification: The extracted nematode infective juveniles from different fields were cultured through *Galleria mellonella.* 10 *Galleria* larvae were infected with one hundred (100-200) nematode infective juveniles for each test isolate. The cadavers were dissected in ringer's solution according to procedure given aby Kaya and Stock (1997). The 1st generation males and females were recovered 2-3 days after infection and others on 5-6 days for the 2nd generation of the both sexes in case of *Steinernema* sp.. For *Heterorhabditis* sp.; dissections were done 3-4 days after infection to recover 1st generation hermaphrodites, and 6-9 days after infection for 2nd generation males and females. The third stage nematode infective juveniles were collected during the 3 days after initial emergence. Overall, twenty 1st and 2nd generation adults and twenty infective juveniles were observed. The nematodes were killed in hot water at 60°C and fixed in equal amount of hot TAF (60°C) and ringer's solution. The nematodes were left in the fixative for 2 days. After processing to glycerin in desiccator as explained by Kaya and Stock (1997), the nematodes were mounted on the glass slides and observed for different morphological characters; body length (TBL), maximum body width (MBW), tail length (TL), anal body width (ABW), distance from the anterior end to oesophagus (ES), distance from anterior end to excretory pore (EP), distance from anterior end to nerve ring (NR), spicule length (SPL) and Gubernaculum length (GUL) for males and for females, distance from anterior end to vulva (AV) including all the characters studied for males. The infective juveniles (IJs) were also observed for total body length, maximum body width, tail length, anal body width, distance from the anterior end to oesophagus, distance from anterior end to excretory pore, and distance from anterior end to nerve ring.

Molecular identification:

DNA of different EPN strains were extracted by DNeasy® DNA extraction method by following the modifications of Adams et al. (2007). Approximately 0.25 µl pellet of IJs of different strains was prepared in 2 ml microcentrifuge tubes and IJs in the tube were crushed with the pipette end. 180 µl Buffer ATL was added in the tubes followed by 20 µl proteinase K. The mixture was mixed thoroughly by vortexing, and then incubate at 60°C for 2-3 hours while vortexing every 15 min, until the tissue was completely lysed. After that, 200 µl Buffer AL was added to the sample, and mixed thoroughly by vortexing. It was followed by addition of 200 µl ethanol (100%), and mixed again thoroughly by vortexing. This mixture was pipetted into the DNeasy mini spin column placed in a 2 ml collection tube and centrifuge at 8000 rpm for 1 min. The DNeasy mini spin column was placed in a new 2 ml collection tube and 500 µl Buffer AW1 was added, and centrifuged for 1 min at 8000 rpm. Again, the DNeasy mini spin column was placed in a new 2 ml collection tube and 500 µl Buffer AW2 was added followed by centrifugation for 3 min at 14,000 rpm. Finally, the DNeasy Mini spin column was placed in a clean 1.5 ml or 2 ml microcentrifuge tube and 200 µl Buffer AE was added directly onto the DNeasy membrane. The tubes were incubated at room temperature for 1 min, and then centrifuged for 1 min at 8000 rpm to elute. The PCR reactions were carried out in 0.1 ml micro centrifuge tubes. The contents for the reaction mixture were 2.5 µl Thermopol buffer, 0.5 µl each dNTPs, 1.25 µl of each forward and reverse primer, 0.2 µl Taq polymerase and 17.3 µl ultrapure nuclease free water providing total volume of 23 µl. The contents were mixed on ice in the laminar flow. In the PCR tubes, 2 μl of DNA template as added with 23 µl reaction mixture for a total reaction volume of 25 µl. The tubes were placed in thermal cycler following generic cycling parameters; initial denaturation at 95°C for 10:00 min; denaturation at 94°C for 1:00 min; annealing at 50°C for 1:00 min; elongation at 72°C for 2:00 min; cycling to step 2 for 39 more times; and followed by final elongation at 72°C for 10:00 min. The primers used in PCR were forward ITS-F (5'-TTGAACCGGGTAAAAGTCG-3') and reverse ITS-R (5'-TTAGTTTCTTTTCCTCCGC-3'). 5 µl of the PCR product was visualized on ethidium bromide stained agarose gel in gel electrophoresis for all the strains and the presence or absence of DNA was demonstrated by the DNA bands on the gel. The strains showing smeared bands were purified using gel extraction protocol by using IBI Gel PCR DNA Fragment Extraction Kit. The purified PCR products were then sent for sequencing on both directions together. Another set of primers was used i.e. FNem18S (5'-TTGATTACGTCCCTGCCCTTT-3') and rDNA1.58s(rev) (5'-ACGAGCCGAGTGATCCACCG-3'). The samples has been sent for sequencing in Dr. Byron Adams laboratory at Brigham Young University, Provo.

3. To test the efficacy of found native EPNs against wireworms

Nematode rearing and dose preparations: The same procedure used for rearing of available EPNs in objective 1 was followed for the rearing of native EPNs. After rearing, 4 doses; 5600, 2800, 1400, 700 IJs were prepared by counting the number of infective juveniles.

Laboratory bioassay: 500 ml plastic cups were filled with 150 g autoclaved sandy loam soil (area-140 cm^2). 5 medium sized wireworm larvae were added in each cup. Once the wireworm larvae entered the soil in the cups, 4 EPN doses; 3500 IJs/cup (700 IJs/ml), 7000 IJs/cup (1400 IJs/ml), 14000 IJs/cup (2800 IJs/ml), and 28000 IJs/cup (5600 IJs/ml)) in 5 ml of water. The control cups received 5 ml of water only without any nematodes. The moisture content of soil was standardized to 15%. The wireworm mortality was observed at weekly intervals. The penetration rate was also observed whenever possible.

Statistical Analysis: Factorial ANOVA was performed to determine the effects of EPN strains, doses, and time on wireworm mortality. One way ANOVA was used to analyze the penetration of all the EPN strains. Factorial ANOVA was used to analyze the effect of promising EPN strains on the wireworm morality in shade house experiments. There was no mortality found in control so the data regarding control has not been included in the analysis. Factorial ANOVA was used to analyze the data regarding native EPN bioassay. Data from two laboratory trials repeated in time were combined as no significant interactions were detected between trials. Tukey's HSD test was used as a post hoc test for multiple comparisons between the means at probability ($\alpha = 0.05$). The data was analyzed using the software statistical package R 2.15.1 (R Development Core Team, 2017).

Results and discussion

1. Efficacy of available EPN strains against wireworms:

Laboratory bioassay: The data for wireworm mortality for 10 wireworms for each dose and each EPN strain was averaged for one repetition. So, overall there were 5 replications (repetitions considered as replications) with average of 10 wireworm larvae per replication. The cumulative average larval mortality at weekly intervals was calculated by taking average of 5 replications at 7 DAT (days after treatment), 14 DAT, 21 DAT, 28 DAT and statistical analysis was performed. The *L. californicus* larvae infected with different EPN strains are shown in figure 3.

The overall model included the effect of individual effect of EPN strain, dose, and time and interaction between these 3 factors. There was no significant interaction between EPN strain, dose and time ($F = 0.263$; df = 81, 640; p-value = 1.00). So, the interaction effect was removed from the model. The different EPN strains ($F = 59.93$; df = 9, 640; p-value <0.00001), time ($F = 88.74$; df = 3, 640; p-value < 0.00001), and dose ($F = 40.61$, df = 3, 640, p-value<0.0001) had significant effect on the larval mortality in laboratory bioassay. Also, interaction between EPN strains and doses ($F = 2.532$; df = 27, 640; p-value<0.0001) and between EPN strains and time ($F = 2.859$, df = 27, 640; p-value<0.0001) was found to be significantly different.

In case of 5600 IJs/larva dose (Figure 4a), the larval mortality was less than 20% after one week except Sr 355 and Sr 7-12 with 25-35% mortality. After 2 weeks, mortality reached 40% in all strains except Sr 355, Sr 7-12 and HbVS which showed 50-60% mortality. After four weeks, mortality increased and reached 70% in case of Sr 7-12, ScA11, and ScCxrd. Overall, six strains; Sr 7-12, ScA11, ScCxrd, Sr 17 c+e, Sr 355, and HbVS caused significantly higher mortality as compared to other strains. The mortality decreased as the dose decreased. In case of 2800 IJs/larva (Figure 4b), the same six strains showed high mortality (37-68%) as compared to other 4 strains. There were no significant differences between doses 2800 IJs/larva and 1400 IJs/larva with respect to wireworm larval mortality. The mortality ranged from 40-70% in the effective six strains; Sr 7-12, ScA11, ScCxrd, Sr 355, Sr 17 c+e and HbVS in case of 1400 IJS/larva dose (Figure 4c). However, in case of 2800 IJs/larva dose, the overall mortality was higher (7-57%) as compared to 7-51% in case of 1400 IJs/larva after two weeks. In case of 700 IJs/larva dose (Figure 4d), the mortality was the lowest in all the strains except ScCxrd strain which showed 75% mortality after 4 weeks even higher than 5600 IJs/larva dose with 70% mortality. In all other strains, mortality did not exceed 40% after 4 weeks except ScA11 with 54% and Sr 7-12 with almost 51% mortality in case of 700 IJs/larva dose. Overall, strains ScA11, ScCxrd, Sr 355, Sr 7-12, Sr 17 c+e, and HbVS showed more than 50% mortality in highest dose i.e. 5600 IJs/larva dose. These promising strains and two doses, 2800 IJs/larva and 700 IJs/larva were selected for the further shade house experiments. There was no mortality found in control treatment.

Penetration rate: The penetration rate was counted for all 10 EPN strains but average data (n=20) for effective six strains; ScA11, ScCxrd, Sr 17 c+e, Sr 355, Sr 7-12, and HbVs are presented here in Figure 5.

Overall, number of infective juveniles penetrated inside the larval bodies was higher in 5600 IJs/larva in all the strains. There were significant differences between different doses regarding the number of IJs penetrated inside the larvae except doses 700 IJs and 1400 IJs. In case of 5600 IJs, strain Sr 7-12 had more number of IJs (522.95 ± 30.89) penetrated inside the wireworm larva followed by HbVS (435.15 ± 41.18), Sr 355 (432.15 ± 52.66), Sr 17c+e (427.55 ± 45.74), ScA11 (361.15 ± 36.61), and ScCxrd (358.9 ± 29.44). In dose 1400 IJs, Sr 7-12 had highest penetration rate as compared to other strains.

Overall, these results showed that higher the dose, higher the penetration rate. It is directly correlated to the higher mortality. The reason behind the higher mortality in high doses; i.e. 5600 IJs/larva can be the higher number of IJs entering inside the larval bodies. More number of IJs might have killed the larvae faster than the lower number of IJs in the lower doses.

Shade house experiment:

The model included the effect of individual effect of EPN strain, dose, and time and interaction between these factors. There was no significant interaction between EPN strain, dose and time ($F = 1.061$; df = 15, 144; p-value = 0.40). So, the interaction effect was removed from the model. The different EPN strains ($F = 4.98$; df = 5, 182; p-value = 0.0003) and time ($F = 21.39$; df = 3, 182; p-value < 0.0001) had significant effect on the larval mortality. However, 2 doses used did not have significant differences (($F = 1.18$; df = 1, 182; p-value = 0.0003). All 6 strains used caused less than 30 % wireworm mortality after 2 weeks (Figure 6). But after two weeks, mortality was high all the strains. The EPN strain; Sr 355 caused significantly high mortality (40-50%) within 2-3 weeks in both the doses. After 3 weeks, Sr 7-12 showed 60% mortality in case of 60,000 IJs but showed 30 % in case of 15,000 IJs. Similarly, ScA11 showed 60% mortality after 4 weeks in case of 60,000 IJs as compared to only 30% mortality in case of 15,000 IJs. The strain ScCxrd caused 20 to 35% mortality in case of 60,000 IJs dose and 20-45% mortality at 15,000 IJs dose. Overall, Sr 355, Sr 7-12, ScA11, and ScCxrd showed higher mortality as compared to other two strains; HbVS and Sr 17 c+e with 20-30% mortality only. There was no mortality found in control treatments.

2. To extract and identify the native EPN strains in Golden Triangle Area of Montana

Overall, 19 samples out of 150 samples were found to have nematodes. But, we were able to culture only 4 samples. This might be due to a number of factors like Galleria as inappropriate host for some particular species, unfavorable environmental conditions in the laboratory, low number of nematodes present in the soil samples to infect the host. The four nematode species were named as JMS3, KP, MLS1, and MLS2 and identified using morphological and molecular techniques. The species named JMS3, KP, and MLS1 were found to be Steinernematids and MLS2 as Heterorhabditid on the basis of change in color of waxmoth larvae after nematode infection. The color was pale yellowish to grey in case of Steinernematids and reddish brown for Heterorhabditid infected larvae. The measurements regarding morphological observations are given in Tables 2, 3, 4, and 5. We are still waiting on the sequencing results from Dr. Byron Adams.

3. To test the efficacy of found native EPN strains against wireworm

The different EPN strains were significantly different in regards to larval mortality ($F = 26.64$; df = 5, 668; p-value <0.00001). The other factors; time ($F = 51.29$; df = 3, 668; p-value < 0.00001), and dose ($F = 22.98$, df = 3, 668, p-value < 0.00001) had significant effect also on the larval mortality . Overall, JMS3 showed significantly higher mortality followed by KP, MLS1, and MLS2.

In case of 28000 IJs dose (Figure 7a), the larval mortality was less than 30% after one week. After 2 weeks, the mortality reached 58% in JMS3 strain. After four weeks, mortality increased and reached more than 50% in case of JMS3 (62%) and MLS1 (50%). The range of mortality decreased as the dose was low. In case of 14000 IJs (Figure 7b), the strains KP caused higher mortality (12-52%) followed by JMS3 with 28-50% mortality in 4 weeks. There were no significant differences between two high doses; 28000 IJs and 14000 IJs with respect to wireworm larval mortality. The mortality was lower in dose 7000 IJs and did not exceed 50% (Figure 7c) even in JMS3 and KP. In case of 3500 IJs dose (Figure 7d), the mortality was the lowest in all the strains and did not exceed 30 %. The mortality remained same after 2 weeks in JMS3 and KP and the mortality was almost double as compared to other 2 strains i.e. MLS1 and MLS2. Overall, JMS3 and KP were found to be effective against wireworms and will be used in further experiments. The mortality remained almost same after 3 weeks as there was no significant difference between mortality at 3 weeks and mortality at 4 weeks after nematode treatments.

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References

Adams, B. J., Peat, S. M., and Dillman, A. R. (2007) Phylogeny and evolution. In Entomopathogenic Nematodes: Systematics, Phylogeny, and Bacterial Symbionts; Nguyen, K.B., Hunt, D.J., Eds.; Brill: Boston, MA, USA, Volume 5, pp. 693–733.

Bedding, R. A. and R. J. Akhurst. (1975) A simple technique for the detection of insect parasitic rhabditid nematodes in soil. Nematologica. 21, 109–116.

Kaya, H. K. and Stock, S. P. (1997) Techniques in insect Nematology. In: Lacey LA (ed) Manual of Techniques in Insect Pathology, pp 281±324. Academic Press, New York.

R Development Core Team (2017) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Available: http://www.R-project.org. Cited 19 December 2017.

Figure 3. Nematodes infected wireworm larvae; Left: IJs emerging out of the wireworm larva, Right: EPN adults after dissecting the dead wireworm larva

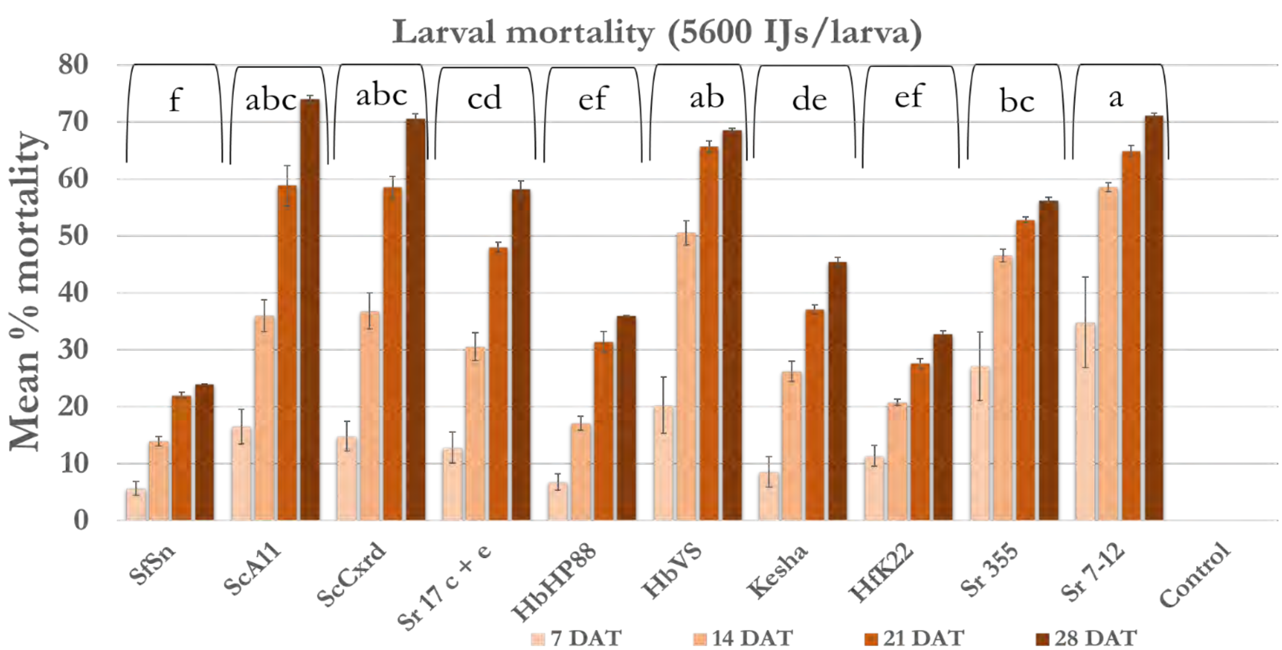

Figure 4a. Mean percentage larval mortality at 5600 IJs/larva

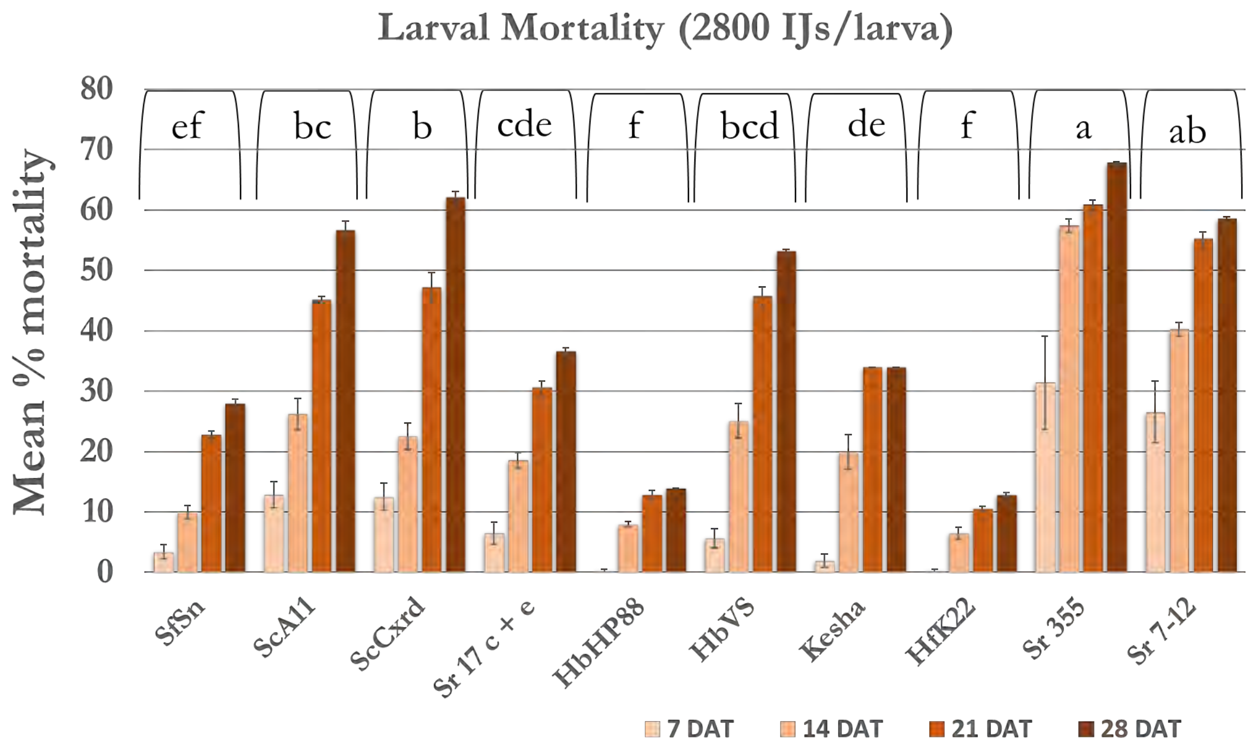

Figure 4b. Mean percentage larval mortality at 2800 IJs/larva

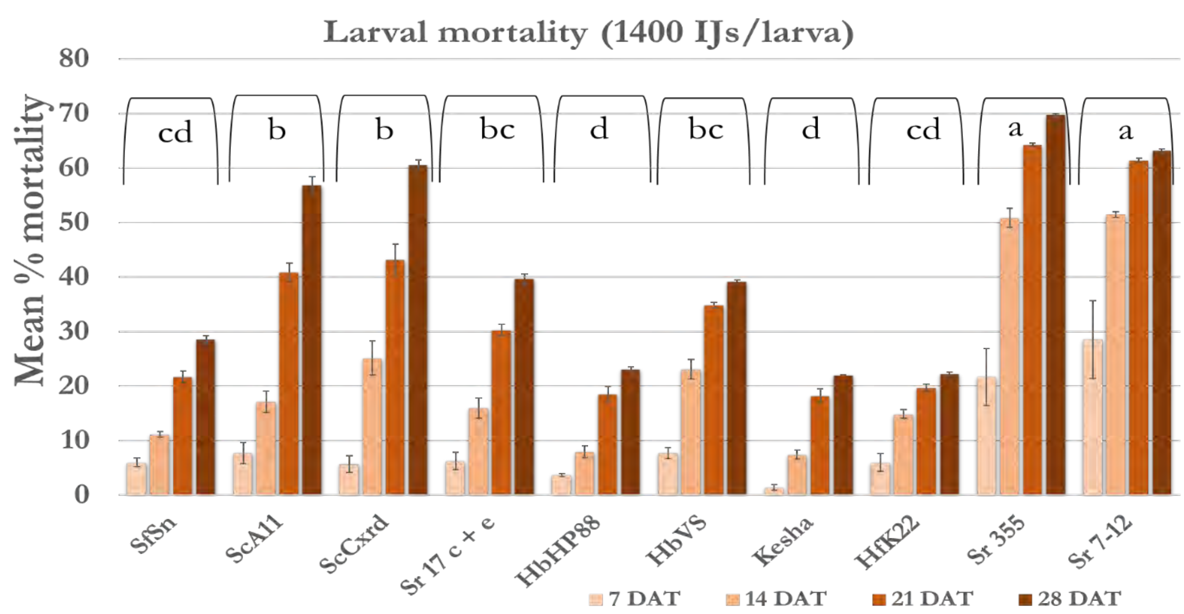

Figure 4c. Mean percentage larval mortality at 1400 IJs/larva

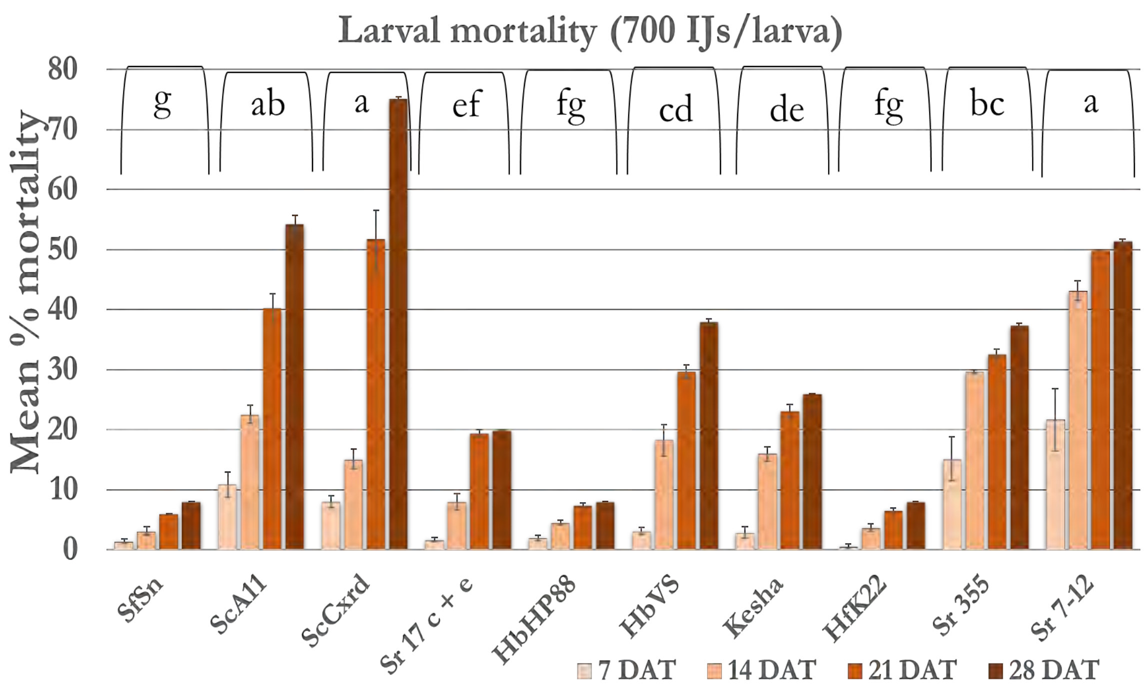

Figure 4d. Mean percentage larval mortality at 700 IJs/larva

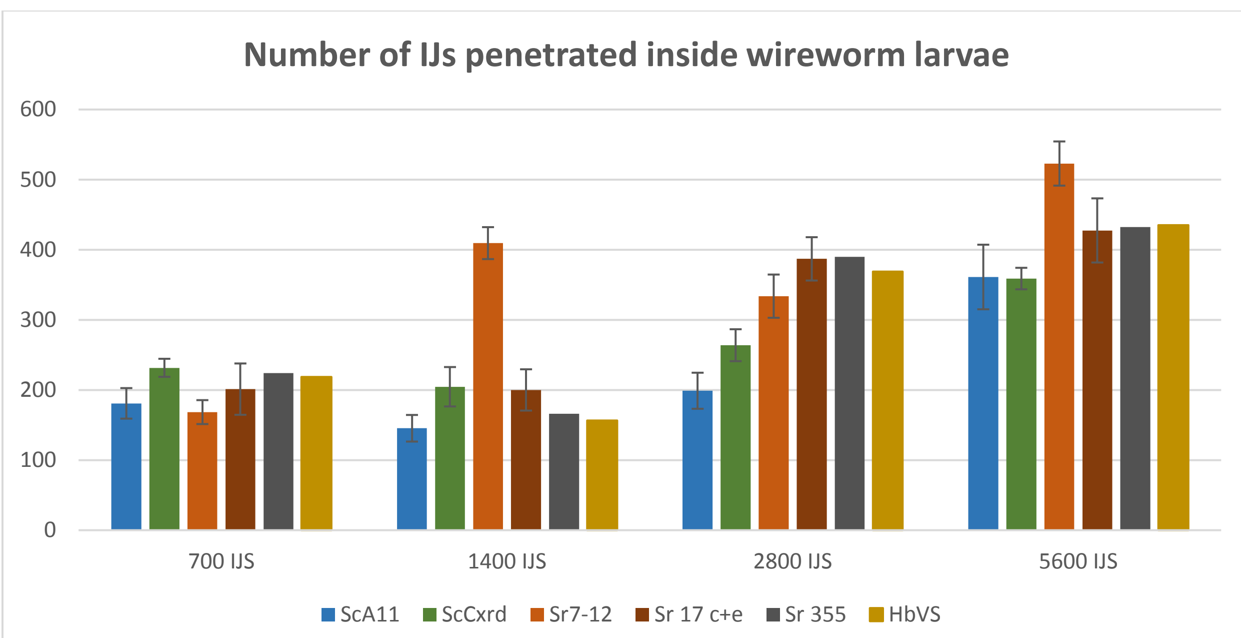

Figure 5. Number of infective juveniles penetrated inside wireworm larvae

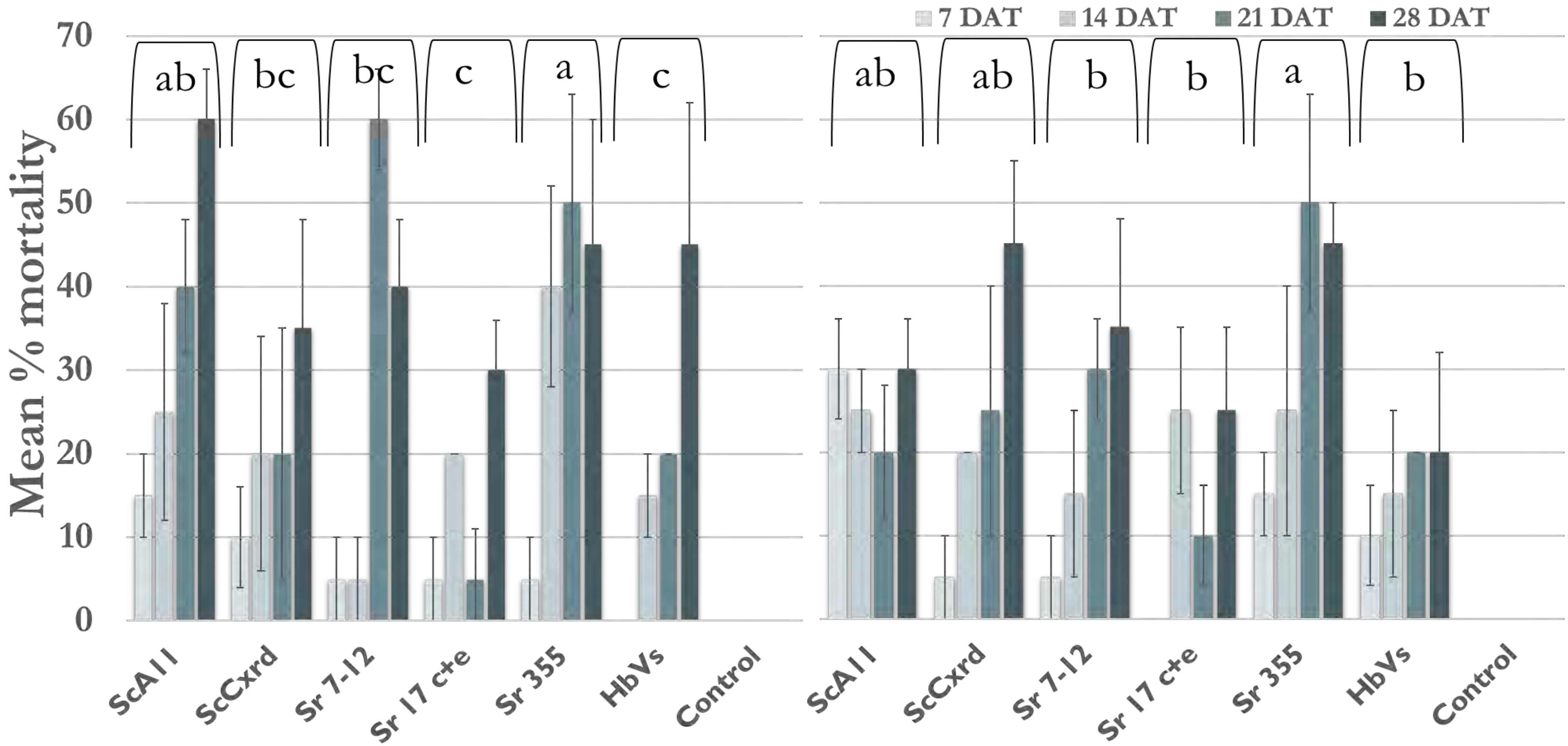

Figure 6. Percentage mean larval mortality; Left: larval mortality at 60000 IJs/pot; Right: larval mortality at 15000 IJs/pot

Table 2. Morphology of JMS3

Character	1st gen female	1st gen male	2nd gen female	2nd gen male	IJ
Body length (L)	4541.9 ± 376.51 (2137-7291)	1494 ± 57.18 (1128-2086)	1857.25 ± 52.09 (1543-2491)	997.3 ± 45.15 (724-1578)	663.05 ± 9.05 (618-793)
Maximum Body dia (D)	198.2 ± 8.19 (150-281)	127.35 ± 4.63 (92-163)	115 ± 3.78 (85-163)	80.35 ± 2.05 (66-100)	25.86 ± 0.56 (21.2-30.3)
Stoma length	6.6 ± 0.33 (4-9)		5.5 ± 0.26 (4-8)		
Stoma width	6.7 ± 0.27 (4-9)		7.25 ± 0.25 (6-9)		
EP	96.5 ± 2.02 (82-118)	98.05 ± 2.22 (76-114)	82.85 ± 2.00 (69-110)	78.85 ± 2.23 (61-94)	59.38 ± 0.83 (53-69)
NR	119.65 ± 3.79 (101-156)	105.6 ± 2.18 (89-123)	109.05 ± 3.38 (91-163)	100.435 ± 2.09 (75-114)	65 ± 0.84 (57-72)
ES	188.95 ± 3.99 (161-218)	152.4 ± 1.85 (133-171)	165.4 ± 2.16 (150-191)	143.05 ± 4.24 (113-199)	91.45 ± 0.78 (84-98)
Tail length with sheath (T)	61.35 ± 2.18 (45-78)	46.05 ± 1.36 (32-59)	50.1 ± 1.63 (38-64)	41.7 ± 1.09 (35-51)	57.43 ± 1.16 (41-64.1)
Tail length without sheath					36.13 ± 1.00 (25.2-43)
Anal body diameter (ABD)	88.95 ± 5.01 (60-125)	59.65 ± 1.89 (39-75)	55.25 ± 2.02 (42-69)	51 ± 1.17 (42-62)	
Distance from anterior end to vulva	2006.2 ± 128.008 (1236-3218)		1055.4 ± 50.59 (768-1423)		
Spicule length (SP)		75.25 ± 1.64 (54-89)		68.15 ± 1.99 (51-82)	
Spicule width		10.55 ± 2.18 (54-89)		11.2 ± 0.47 (8-16)	
Gubernaculum length (GU)		51.1 ± 1.42 (39-61)		41.7 ± 0.85 (33-49)	
V	48.87 ± 4.20 (28.40-96.09)		57.57 ± 3.12 (35.12-88.59)		
A					25.89 ± 0.66 (21-30.75)
B					7.26 ± 0.11 (6.61-8.62)
C					11.65 ± 0.31 (9.64 ± 15.61)
D% = EP/ES × 100		64.42 ± 1.44 (53.80-75.34)		79.14 ± 2.61 (53.51-96.91)	64.98 ± 0.92 (57.77-71.43)
E% = EP/T × 100					104.38 ± 2.87 (89.37-145.61)
SW% = SP/ABD × 100		127.96 ± 3.79 (105.33-168.89)		134.83 ± 4.90 (98.08-185.71)	
GS% = GU/SP ×100		68.57 ± 2.42 (48.15-89.71)		62.01 ± 1.90 (50.77-85.19)	

Table 3. Morphology of KP

Character	1st gen female	1st gen male	2nd gen female	2nd gen male	IJ
Body length (L)	2697.95 ± 195.88 (1723-4942)	1570.35 ± 36.84 (1259-1813)	2205.65 ± 47.34 (1836-2546)	1189.4 ± 24.85 (980-1464)	820.25 ± 11.16 (711-900)
Maximum Body dia (D)	140.85 ± 4.71 (119-207)	96.93 ± 3.01 (76-130)	92.5 ± 2.88 (73-129)	86.32 ± 2.65 (65-119)	28.48 ± 0.73 (22-34.4)
Stoma length	8.1 ± 0.43 (6-15)		7.4 ± 0.40 (5-11)		
Stoma width	10.95 ± 0.60 (6-16)		10.15 ± 0.70 (6-20)		
EP	84.75 ± 2.52 (72-106)	90.06 ± 2.25 (73-115)	100.15 ± 3.4 (59-124)	69.65 ± 1.023 (60-78)	64.45 ± 1.94 (48-80)
NR	110.3 ± 3.16 (91-141)	98.35 ± 1.63 (88-113)	98.95 ± 2.51 (69-115)	93.6 ± 1.35 (82-103)	72 ± 2.83 (42-91)
ES	165.85 ± 3.49 (134-193)	145.55 ± 2.80 (121-167)	144.25 ± 4.02 (95-164)	135.2 ± 1.94 (110-149)	90.2 ± 2.97 (61-114)
Tail length with sheath (T)	67.7 ± 3.15 (48-85)	41.65 ± 0.75 (36-48)	50.2 ± 1.72 (34-67)	47.35 ± 0.61 (41-52)	79.34 ± 1.49 (61-90)
Tail length without sheath					52.66 ± 1.11 (42-60)
Anal body diameter (ABD)	44.35 ± 2.45 (28-73)	44.72 ± 1.07 (35-51)	40.15 ± 1.88 (26-58)	45.5 ± 1.20 (38-56)	
Distance from anterior end to vulva	1425.85 ± 61.1 (970-2000)		1188.15 ± 31.83 (1021-1690)		
Spicule length (SP)		80.35 ± 1.41 (67-92)		69.85 ± 0.93 (62-77)	
Spicule width		9.4 ± 0.56 (6-14)		10 ± 0.41 (6-13)	
Gubernaculum length (GU)		49.95 ± 1.11 (41-59)		49.4 ± 1.03 (40-56)	
V	58.05 ± 4.42 (23.48-93.44)		54.52 ± 2.20 (40.55-89.42)		
A					29.15 ± 0.81 (24.58-39.68)
B					9.31 ± 0.36 (7.45-13.15)
C					10.40 ± 0.21 (8.67-13.14)
D% = EP/ES × 100		62.09 ± 1.47 (49.08-72.34)		51.72 ± 1.05 (45.45-62.5)	72.42 ± 2.36 (55.24-87.91)
E% = EP/T × 100					81.60 ± 2.63 (63.16-108.11)
SW% = SP/ABD × 100		181.27 ±4.51 (145.65-235.90)		156.033 ± 5.18 (114.29)	
GS% = GU/SP ×100		62.74 ± 2.13 (49.40-85.51)		71.11 ± 1.97 (53.25-83.08)	

Table 4. Morphology of MLS1

Character	1st gen female	1st gen male	2nd gen female	2nd gen male	IJ
Body length (L)	2636.2 ± 87.81 (2013-3800)	1304.8 ± 43.3 (913-1570)	1368.85 ± 32.62 (1089-1672)	1442.5 ± 43.20 (1117-1940)	807.85 ± 9.60 (743-906)
Maximum Body dia (D)	157.9 ± 3.51 (112-178)	96.05 ± 3.14 (65-119)	83.74 ± 1.83 (62-93)	94.1 ± 3.50 (62-137)	29.93 ± 0.57 (26-35)
Stoma length	18.6 ± 0.91 (12-27)		6.79 ± 0.31 (4-9)		
Stoma width	17.9 ± 0.87 (10-25)		10.25 ± 0.53 (7-18)		
EP	115.7 ± 5.34 (79-160)	93 ± 1.55 (84-109)	89.15 ± 2.46 (66-103)	93.1 ± 1.29 (83-107)	55.25 ± 1.72 (43-67)
NR	140.45 ± 5.57 (89-201)	100 ± 1.18 (88-110)	115.1 ± 1.87 (101-131)	109.05 ± 1.52 (98-120)	59.65 ± 2.01 (48-81)
ES	179.25 ± 3.20 (160-212)	164.55 ± 1.72 (154-180)	175.65 ± 1.69 (160-185)	155.95 ± 1.50 (143-168)	87.7 ± 2.02 (48-81)
Tail length with sheath (T)	71.25 ± 3.00 (55-114)	52.75 ± 2.62 (34-72)	58.4 ± 1.67 (44-78)	64.75 ± 1.57 (53-82)	80.85 ± 1.09 (74-89)
Tail length without sheath					26.5 ± 0.55 (22-31)
Anal body diameter (ABD)	93.75 ± 2.50 (77-117)	62.85 ± 3.00 (45-91)	42.55 ± 1.00 (35-49)	59.75 ± 1.64 (48-73)	
Distance from anterior end to vulva	1239.6 ± 30.58 (1044-1540)		670.75 ± 12.13 (557-760)		
Spicule length (SP)		71.5 ± 2.21 (58-98)		75.65 ± 1.96 (63-91)	
Spicule width		9.9 ± 0.58 (5-15)		7.8 ± 0.70 (2-13)	
Gubernaculum length (GU)		45.85 ± 0.86 (40-53)		50.52 ± 1.45 (43-66)	
V	47.022 ± 1.41 (36.29-59.26)		49.42 ± 1.25 (38.84-64.92)		
A					27.19 ± 0.6 (23.23-32.78)
B					9.31 ±0.25 (7.40-11.13)
C					10.02 ± 0.16 (8.78-11.19)
D% = EP/ES × 100		56.56 ± 0.86 (51.14-65.19)		59.83 ± 1.09 (52.17-72.29)	63.62 ± 2.37 (39.81-83.33)
E% = EP/T × 100					68.42 ± 2.11 (51.81-86.84)
SW% = SP/ABD × 100		117.34 ± 6.81 (63.74-168)		127.94 ± 3.88 (91.30-163.46)	
GS% = GU/SP ×100		66.35 ± 2.16 (51.19-91.38)		67.36 ± 2.09 (48.86-90.47)	

Table 5. Morphology of MLS2

Character	Hermaphrodite	2nd gen male	2nd gen female	IJ
Body length (L)	3182.5 ± 121.15 (2260-4300)	802.1 ± 20.16 (610-920)	1647.35 ± 85.89 (1100-2740)	602.25 ± 9.48 (513-654)
Maximum Body dia (D)	179.15 ± 4.07 (147-213)	62.3 ± 1.99 (50-78)	117 ± 3.49 (92-150)	24.74 ± 0.64 (18-31)
Stoma length	8.25 ± 0.38 (6-11)		6.27 ± 0.26 (4-8)	
Stoma width	9.85 ± 0.52 (6-13)		9.65 ± 0.38 (7.5-13)	
EP	147.15 ± 1.85 (138-168)	77.9 ± 1.17 (70-90)	92.25 ± 1.42 (79-104)	77.35 ± 2.24 (55-95)
NR	159.5 ± 3.44 (148-216)	80.45 ± 1.32 (70-91)	89.55 ± 2.16 (72-108)	78.2 ± 1.32 (68-90)
ES	249.25 ± 8.90 (202-327)	110.25 ± 1.97 (97-129)	126.85 ± 1.77 (109-141)	106.5 ± 3.10 (93-140)
Tail length with sheath (T)	111.55 ± 2.20 (98-125)	61.58 ± 3.59 (41-110)	64.2 ± 2.77 (46-90)	91.26 ± 4.52 (56-140.3)
Tail length without sheath				57.09 ± 4.17 (37-101)
Anal body diameter (ABD)	54.7 ± 1.38 (43-65)	34.51 ± 0.67 (30-39.4)	64.35 ±3.36 (41-91)	
Distance from anterior end to vulva	1404 ± 33.52 (1080-1650)		862.5 ± 38.06 (610-1290)	
Spicule length (SP)		41 ± 1.26 (32-51)		
Spicule width		3.6 ± 0.27 (2-6)		
Gubernaculum length (GU)		22.95 ± 0.74 (14-28)		
V	45.15 ± 1.81 (35.12-60.25)		55.35 ± 4.49 (32.34-117.27)	
A				24.34 ± 0.60 (14.93-28.5)
B				5.65 ± 0.18 (3.063-5.52)
C				6.60 ± 0.29 (2.10-9.16)
D% = EP/ES × 100		70.90 ± 1.19 (63.2-83.50)		72.63 ± 2.61 (72.29-59.14)
E% = EP/T × 100				84.75 ± 5.04 (49.52-98.21)
SW% = SP/ABD × 100		119.83 ± 4.69 (91.37-164.52)		
GS% = GU/SP ×100		56.85 ± 2.61 (41.18-87.5)		

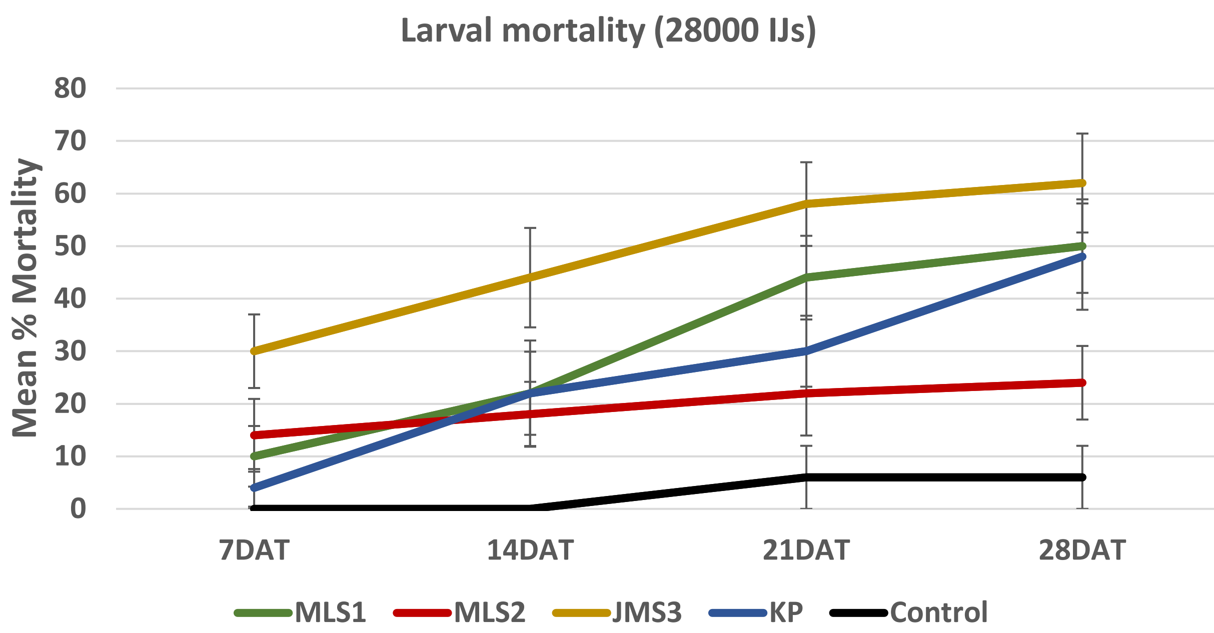

Figure 7a. Mean percentage larval mortality at 28000 IJs/cup

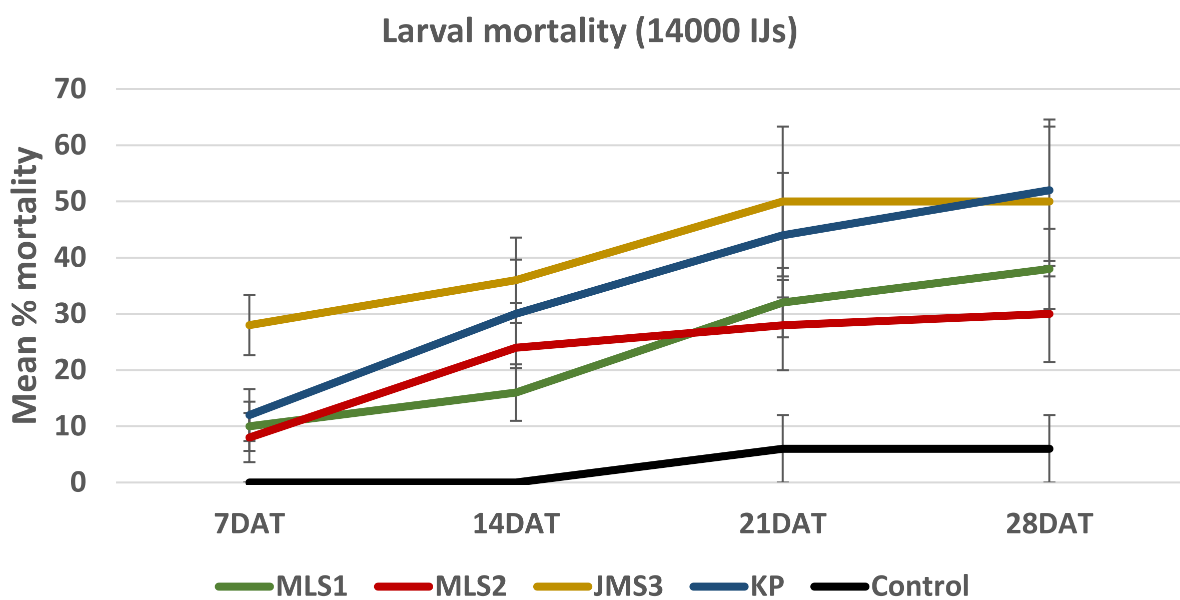

Figure 7b. Mean percentage larval mortality at 14000 IJs/cup

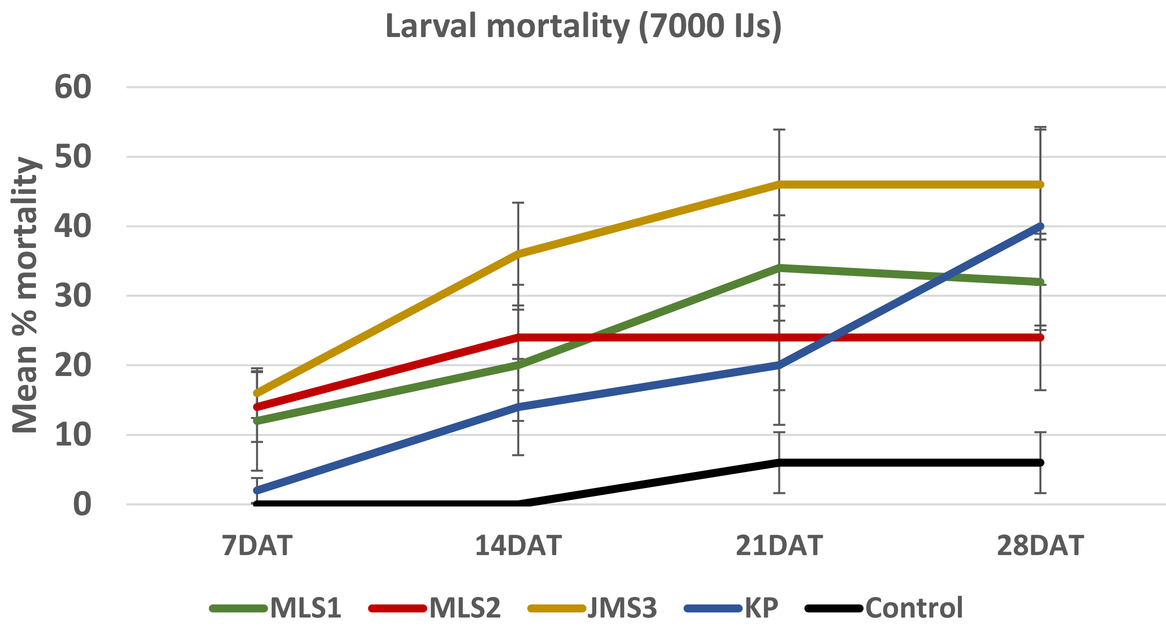

Figure 7c. Mean percentage larval mortality at 7000 IJs/cup

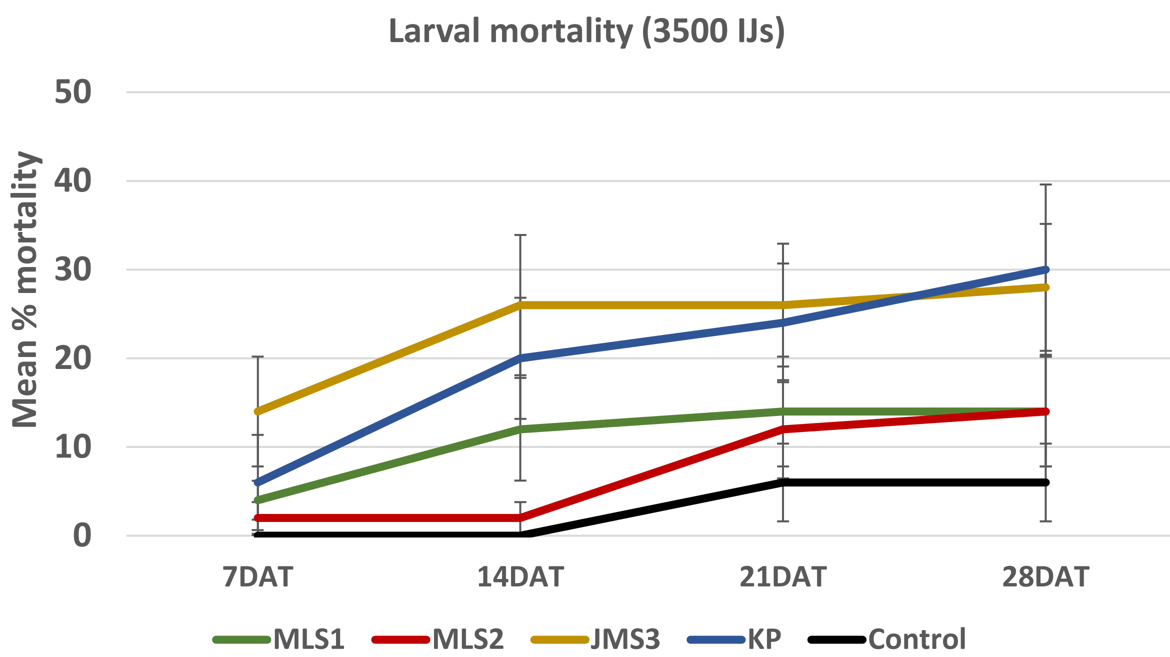

Figure 7d. Mean percentage larval mortality at 7000 IJs/cup

Monitoring of Wheat Midge and its Parasitoids *Macroglenes penetrans* and *Platygaster tuberosula* in Irrigated and Dryland Spring Wheat in Golden Triangle, Montana

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Project personnel: Govinda Shrestha and Ramadevi L. Gadi

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Aim of the study

The objectives of this study were: 1) to assess the wheat midge population trend in Golden Triangle, Montana, 2) the wheat midge population dynamics in irrigated and dryland spring wheat fields and 2) to monitor the wheat midge parasitoid *M. penetrans* and *Platygaster tuberosula* population, in irrigated and dryland spring wheat fields.

Materials and methods

Wheat midge populations

Western Triangle Agricultural Research team installed 15 delta traps baited with wheat midge pheromone lures (2S, 7S)-nonadiyl dibutyrate in spring wheat fields (dryland and irrigated) in multiple locations of Pondera, Toole, Teton and Chouteau Counties of Golden Triangle, Montana (Table 1). Pheromone traps were installed in 2nd week of June, 2018. Traps were checked at 1-3 days interval in Pondera (Ledger, Valier and WTARC trap sites) and Toole (Ledger), while at 15 days interval in Toole, Teton and Chouteau Counties locations. The monitoring work was wrapped up from last week of July to first week of August, 2018.

Parasitoids *Macroglenes penetrans* and *Platygaster tuberosula* population levels

The parasitoids adult population levels were monitored in traps installed in dryland and irrigated spring wheat fields located at Valier, WTARC and Ledger locations. Two methods such as sweep net and parasitoid pheromone traps were used to sample the adult parasitoids from each field. For sweep net sampling, 150 sweeps were made per field and the sampling was done at least 15 m from inside fields. The sweep net sampling was began in June 20 and completed in July 20, 2018. Parasitoid adults were monitored at 3-4 days interval throughout wheat midge adult activity period. Parasitoid pheromone lures baited on delta trap were installed in 3rd week of June, 2018. The total number traps were four and three for irrigated and dryland spring wheat fields, respectively. The traps were checked at 15 days interval. The collected samples were stored at -20 °C until processing. The parasitoids were identified under a microscope.

Results

Wheat midge population levels in the Golden Triangle, Montana

Total cumulative midge count observed in our trap established locations are shown in Table 1.

Table 1. Total cumulative wheat midge count per trap observed in Pondera, Toole, Teton and Chouteau Counties of Montana.

County	Field name	Lat.	Lng.	Total cumulative count/trap	Parasitoid observed
Pondera	Kyle Dean House-irrigated	48.3958	-112.2189	1179	Yes
Pondera	Kyle Dean Rock city-irrigated	48.41	-112.196	800	Yes
Pondera	Kyle Dean-dryland	48.3945	-112.1838	10	Yes
Pondera	Cory Crawford Crestview-irrigated	48.3024	-112.1433	199	Yes
Pondera	Cory Crawford VHW-dryland	48.3074	-112.1726	203	Yes
Pondera	Jodi Hobel BHR-irrigated	48.2865	-112.0566	904	Yes
Pondera	Jodi Hobel BHR-dryland	48.2905	-112.0565	25	Yes
Pondera	Jodi Hobel House-dryland	48.2999	-112.12	57	Yes
Pondera	WTARC-irrigated	48.3071	-111.9221	91	Yes
Pondera	WTARC-dryland	48.305	-111.9244	30	Yes
Pondera	Terry Peters Pondera-dryland	48.2567	-111.667	14	Yes
Toole	Terry Peters CS-dryland	48.2524	-111.6012	10	Yes
Toole	Devon-dryland	48.55311	-111.39644	3	No
Teton	Scott Inbody-dryland	47.9112	-112.03736	5	No
Chouteau	Knees-dryland	47.99638	-111.36411	0	No

In 2018, wheat midge populations were monitored in seven counties (Liberty, Toole, Teton, Choteau, Glacier, Cascade and Pondera) at the Golden Triangle, Montana. Portion of the wheat midge count data was extracted from Pestweb Montana. Total number of wheat midge pheromone traps installed in wheat fields were 39 in 2018. Among the seven counties, the highest wheat midge population level per trap was observed in Liberty County in comparison to no presence of wheat midge in Cascade and Glacier County (Fig. 1). The second highest wheat midge populations were noticed at Pondera County followed by Toole and Teton Counties (Fig. 1). Compared to the last year, wheat midge population was low in Toole County but higher in Pondera and Liberty Counties.

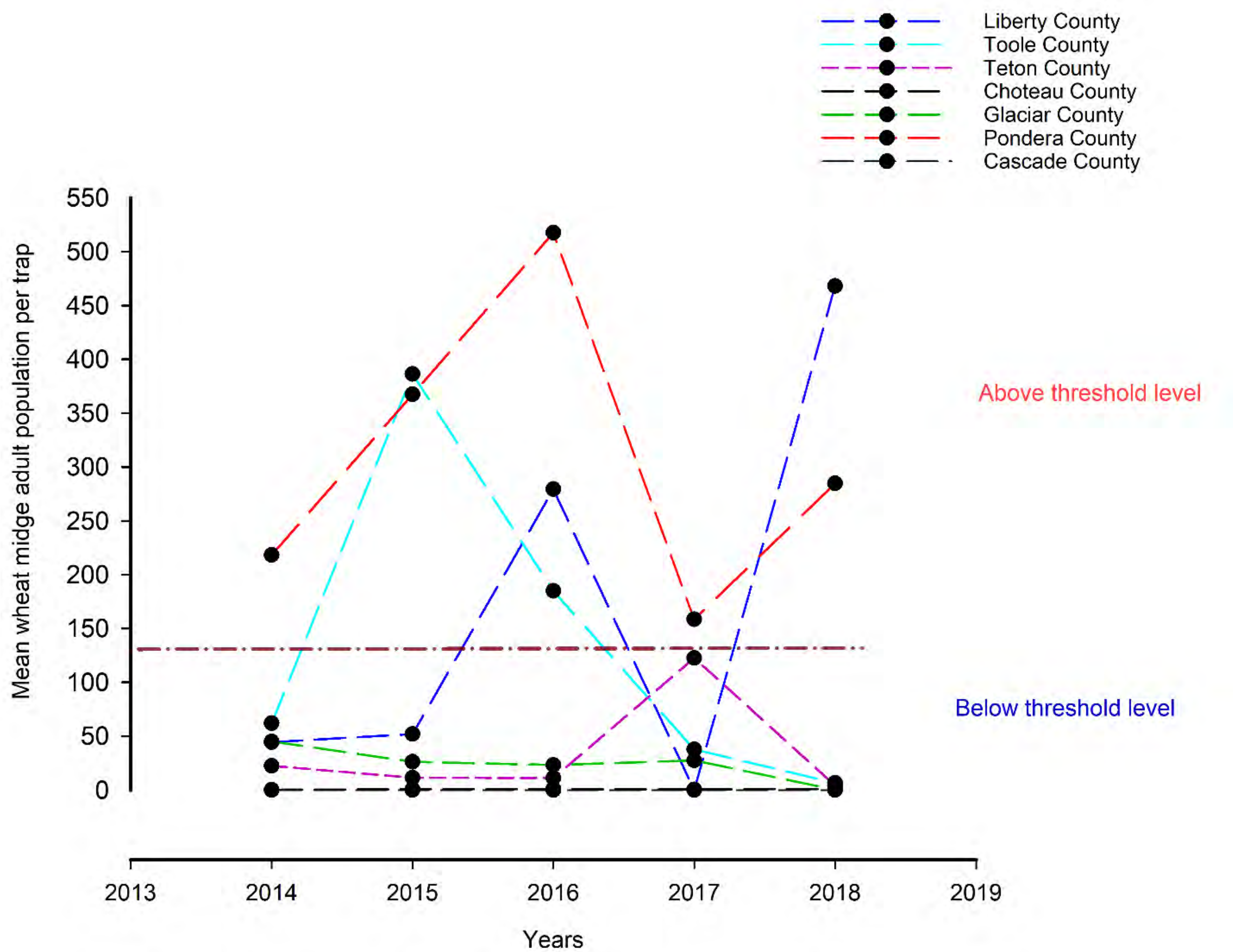

Figure1. Wheat midge population levels in the Golden Triangle, Montana from 2014-2018.

Wheat midge population level: Irrigated vs. dryland spring wheat fields

In overall, the flight activity of wheat midge adults began about one and half weeks later (June 30-July 5) in 2018 when compared to 2017 with emergence occurred on June 15-21 in Pondera County (Fig. 2). The midge adult activity reached a peak on July 15-25, 2018, and that contrasted adult emergence in 2017 (i.e., June 30- July 5) (Fig. 2). It thereby indicates that environmental conditions could influence the wheat emergence patterns. In 2018, we had similar results as like 2017 regarding wheat midge population levels in irrigated and dryland wheat fields. Wheat midge populations were relatively at higher levels in irrigated fields compared to dryland spring wheat fields. However, it is interesting to report that wheat midge population levels were nearly fourteen-fold higher in irrigated compared to dryland fields in 2018. The total cumulative numbers of male adults captured per pheromone trap were: 700 and 50 in irrigated and dryland fields, respectively (Fig. 2). In contrast in 2017, wheat midge population levels were only two folds higher in irrigated compared to dryland fields. The total cumulative numbers of male adults captured per pheromone trap were: 325 and 180 in irrigated and dryland fields, respectively (Fig. 2). Consequently, environmental factors could be the main triggering factors for wheat midge population dynamics in irrigated and dryland spring wheat fields in Montana.

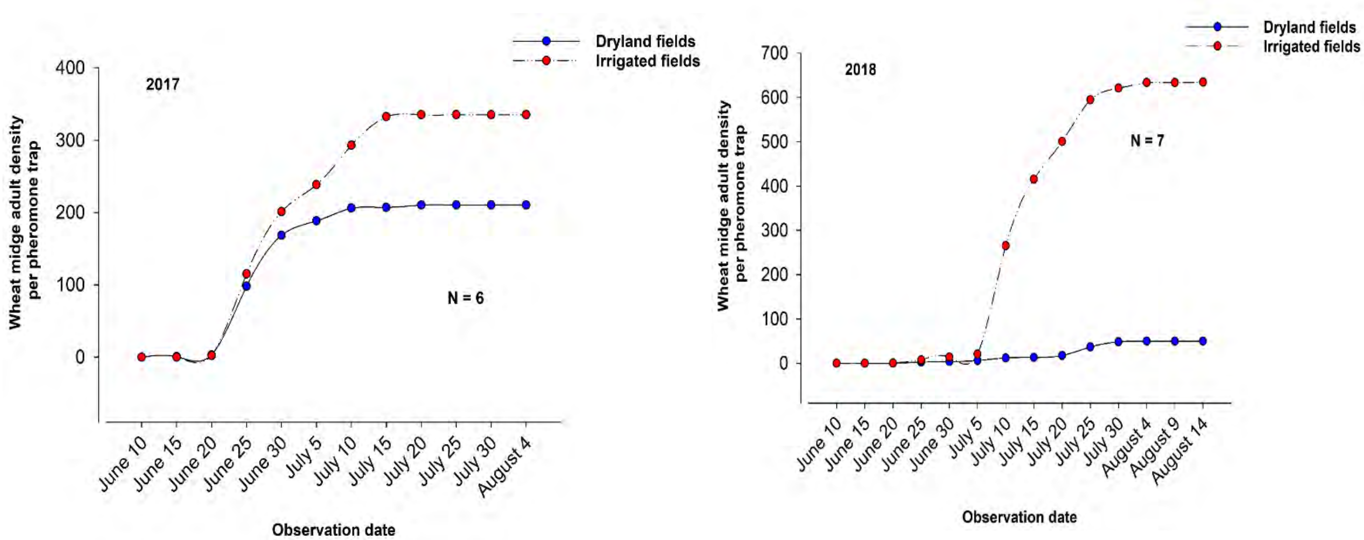

Figure 2. Wheat midge adult activity based on pheromone trap catch in dryland and irrigated spring wheat fields (2017-2018).

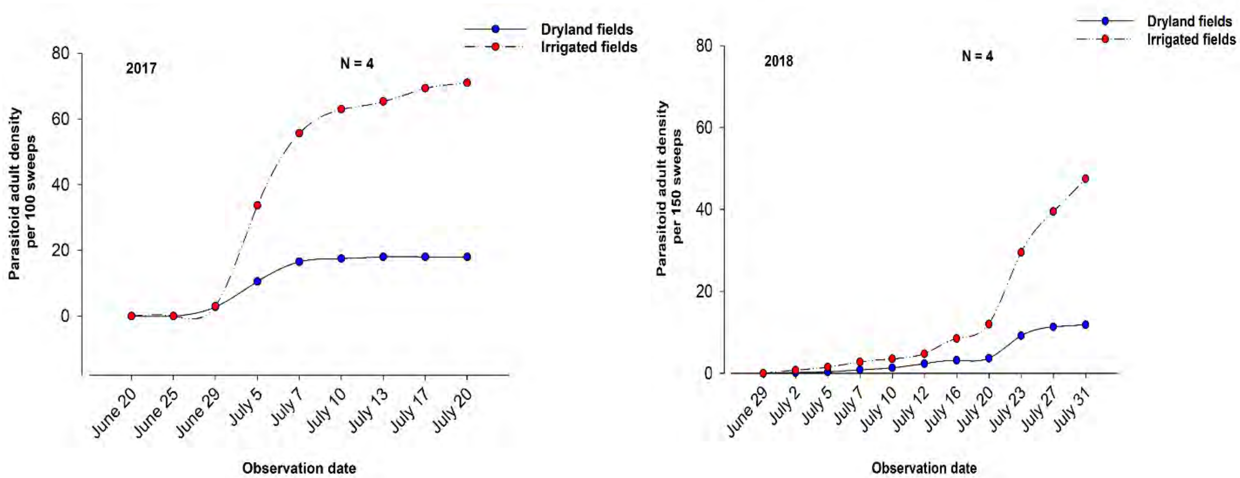

Figure 3. Wheat midge parasitoid, *Macroglenes penetrans* adult population levels in dryland and irrigated spring wheat fields (2017- 2018).

Parasitoid population level: Irrigated vs. dryland spring wheat fields

Based on sweep net sampling method, in 2018, *Macroglenes penetrans* population was observed at higher levels in irrigated compared to dryland spring wheat midge infested fields and it was also expected (Fig 3). In both management systems, the emergence of parasitoid begun nearly at the same time (July 10 - July 12, 2018) (Fig 3). As compared with previous year 2017, the *M. penetrans* adult population was low both in the dryland and irrigated fields in 2018. In 2018, the total cumulative parasitoid numbers per 150 sweeps were 48 and 12 respectively, in irrigated and dryland fields. Regarding to other parasitoid species *P. tuberosula*, we found in four irrigated and one dryland spring wheat fields of Valier, Montana but at a very low number.

Acknowledgements

This work was supported by Montana Wheat and Barley Committee. We would like to thank summer intern Bert Paulsen for assistance with field work.

Introduction of two Biocontrol Agents *Euxestonotus error* and *Platygaster tuberosula* for the Management of Wheat Midge Population in Montana

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Aim of the Study

The aims of this study were: 1) to rear two tiny black parasitoid species *Euxestonotus error* and *Platygaster tuberosula* under WTARC laboratory conditions and 2) to release the *E. error* and *P. tuberosula* at wheat midges infested fields in the Golden Triangle, Montana

Material and Methods

The release process of parasitoids were illustrated in Fig 1.

Collection and storage of parasitoids

A federal import permit (Permit number # P526P-18-01709) was obtained by USDA-Animal and Plant Health Inspection Service on May 2, 2018, for the collection of *Euxestonotus error* and *Platygaster tuberosula* (Hymenoptera: Platygastridae) for Canada. In August 2018, about 25,000 wheat heads were collected from spring wheat fields of Langenburg, Saskatchewan, Canada. In 1993 and 1994, *E. error* and *P. tuberosula* had been released by Canadian Entomologists and are currently known to be established well in this region. After the wheat heads collections, parasitoids were immediately transported to Western Triangle Agriculture Research Center (WTAC), Montana State University. The wheat heads were spread out in an even layer and left at room temperature (19–22°C) to dry for approximately 2 weeks in the WTARC laboratory. De-awning machine was used to gently thresh dried heads. Midge larvae were separated from the seeds and the chaff with an air cleaner (Fig.1). Approximately 30000 larvae were harvested in this manner from 25,000 infested wheat heads. Harvested larvae were then placed in a soil-less mixture of vermiculite and sphagnum and stored at 2–4°C.

Fig 1. Whole release process of parasitoids

When to take out parasitoid larvae from cold storage?

Parasitoid larvae are currently stored at 5°C in 473 ml round plastic deli containers that had been filled with vermiculite and peat moss. Larvae were placed at the top surface layer of the containers. Each container contained 500 larvae. It is usually difficult to assess when would be the optimum time to take out parasitoid containers from the refrigerator and to begin rearing for field releases? Affolter (1990) described that parasitoids *E. error* and *P. tuberosula* emergences can occur within 4-5 weeks under laboratory conditions at 22ºC. This study also demonstrated that parasitoid puparium can be formed after 18 days of incubation and the pupal stage could last for 12 ± 1.5 days (n=9) and 21 ±2 days (n=7) respectively, for male and female, under optimal conditions. Based on our 2016 parasitoid rearing experiences, we observed that all parasitoids often not emerge on the same time and saw 15 days variations in emergence timing. Therefore, it can be like a "**catch 22**" for when to take out parasitoids from refrigerator that can coincide with wheat midge emergence peak. In Golden Triangle, Montana, we have observed two trends on wheat midge emergence peak. For instances, midge emergence peak can be on June 30 to July 5 when the winter environmental conditions are mild, but on July 15 to 25 when conditions are colder. Therefore, these aspects will be taken under considerations for taking out parasitoids from refrigerators.

How to identify two parasitoid species?

The protocol to determine the morphological characteristic of *E. error* and *P. tuberosula* was developed with the great assistance of Peeter Neerup Buhl, a taxonomist working within the field of platygastridae. The criteria to identify the two parasitoid species are highlighted in Fig 2.

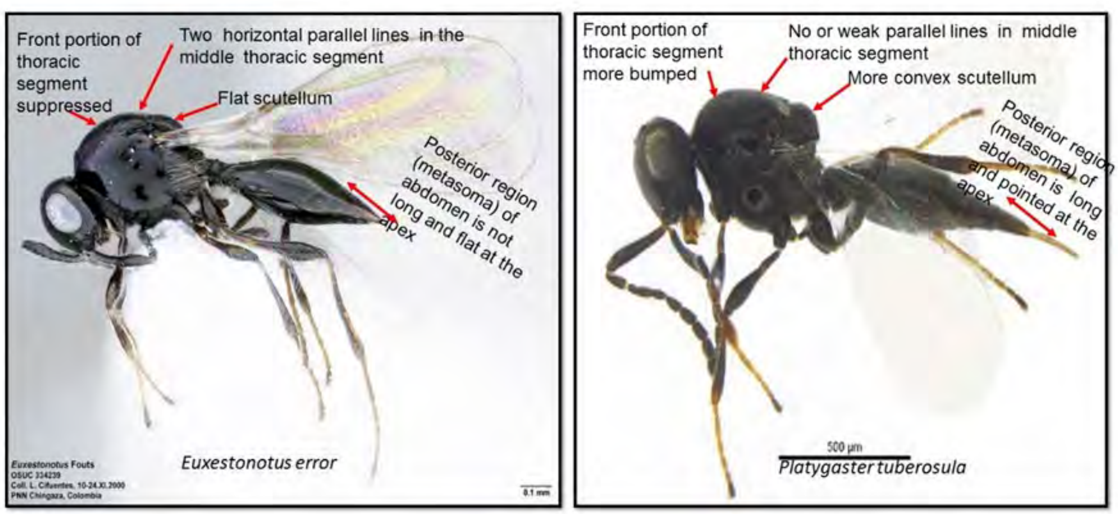

Fig 2. Morphological characteristics of parasitoids

How to rear parasitoids under lab conditions?

Based on our previous year's experiences, it is expected that the parasitoid larvae will be taken out of the cold storage chamber from end of May to 1st week of June, 2019. The parasitoid larvae will be placed in plastic round deli containers. However, the containers will be first filled with garden soil and afterward the larvae will be placed in the top layer of the soil. These containers will be sprayed (hand sprayer) with distilled water (3-4 ml) to moisten the soil. When the parasitoids will be expected to emerge (3 weeks after incubation), all these containers will be taken out from the growth chamber and placed in insect cages where they will be further sprayed with distilled water at 1-2 days intervals. In each insect cage, about 5-7 plastic containers will be placed and the emergence of parasitoids will be observed every day. After 1-2 days of parasitoid emergence in an insect cage, they will be taken out with the help of an aspirator and kept in Petri dishes (1 parasitoid per Petri dish). These Petri dishes will be then kept in a cooler growth chamber (10°C) for 2 hours and subsequently, the parasitoid species were identified under a stereomicroscope.

When and where to release parasitoids?

Four to six highly infested wheat midge fields will be selected in summer 2018 in Valier and/or in areas that have high midge infestations. The midge infestation will be based on midge trap count data. Immediately after the fields' selection, sweep netting activity (1-2 times before the parasitoids release) will be performed to assess whether there are presence of *E. error* and *P. tuberosula* prior to their release at field sites. Selected spring wheat producers will be requested for not to spray insecticide in release area or to inform us of their insecticide spray schedule. As a result, we could better plan for release dates of the parasitoids.

Results

The results of this study will be presented on 2019 annual report.

Acknowledgements

This work was supported by Montana Wheat and Barley Committee.

References

Affolter, F. 1990. Structure and dynamics of the parasitoid complex of the wheat midges *Sitodiplosis mosellana* (Géhin) and *Contarinia tritici* (Kirby). International Institute for Biological Control, Delémont.

Laboratory bioassays and cage trials for the evaluation of the effect of biopesticides on field-collected pea leaf weevil adults and the impact on non-target organisms

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Aim of the Study

The aim of the study was: 1) to evaluate commercially available bio-pesticides such as Entrust WP® (Spinosad, *Saccharopolyspora spinosa*), PyGanic EC® (Pyrethrin), Mycotrol ESO® (*Beauveria bassiana* GHA), Xpulse OD® (*B. bassiana* GHA + Cold pressed Neem extract) and Xpectro OD® (*B. bassiana* GHA + Pyrethrin) against pea leaf weevil adults *Sitona lineatus* under lab and cage conditions and 2) to test the toxicity of bio-pesticides on the two natural enemies (lacewing and ladybeetle).

Materials and methods

Plants

Green pea, *Pisum sativum* L. cv. 'Banner', was used as a plant material source for the cage experiments. Seeds were sown on tapered square pots (13 ×13 ×13.5 cm) at a rate of six seeds per pot from 2nd - 4th weeks of May, 2018. Each pot contained 1.62 kg of prepared soil mixture, with 1:1:2 proportions sand, potting mix and clay loam soil, respectively. Pots were placed inside insect cages (68 ×75 × 82 cm) and plants were maintained in outdoor natural environmental condition at the Western Triangle Agricultural Research Center (WTARC) of Montana State University, USA, until plants used for experiments.

Insect

Pea leaf weevil

Spring population of *S. lineatus* adults collected in pea and alfalfa fields, were used for all the experiments. Adults were collected either using the pitfall traps baited with lures 4-methyl-3, 5-heptanedione (ChemTica Internacional, Costa Rica) in pea fields (Reddy et al., 2018) or the sweep net sampling in 2016 and 2018, Pondera County, Montana, USA. Collected adults were placed inside deli cups (diameter = 12 cm and height = 8 cm) (50 per cup), reared with alfalfa foliage (5-6 stems) and maintained in a climate cabinet at 12 ^{o}C for 2-3 days, until sufficient adults were obtained to perform the experiments.

Beneficial insects

One- to two-day-old first instar green lacewing, *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae) and two-spotted ladybeetle, *Adalia bipunctata* L. (Coleoptera: Coccinellidae) larvae were purchased from Biobest Canada Ltd. (www.biobestgroup.com). The flour moth, *Ephestia kuehniella* Zeller (Lepidoptera: Pyralidae) eggs were supplied from Beneficial Insectary, CA (www.insectary.com) and used as a source of food materials for rearing of beneficial insect species.

Chemical source and rate

Five bio-pesticide products of commercial formulations were used for the study (Table 1). Mycotrol ESO® (*Beauveria bassiana* GHA), Xpectro OD® (*Beauveria bassiana* GHA + pyrethrins) and Xpulse OD® (*Beauveria bassiana* GHA + Azadirachtin) were obtained from Lam International (Butte, MT), Entrust WP® (Spinosad 80%) from Dow Agro Sciences (Indianapolis, IN) and, PyGanic EC® 1.4 (Pyrethrin) from McLaughlin Gormley King (Minneapolis, MN).

Table 1. Materials and application rates of bio-pesticides used for the laboratory bioassays against *Sitona lineatus* adults.

Treatment	Chemical name	Trade name	Concentration (ml/L)
T1	Untreated Control		
T2	Spinosad (*Saccharopolyspora spinosa*)	Entrust WP®	0.0091, 0.0455, 0.091 and 0.182
T3	*Beauveria bassiana*	Mycotrol ESO®	0.072, 0.36, 0.72 and 1.44
T4	*B. bassiana* GHA + Pyrethrin	Xpectro OD®	0.25, 1.25, 2.5 and 5
T5	*B. bassiana* GHA + Cold pressed neem extract	Xpulse OD®	0.072, 0.36, 0.72 and 1.44
T6	Pyrethrin	PyGanic EC®	0.072, 0.72, 1.44 and 2.88

Laboratory experiments

Pea leaf weevil adult mortality

The bioassay experiment was performed to quantify the susceptibility of *S. lineatus* adults to four concentrations of each product material (0.1, 0.5, 1.0 and 2.0 fold lowest label rate) and a control (water). Stock solutions were first prepared for each product by dissolving the product materials in tap water and the lower concentrations were prepared via. serial dilutions with tap water (Table 1). However, prior to executing experiments, the two spraying methods-immersion and topical (bottle and perfume sprayer) were assessed to find out the most appropriate one for experiments. The perfume sprayer method was found suitable for bioassay experiment as other spraying techniques caused the higher adults mortality (~ 80%) both in treatments and control groups after 48 h.

Similar sized pea leaf weevil adults (length = 5-5.5 mm) were placed in groups of seven adults in a Petri dish lined with a filter paper (diameter = 9 cm). Placement of the adults was accomplished with the help of a fine camel paint brush. The Petri dishes were then maintained in a cold climate cabinet (5 ^{o}C) for 1 h to minimize adults’ movement. Adult individuals group were placed in the center of Petri dish and then topically treated with 1 ml of tested bio-pesticide product suspension. Controls were treated with 1.0 ml of tap water. After the spray applications, a fresh alfalfa stem about 5 cm long with 9-12 leaves, was placed close to the treated adult individuals inside a Petri dish as a source of feeding materials. Feeding materials were replaced within 2-3 day intervals. Dishes were incubated in a climate cabinet at 22 ± 1 ºC, 16:8 h L:D and 75% RH. The number of replicates (one replicate equals one Petri dish) per treatment were 5 and 3, respectively, in the first and second experimental run (providing a total of 8 replicates per treatment).

Starting one day after the treatment, adult mortality was checked daily for 9 days. *S. lineatus* adults have a specific characteristic such as acting like dead weevils "dead play" even with minimum disturbance (Jackson and Macdougall, 1920). Therefore, by gentle prodding with a camel paint brush, the adult mortality was determined in Petri dish. Any adults that lacked movement were considered to be dead. Dead weevils, mainly from insect pathogenic fungi or mixture with other product, were further placed on moist filter paper lined in a Petri dish to check for sporulation.

Beneficial insects: Laboratory bioassay

The bioassay experiment was performed to determine the toxicities of Mycotrol (1.44 ml/L), Xpectro (5 ml/L) and Entrust (0.182 ml/L) bio-pesticide products on the first instar larvae of lacewing and two-spotted ladybeetles. Similar sized larvae of each beneficial insect species were placed in groups of 10 individuals in a Petri dish (diameter = 9 cm). Placement of the larvae was accomplished with the help of a fine camel paint brush, and placed in the center of Petri dish. Each bio-pesticide product was sprayed topically to test individuals using a 750 ml hand-held sprayer, with a spray volume of 1 ml per Petri dish. Controls were treated with 1.0 ml of tap water. Immediately after spraying (about 5 sec), the bio-pesticide exposed larvae were transferred individually to plastic deli cups with an excess of *E. kuehniella* eggs. Dishes were incubated in a climate cabinet at 22 ± 1 ºC, 16:8 h L: D and 75% RH. Beginning from day one after the treatment, larval mortality was checked at one-two days interval for seven days. Dead larvae, particularly from insect pathogenic fungi (Mycotrol) or mixture with other product (Xpectro), were removed and placed on moist filter paper in a Petri dish to check for sporulation. The bioassay experiment was performed 2-3 times within a period of two months (October-December, 2017). The number of replicates (one replicate = one Petri dish) per treatment was three in each experimental run (providing a total of six to nine replicates per treatment).

Cage experiments

Cage experiments were performed to determine the impact of bio-pesticide products on foliage damage and pea leaf weevil adult mortality. Pea plants established outdoors were transported to a lab, placed in small cages with three pots per cage and contained four plants in each pot. Each potted plant was marked individually to know the order of plant monitoring. Caged plants were inoculated with 8-9 adult individuals per pot (totaling 25 weevil individuals in three pots of each cage). At the time of biopesticide application, the pea plants were 24 days old and had three pairs of unfolded leaves. Plants inoculated with adults were transported to spraying room and were immediately sprayed with a 750 ml hand-held sprayer at concentrations of 1.44 ml/L, 0.182 ml/L and 5 ml/L for Mycotrol, Entrust and Xpectro, respectively. Twelve plants in each cage were sprayed with 10 mL of each product concentration. Control plants were treated with tap water. Adult mortality and leaf notch damage caused by adults were assessed 1, 3, 7 and 9 days post treatment. In addition, plants were always checked in counter clock fashion for maintaining consistency in repeated observations for leaf notch damage. The experiment was performed twice within a month. The number of replicates (one replicate = one cage) per treatment was four in each experimental run (providing a total of eight replicates per treatment).

Statistical analysis

Lab bioassay data on cumulative mortality were corrected for the mortality in the controls (Abbott, 1925). Mortality data were angular transformed. Two way analysis of variance (ANOVA) was performed in order to determine the overall influence of biopesticide product and concentration level on mortality. One way analysis of variance (ANOVA) was carried out to determine 1) the effect on mortality across biopesticide product and 2) the effect on mortality across concentration level. For cage experiments, one way analysis of variance (ANOVA) was carried the impact of bio-pesticide products on foliage damage and adult mortality. Similar procedure was used to examine the toxicities of Mycotrol, Xpectro and Entrust bio-pesticide products on the beneficial insects' larvae. Tukey's contrast pairwise multiple comparison was used to compare significant differences in means.

Log-rank Kaplan–Meier survival analyses were performed to compare survival in treatments for each biopesticide product. Pairwise multi comparison procedures were conducted to compare survival among the five treatments, using Holm-Sidak method. Survival analyses were conducted with Sigma Plot 12.3.

Results

Laboratory experiments

Pea leaf weevil adult mortality

Overall, this bioassay study revealed significant main effects on pea leaf weevil adult mortality for both concentration level (F = 119.52; df = 4, 140; P < 0.0001) and biopesticide product type (F = 157.01; df = 4, 140; P < 0.0001) with a significant interaction effect (F = 6.13; df = 12, 140; P < 0.0001).

Across the biopesticide product type, significant differences in adult mortality occurred when adults were treated with either high (F = 69.98; df = 4, 35; P < 0.0001), medium (F = 72.65; df = 4, 35; P < 0.0001), low (F = 22.98; df = 4, 35; P < 0.0001) or very low (F = 15.38; df = 4, 35; P < 0.0001) label rates of each biopesticide product. Among five products, Entrust was found to be highly effective, Mycotrol and Xpectro as moderately effective and the Xpulse and Pyganic as less effective products, with evidence of significant differences between products (Table 2).

Within each biopesticide product treated with high, medium, low or very low label rate of biopesticide product, there was a significant difference in mortality inflicted by biopesticide product: Entrust (F = 204.1; df = 3, 28; P < 0.0001), Xpectro (F = 21.99; df = 3, 28; P < 0.0001), Mycotrol (F = 28.67; df = 3, 28; P < 0.0001), Xpulse (F = 11.48; df = 3, 28; P < 0.0001)and Pyganic (F = 4.58; df = 3, 28; P < 0.01). The mortality caused by the biopesticide was generally dose-dependent with the highest mortality recorded with highest concentration, except that no significant difference was observed in the mortality of adults treated with high or medium concentration of Entrust (Table 2). Mean levels of mortality in biopesticide treated groups ranged from 36 to 100 % for Entrust, 6 to 60 % for Xpectro, 6 to 62 % for Mycotrol, 5 to 32 for Xpulse and 3 to 17 % for Pyganic (low dose to high label rate, respectively; Table 2). The average control mortality (± SE) was 4.32 ± 2.40, 9 days post-inoculation.

Table 2. Effect of biopesticide products on total mortality of pea leaf weevil adults. Mean percentage of corrected mortality (± SE) 9 days post inoculation.

	Concentration			
Treatments	2 X	1 X	0.5 X	0.1 X
Entrust	100.00 ± 0.00Aa	100.00 ± 0.00Aab	62.50 ± 4.91Ac	36.25 ± 3.75Ad
Xpectro	60.62 ± 6.30Ba	32.50 ± 6.34Bb	19.37 ± 3.95Bbc	6.25 ± 1.82Bd
Mycotrol	62.50 ± 4.91Ba	38.12 ± 5.97Bb	11.25 ± 3.37Bcd	6.24 ± 1.83Bd
Xpulse	32.50 ± 5.67Ca	21.25 ± 3.75BCab	8.12 ± 2.98Bcd	4.99 ± 1.89Bd
Pyganic	17.49 ± 4.00Ca	11.25 ± 3.37Cab	5.62 ± 3.19Bb	3.74 ± 1.83Bb

Mean values within columns bearing the same upper case letter and within rows bearing the same lower case letters are not significantly different (Tukey test, P > 0.05). Data pooled over the two experimental runs. The total numbers of replicates were eight per treatment.

Survival curve

Pea leaf weevil adults exposed with different concentrations of biopesticide products were significantly affected in terms of adult survival curve over the nine days post inoculation period: Entrust (log-rank, df = 4; x^2= 332.94; P<0.001), Xpectro (log-rank, df = 4; x^2= 75.68; P<0.001), Mycotrol (log-rank, df = 4; x^2= 91.59; P<0.001) and Xpulse (log-rank, df = 4; x^2= 29.14; P<0.001) (Figure 1). Expect, the Pyganic biopesticide product had no significant effect (log-rank, df = 4; x^2= 7.20; P>0.05) on adult survival curve (Fig. 1). In Entrust treatment, across the concentration levels, significantly lower survival curve of pea leaf weevil adults were recorded when adults were exposed with high, medium and low concentrations compared with control treated groups (Figure 1).There were also significant differences in the survival curve of adults exposed to high, medium and low concentrations of Entrust (Figure 1). For both Xpectro and Mycotrol treatments, adults exposed with high and medium concentrations had only significantly lower survival curve and merely with high concentration of Xpulse, when compared with control treatment (Figure 1).

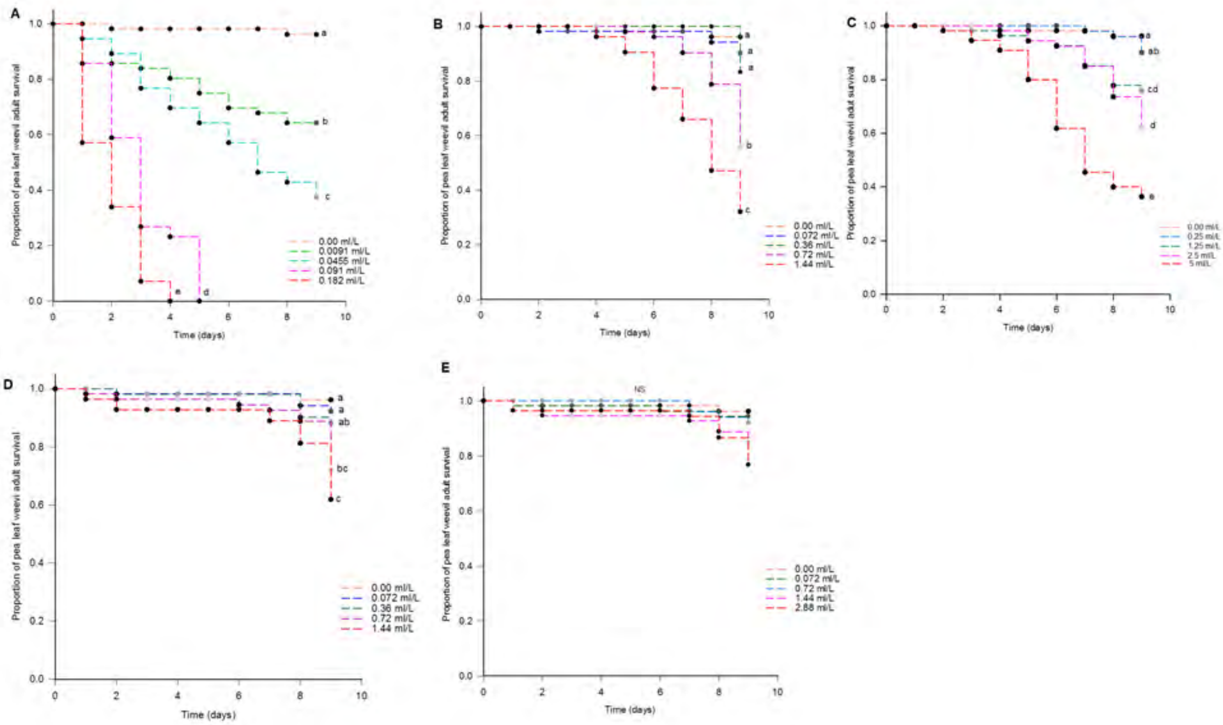

Figure 1. Survival curves for pea leaf weevil adults subjected to increasing sublethal concentrations of Entrust (A), Xpectro (B), Mycotrol (C), Xpulse (D) and Pyganic (E). Survival curves of different colors differed by Holm-Sidakis test (P > 0.05).

Cage experiments

Leaf damage assessment

In overall, this study demonstrated main significant effect on pea leaf damages for both treatment and sampling timing, regardless of experiment: Exp. 1 (treatment: F = 96.27; df = 3, 224; P = 0.0001; sampling time: F = 50.16; df = 3, 224; P = 0.0001) and Exp 2. (treatment: F = 45.66; df = 3, 152; P = 0.0001; sampling time: F = 11.80; df = 3, 152; P = 0.0001) (Figure 2). There was also significant interaction between treatment and sampling time (Exp.1: F = 8.75; df = 9, 224; P = 0.0001 and Exp. 2: F = 5.14; df = 9, 152; P = 0.0001) (Figure 2). In both experiment, significant difference in pea leaf weevil leaf damage occurred in all post treatment across the treatment levels: 1 day (Exp.1: F = 37.48; df = 3, 56; P = 0.0001 and Exp. 2: F = 7.36; df =38; P = 0.0001), 3 days (Exp.1: F = 31.43; df = 3, 56; P = 0.0001 and Exp. 2: F = 9.53; df = 3, 38; P = 0.0001), 7 days (Exp.1: F = 29.34; df = 3, 56; P = 0.0001 and Exp. 2: F = 13.71; df = 3, 38; P = 0.0001) and 9 days (Exp.1: F = 31.25; df = 3, 56; P = 0.0001 and Exp. 2: F = 18.7; df = 3, 38; P = 0.0001) (Figure 2).

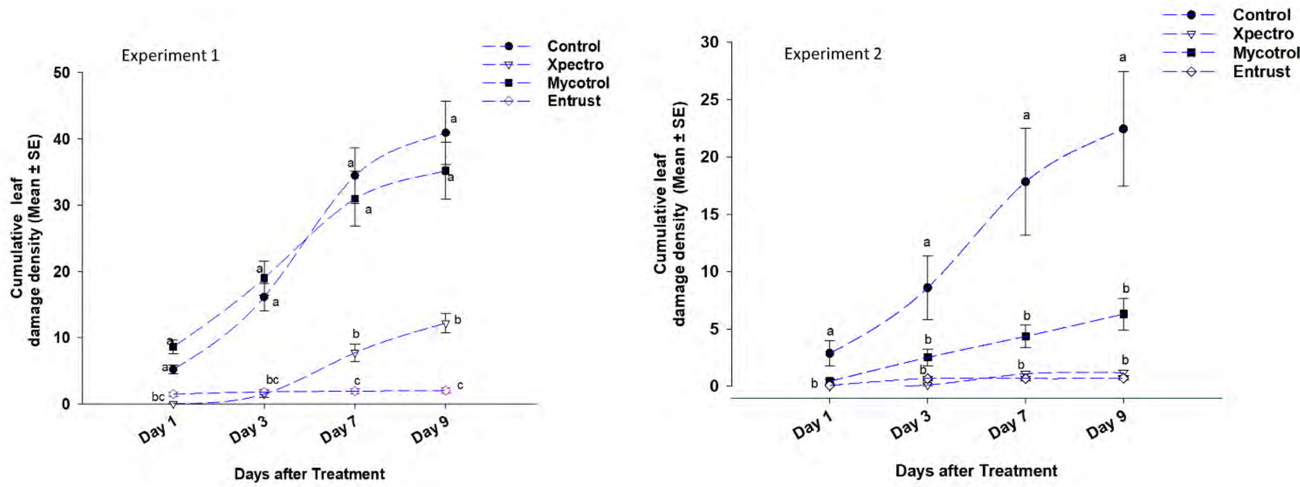

Figure 2. Impact of bio-pesticide products on pea foliage damage measured via leaf notch numbers caused by pea leaf weevil adults. Mean values within line graph at each sampling time bearing the same lower-case letters are not significantly different (Tukey test, $P > 0.05$).

In experiment 1, Entrust and Xpectro were significantly effective in reducing pea leaf weevil adult damage compared to the control and the Mycotrol treatment throughout sampling times, keeping the numbers of notch below 12 (Figure 2). Adults generally caused similar level of leaf damage when compared with untreated leaves (water) and leaves treated with Mycotrol (Figure 2). Similarly, in the experiment 2, significantly less leaf damage was recorded not only for the treatments with Entrust and Xpectro but also with Mycotrol compared to the untreated leaf (water) (Figure 2).

Pea leaf weevil adult mortality

This cage study depicted that the treatments had significant impact on pea leaf weevil adult mortality (Exp. 1: $F = 31.80$; $df = 3, 16$; $P = 0.0001$; Exp. 2: $F = 37.58$; $df = 3, 16$; $P = 0.0001$) (Figure 3). In Exp. 1, adults exposed to the Entrust (mean ± SE: 83.00 ± 8.12) and Xpectro (mean ± SE: 37.68 ± 6.25) caused significantly higher total mean mortality than those treated with the water (mean ± SE: 8.41 ± 1.11) (Figure 3). There were no significant differences on total mortality either between adults treated with the Mycotrol and Xpectro or with the Mycotrol and water (Figure 3). Also, in the experiment 2, significantly higher adult mortality was found not only for the treatments with Entrust (mean ± SE: 91.78 ± 4.79) and Xpectro (mean ± SE: 70.68 ± 6.41) but also with Mycotrol (mean ± SE: 40.52 ± 5.12) compared to the adults treated with water (control) (mean ± SE: 9.89 ± 2.95) (Figure 3).

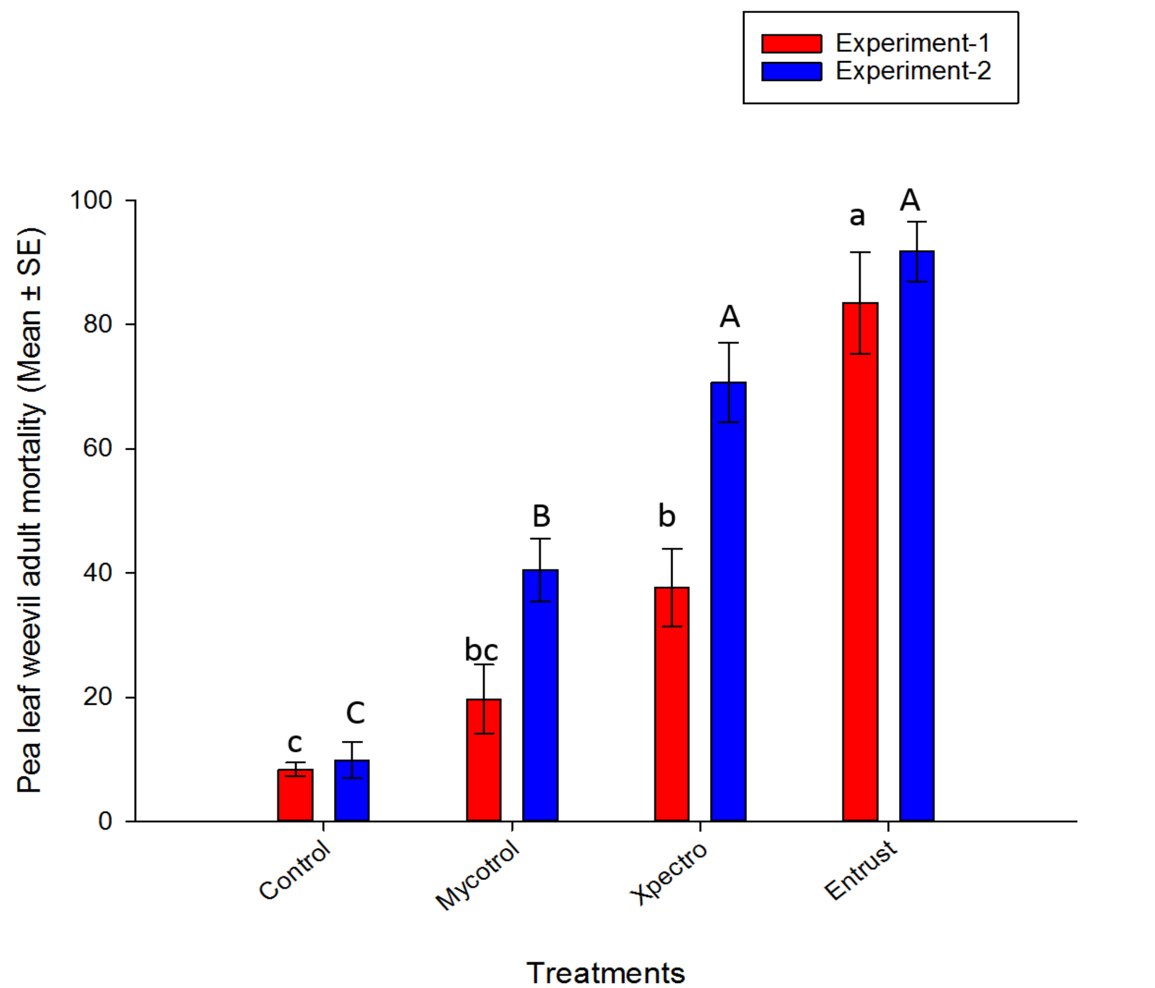

Figure 3. Cage experiments on effect of biopesticide products on total mortality of pea leaf weevil adults. Mean percentage of corrected mortality (± SE) 9 days post inoculation. Mean values within each color bar bearing the same upper or lower case letters are not significantly different (Tukey test, $P > 0.05$).

Biopesticide product toxicity to beneficial insects

This study depicted that the treatments had significant impact on ladybeetle larval mortality (F = 28.4; df = 3, 20; P = 0.0001). Between the three bio-pesticide products, Xpectro was found to be highly toxic to ladybeetle larvae, causing about 98 ± 1.66 % (Mean ± SE) mortality when compared to the control treatment (11.67± 6.54). However, Mycotrol and Entrust inflicted minimal larval mortality and were not significantly different when compared to the control treatment (Figure 4).

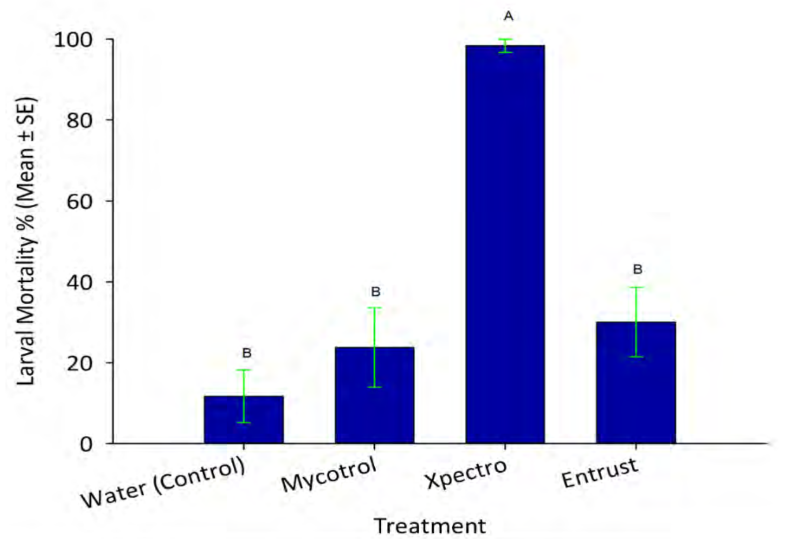

Figure 4. Toxicity of three bio-pesticide products against the first instar ladybeetle larvae. Mean values within bar bearing the same letters are not significantly different (Tukey test, P > 0.05).

Figure 5. Toxicity of three bio-pesticide products against the first instar green lacewing larvae. Mean values within bar bearing the same letters are not significantly different (Tukey test, P > 0.05).

Generally, lacewing larvae were found to be less susceptible to the three tested bio-pesticide products in comparison to the ladybeetle larvae. However, significant differences were recorded between treatments (F = 6.66; df = 3, 32; P = 0.0013). Among the three bio-pesticide products, Xpectro (Mean ± SE; 37.16 ± 5.06) was causing the high mortality followed by Entrust (Mean ± SE; 30.00 ± 4.40) and Mycotrol (22.46 ± 3.22) when compared to the control treatment (Mean ± SE; 13.58 ± 2.45) (Figure 5). There was no significant difference in treatments between water and Mycotrol, indicating that this product is less toxic to lacewing larvae.

Acknowledgements
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References

Abbott, W. 1925. A method of computing the effectiveness of an insecticide. J. Econ. Entomol. 18, 265–267.

Jackson, D. J., and Macdougall, K.S. 1920. "Bionomics of weevils of the genus *Sitones* injurious to leguminous crops in Britain. Ann. Appl. Biol. 7, 269-298.

Reddy, G.V.P., Shrestha, G., Miller, D., and Oehlschlager, A. 2018. Pheromone-trap monitoring system for pea leaf weevil, *Sitona lineatus*: Effects of trap type, lure type and trap placement within fields. Insects, 9(3), 75.

Evaluation of commercially available bio-pesticides against crucifer flea beetles and cabbage seed pod weevils on canola

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Aim of the study

The aim of the study was to test the impact of three bio-pesticides: 1) Mycotrol ESO® (*Beauveria bassiana* GHA), 2) Aza-Direct® (azadirachtin) and 3) Entrust WP® (spinosad 80%) in comparison to two conventional insecticides, Gaucho® (imidacloprid) and Mustang Maxx® (Zeta-cypermethrin) on crucifer flea beetles (*Phyllotreta cruciferae*) and cabbage seed pod weevils (*Ceutorhynchus obstrictus*) on canola.

Figure 1. Flea beetle feeding damage on Canola at Conrad in 2018.

Material and Methods

Study sites

Field trials were conducted at two locations in Conrad (48° 18.627'N, 111° 55.402' W) at the Western Triangle Agricultural Research Center research field area and Cut Bank (48° 30.77'N, 111° 92.55' W), both representing dryland rain fed (i.e., non-irrigated) conditions of the West-

Central region of Montana, USA in 2018. Both the sites were sown with canola in 2017. Experimental plots were seeded on May 2, 2018 (Conrad) and June 7, 2018 using Hy-Class® (WindField Solutions, LLC, Houston, Texas) cultivar at a rate of 12 seeds per 30 cm, using a four-row plot drill with 30 cm row-row spacing. At Conrad, round-up ready canola was seeded and at Cut Bank Cibus canola was seeded. Weed control was done by pre-plant application of herbicide RT3® (a.i. glyphosate) at a rate of 2.5 L/ha.

Experimental design and application

The field experiments at both the locations were Randomized Complete Block Design (RCBD). Individual plots measured 3.6 m × 1.2 m in size at Cut Bank and 6 m × 1.2 m in size at Conrad. A buffer zone of 1.2 m was set up between each plot to avoid cross contamination due to spray drift. Treatments were replicated 4 times at each location. Gaucho was applied as seed treatment and other treatments were applied as foliar application after first incidence of flea beetle. Since plot size is different for both sites, the application rate were calculated accordingly (Table 1). Each plot was rated for the flea beetle (*P. cruciferae*) feeding injury along one 3.6-m section of row in each plot, by sampling 10 plants at 0.3 m intervals, four times i.e. cotyledon, four leaf, pre-flowering and pod formation stage during the canola growing season. *Phyllotreta cruciferae* injury measurements were made by visual examination, on a 5-grade scale as defined in OEPP/EPPO (2004). The visual injury ratings were converted into percent leaf area injury, where 1 = 0%; 2 = 2%; 3 = 5%; 4 = 10%; and 5 = 25% injury to the leaf area. Seedpod weevil (SPW) damage assessments on the pods were performed at the canola pod maturation stage. Fifteen pods were randomly sampled per plot and damaged or undamaged pods were determined in the lab by visual inspection using SPW damage characteristics (Feeding holes) followed by the opening of pods with a sharp blade to check the presence of larvae inside the pods.

Post-harvest data collection

The canola plots were straight combined stored and air dried until the seeds were at 10% moisture. The seeds were then cleaned and weighed to determine the seed yield followed by the assessment of canola grain quality parameters including test weight, thousand kernel weight (TKW) and percent oil content. Before harvesting, the plot's areas were calculated. After harvesting, canola from each plot were brought to the WTARC facility and cleaned using a seed cleaning machine (Almaco, Allan Machine Company, Iowa, USA). The plot and test weight was measured using a laboratory balance (Ohaus, Adventure™ Pro model AV8101). Canola samples were processed through a grain analyzer (Perten Instruments IM9500; Hägersten, Sweden) to determine moisture, and oil content.

Statistical analysis

PROC MIXED procedure (PROC MIX, SAS Institute 2018) was performed for determining the effects of conventional insecticides and biopesticides on *P. cruciferae* injury damage ratings and, yield and grain quality parameters including test weight, and percent oil content. An alpha level of 0.05 was used for all tests. Since, effect of pesticides was not significant, least square (LS) mean estimates and their SE are presented for main effects only.

Table 1: Materials and rates of application in each treatment applied on Canola in 2018 at two sites.

Treatment	**Active Ingredient**	**Concentration**	**Rate**	**Source**
Control	Water			
Gaucho® 600 Seed treatment	Imidacloprid	190 ml/45 kg seed	190 ml/45 kg seed	Bayer Crop Science
Aza-Direct®	Azadirachtin	1.43 ml/L (473 ml/acre)	1.43 ml/L	Gowan Company
Mycotrol® ESO	Beauveria bassiana Strain GHA	237-950 ml/gallon 62-250 ml/liter	1.25 ml/litre	LAM International
Mustang Maxx®	Zeta-cypermethrin	118.294 ml/acre	0.028 ml/litre	FMC corporation
Entrust®	Spinosad (a mixture of spinosyn A and spinosyn D)	0.091 ml/L of water 0.34352 ml/ gallon	0.091 ml/L of water	Dow AgroSciences

Table 2: Crucifer flea beetle leaf area feeding injury (LS means estimates ± SEM) to canola seedlings treated with biopesticides and chemical seed treatment in Montana. a and b Injury ratings pre foliar and 15 days after foliar application, respectively. Mean differences among the treatments are based on LSD (0.005).

Treatment	WTARC			Cut Bank		
	Leaf Area Injury pre-treatment	Leaf Area Injury post 15 days treatment	Yield	Leaf Area Injury pre-treatment	Leaf Area Injury post 15 days treatment	Yield
Water	4.3 ± 0.2^{a}	2.5 ± 0.4^{ab}	864 ± 140^{ab}	1.2 ± 0.08^{c}	-	374 ± 90^{a}
Imidacloprid	3.8 ± 0.2^{a}	1.9 ± 0.4^{ab}	834 ± 140^{ab}	1.2 ± 0.08^{a}	-	397 ± 90^{a}
Aza-Direct	3.85 ± 0.2^{a}	3.05 ± 0.4^{a}	734 ± 140^{ab}	1.3 ± 0.08^{bc}	-	432 ± 90^{a}
Mycotrol	3.8 ± 0.2^{a}	2 ± 0.4^{ab}	668 ± 140^{ab}	1.4 ± 0.08^{abc}	-	425 ± 90^{a}
Zeta-cypermethrin	4.25 ± 0.2^{a}	2.8 ± 0.4^{ab}	439 ± 140^{b}	1.3 ± 0.08^{bc}	-	506 ± 90^{a}
Entrust	3.95 ± 0.2^{a}	$\mathbf{1.8 \pm 0.4^{b}}$	$\mathbf{959 \pm 140^{a}}$	1.45 ± 0.08^{ab}	-	587 ± 90^{a}
F, P	0.6 (0.3)	1.2 (0.2)	425 (0.2)	0.2 (0.1)	-	274 (0.5)

Treatment	WTARC			Cut Bank		
	Oil Content (%)	Test Weight (lbs/bu)	TKW (gms)	Oil Content (%)	Test Weight (lbs/bu)	TKW (gms)
Water	45 ± 0.42^{a}	46 ± 0.61^{b}	1.5 ± 1.7^{b}	45 ± 0.65^{a}	48 ± 1.4^{a}	2.2 ± 1.4^{b}
Imidacloprid	44.6 ± 0.42^{a}	47 ± 0.61^{ab}	2.5 ± 1.7^{b}	43 ± 0.65^{b}	48 ± 1.4^{a}	3.6 ± 1.4^{ab}
Aza-Direct	44.7 ± 0.42^{a}	48 ± 0.61^{ab}	3.4 ± 1.7^{b}	44 ± 0.65^{ab}	49 ± 1.4^{a}	2 ± 1.4^{b}
Mycotrol	44 ± 0.42^{a}	48 ± 0.61^{ab}	2.5 ± 1.7^{b}	44 ± 0.65^{ab}	48 ± 1.4^{a}	4 ± 1.4^{ab}
Zeta-cypermethrin	45 ± 0.42^{a}	48.5 ± 0.61^{a}	$\mathbf{9.2 \pm 1.7^{a}}$	44 ± 0.65^{ab}	48 ± 1.4^{a}	5.7 ± 1.4^{ab}
Entrust	45 ± 0.42^{a}	47 ± 0.61^{ab}	2.5 ± 1.7^{b}	44 ± 0.65^{ab}	48 ± 1.4^{a}	$\mathbf{7.7 \pm 1.4^{a}}$
F, P	1.2 (0.67)	1.8 (0.24)	4.6 (0.02)	1.9 (0.3)	0.9 (0.6)	4.2 (0.08)

Results

At both the sites in 2018, no cabbage seed pod weevil was observed. Flea beetle injury at both the sites were recorded before applying treatment. At Cut Bank site, after spraying few flea beetles were observed throughout all the plots with no injury to the plants. A significant decrease in pod and leaf injury was recorded in the Entrust treated plots (F=1.2, df=15; P=0.2) at WTARC site. Almost negligible effect on flea beetle injury level were observed in the plots treated with Aza-Direct (Table 2). In terms of yield at WTARC site, Entrust had significant positive impact on yield (F=425; df=15; P= 0.2). At Cut Bank due to late harvesting and hail damage the yield was less (Figure 2).

Conclusion

At both the sites no cabbage seed pod weevil (*Ceutorhynchus obstrictus*) was noticed on Canola. The flea beetle (*Phyllotreta cruciferae*) damage was not noticed at Cut Bank after application of treatments. At WTARC site, post application of treatment there was an overall reduction in population of flea beetles (Figure 3). However, the best treatment which reduced the damage to canola crop and overall increased the yield. Curiously, greater TKW (thousand kernel weight) was noticed in Mustang treated plots at WTARC and Entrust treated plots at Cut Bank. Although at Cut Bank no significant difference was observed in yield but still greater yield was noticed in Entrust treated plots. Entrust seems to work best in terms of reducing the flea beetle population and also in increasing the yield. In the present study we have applied the treatments only once, and flea beetle infestation was extremely heavy at two cotyledon stage as well as pod stage at WTARC site. In spite of both the factors, Entrust gave a good protection against flea beetle at WTARC.

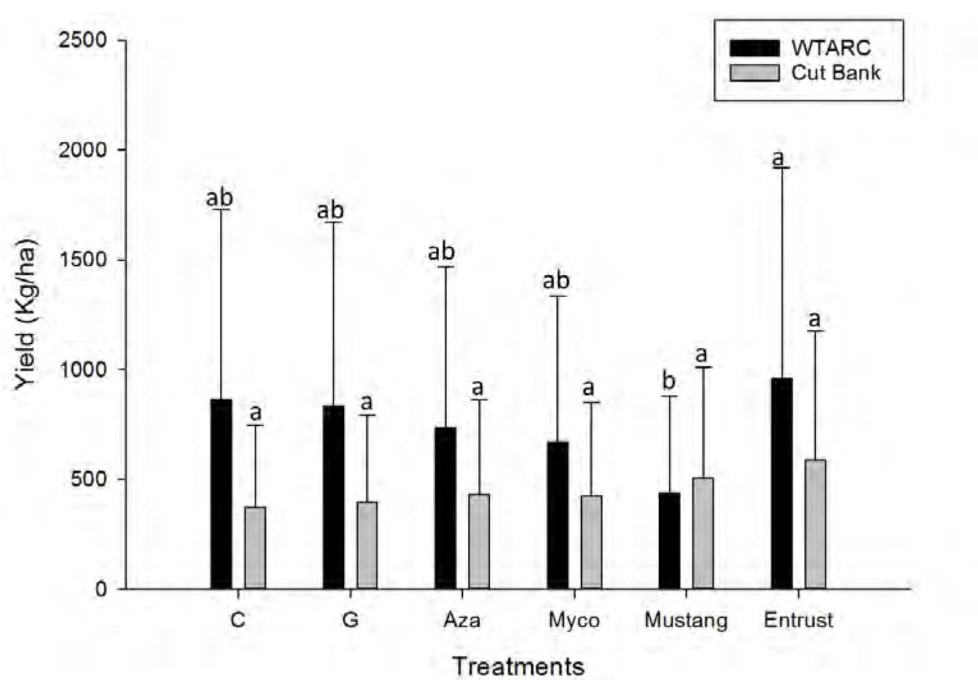

Figure 2. Mean yield (kg/ha) of canola at two sites, WTARC (■) and Cut Bank (□) in 2018. [n = 4]. Different letters above the bars indicate significant differences (α= 0.05). y-axis shows mean yield (mean yield+ SE) and x-axis indicate six treatments.

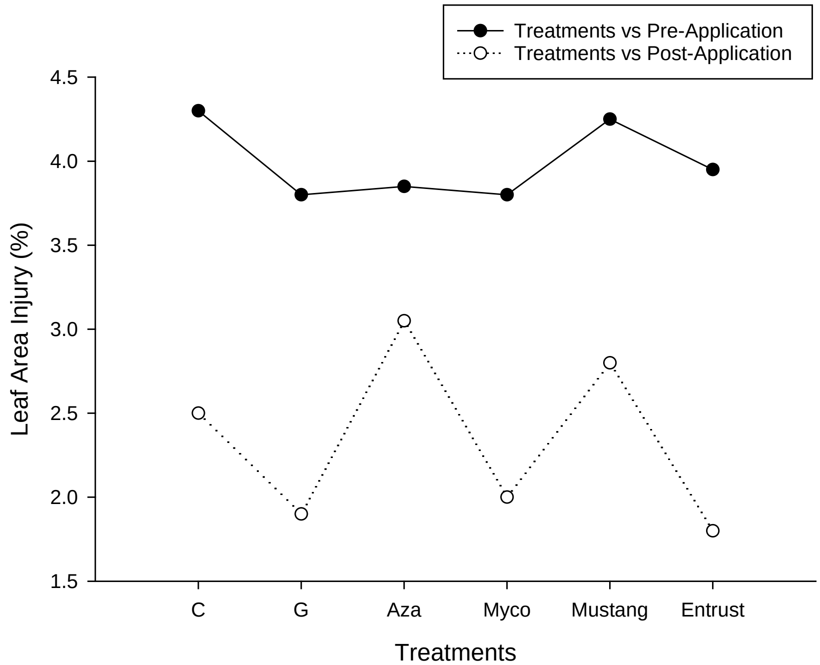

Figure 3. Leaf area injury on canola at WTARC in 2018. Leaf area injury pre-treatment application (●) and post-treatment application (○). [n = 4]. Difference were analyzed between treatments at α= 0.05. y-axis shows leaf area injury (%) and x-axis indicates six treatments.

Acknowledgements
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References:

OEPP/EPPO. 2004. Efficacy evaluation of insecticides. Phyllotreta spp. On rape, pp. 242-244. OEPP/EPPO Bull. Pp 1/218.
SAS Institute Inc. 2018. 9.4 In-Database Products, User's Guide, fifth ed. SAS Publishers, Cary, NC, USA.