Department

of

Research Centers

40th ANNUAL RESEARCH REPORT

WESTERN TRIANGLE AGRICULTURAL RESEARCH CENTER

Montana Agricultural Experiment Station

Conrad, MT

2017 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 '16-17 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 (31 yr)	Difference	Current Year	Average (31 yr)	Difference
September, 2016	2.43	1.21	+1.22	53.4	56.9	-3.5
October, 2016	1.06	0.66	+0.60	41.6	44.7	-3.1
November, 2016	0.15	0.30	-0.15	39.4	32.1	+7.3
December, 2016	0.23	0.21	+0.02	13.3	23.6	-10.3
January, 2017	0.49	0.29	+0.20	16.4	22.6	-6.2
February, 2017	0.48	0.21	+0.27	21.5	24.9	-3.4
March, 2017	0.52	0.39	+0.13	32.0	32.7	-0.7
April, 2017	2.16	1.06	+1.10	41.2	42.7	-1.5
May, 2017	0.64	1.86	-1.22	54.0	51.6	+2.4
June, 2017	2.59	2.92	-0.33	61.1	59.3	+1.8
July, 2017	0.84	1.41	-0.57	71.9	67.0	+4.9
August, 2017	0.04	1.26	-1.22	66.3	66.0	+0.3
Total or Average	11.63	11.77	-0.14	42.7	43.7	-1.0

Last killing frost in spring (32 °F)
2017-------------------------------- May 03
Average 1986-2017-------------- May 17

First killing frost in fall (32 °F)
2017-------------------------------- September 24
Average 1986-2017-------------- September 25

Frost free period (days)
2017------------------------------ 144
Average-------------------------- 131

Maximum summer temperature------- 94 °F (July 09, 2017)
Minimum winter temperature------- -22 °F (December 17, 2016)

Varietal Testing Program

Winter wheat

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/Insect Ecology, Western Triangle Ag Research Center

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

Cooperators: Bradley Farms, North of Cut Bank, MT
Brian Aklestad, North of Devon, MT
Aaron Killion, East of Brady, MT
Inbody Farms, Northeast of Choteau, MT

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

Methods: On station plots consist of the Intrastate, Advanced and Preliminary A nurseries. In the Interstate, Advanced, and Preliminary A nurseries there are 49, 36, and 64 entries replicated three times. Off station winter wheat nurseries consist of 25 entries replicated three times, seeded with a four row plot seeder on one foot spacing. Winter cereal forage trial had 14 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. 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 13. Tables 1 and 2 have the Intrastate data tabulation and Table 3 is for the Advanced nursery. Table 4 contains data from the Preliminary A trial. Table 5 is for the Choteau location, with multi-year data presented in Table 6. Tables 9 and 10 are for the Devon location, with Tables 11 and 12 representing the 'Knees' location. The Cut Bank data are presented in Tables 7 and 8. Winter cereal forage data are presented in Table 13. Table 14 are the soil test results from each location.

Overall, the crop year temperatures where much warmer than 31 year average at the research center, July was 4.9 degrees warmer than the average. But the overall average temperature for the year from September to August was 1 degree cooler than the 31 year average. The winter temperature was well below average, with the exception of November being about 7 degrees warmer than usual. December and January were 10 and 6 degrees colder than the 31 year average while May thru August were warmer than the 31 year average. While we had the colder than normal temperatures in December and January, there was snow cover on the winter wheat.

July was 5 degrees warmer than the normal. Precipitation was generally above the average from September to April, then below normal from May to August. Overall, precipitation was average for the year.

The chemical fallowed soils generally had good moisture while seeding winter wheat during the fall of 2016. Overall, considering the lack of moisture and heat this past summer, the winter wheat did quite well.

Grain yields for the Intrastate nursery were about 13 bu/ac lower than the five year average and test weights were up about the same with respect to the five year average. Seed protein was about the same when compared to the five year average (Table 2). The top yielding varieties were Long Branch, Langin, and Denali at 91.9, 86.8, and 85.1 bu/ac with each also having a test weight over 60 lb/bu (Table 1).

Grain yields and test weights at Choteau were about 2 bu/ac lower and three fourths lb/bu lower than the five year average. Seed protein at Choteau was 1 percent lower than the five year average. The top yielding varieties at Choteau include the Montana State University experimental lines MTW1491, MTS1573, and Brawl CLP at 63.1, 59.8, and 59.4 bu/ac (Table 5 and 6). Grain yields and test weights at Cut Bank were 14.8 bu/ac higher and 3.6 lb/bu higher than the five year average. Seed protein at Cut Bank was 2.7 percent lower than the five year average. At Cut Bank, the top yielding wheat's were Keldin, SY Monument, and the Montana State University experimental line MT1465 with yields of 98.0, 94.1, and 91.5 bu/ac (Table 7 and 8).

Grain yields and test weights at Devon were 2.8 bu/ac higher and 0.7 lb/bu higher than the five year average. Seed protein at Devon was about 0.4 percent higher than the five year average. Top yielders at Devon include Montana State University experimental lines MTW1491, MT1348, and the MT1265 at 75.2, 72.9, and 70.4 bu/ac (Table 9 and 10). Grain yields and test weights at the 'Knees' were 19.8 bu/ac higher and 0.6 lb/bu higher than the five year average. Seed protein at the 'Knees' was 0.5 percent lower than the five year average. The top yielding varieties at the 'Knees' include Brawl CLP, SY Monument, and Keldin at 90.2, 90.0, and 89.9 bu/ac (Table11 and 12).

A winter cereal forage trial was seeded the fall of 2016. The forage data was collected when the plants were in the early milk stage. The top three dry matter yielding varieties were WCF1060, WCF1440, and T1310-221 with 7.3, 7.2, and 6.9 ton/ac (Table 13).

All off station plots had some level of sawfly cutting in the winter wheat. Insignificant amount of adult wheat midge were found at the off station locations.

<u>Summary:</u> 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.

MWBC FY2018 Grant Submission Plans: A similar project will be proposed for FY 2018. The continuation of on and off-station variety trials help elucidate researchers and farmers which varieties are better suited for that particular region in Montana.

Table 1. 2017 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)	Plant height (in)	Seed protein (%)
Long Branch	Dyna-Gro, 2015		91.9	62.4	152.5	29.2	11.9
Langin	Colorado, 2016		86.8	61.6	153.2	28.0	11.3
Denali	Colorado, 2011		85.1	62.1	155.2	29.1	12.5
LCS Jet	Limagrain, 2015		85.0	58.1	157.6	25.9	12.5
CO13003C			83.3	60.8	154.4	31.2	12.0
SY Clearstone 2CL	MT/SY, 2012		80.9	60.2	158.0	34.4	13.2
Brawl CLP	Colorado, 2011		80.4	63.6	152.4	28.8	12.5
Keldin	WestBred, 2011		80.1	62.3	156.7	29.2	13.1
SY Wolf	Syngenta, 2010		79.6	61.7	156.0	29.6	13.1
MTS1588		22.1	79.5	60.8	158.3	29.0	13.8
SY Monument	Syngenta , 2015		79.0	59.7	156.1	29.3	12.1
MT1348			78.5	60.5	156.0	28.7	13.0
MT1542			77.6	59.4	157.6	31.6	12.8
MT1265			77.5	60.3	158.4	32.1	13.1
SY Sunrise	Syngenta, 2015		76.7	62.9	154.5	25.5	12.6
07CL039-7			76.4	63.2	152.4	28.4	12.5
LCS Chrome	Limagrain, 2016		75.9	61.7	155.9	31.2	13.2
MT1563			75.6	59.8	158.0	31.8	12.9
WB4575			74.6	61.8	156.1	29.0	13.5
PSB13NEDH-7-45			74.2	60.0	154.7	29.2	12.8
Northern	Montana, 2015		74.2	60.1	158.4	31.3	13.0
MT1507			74.0	61.0	157.2	32.4	12.9
WB4614	WestBred, 2014		73.7	62.4	156.4	27.7	13.1
Judee	Montana, 2011	18.5	73.5	61.9	156.8	29.2	13.5
MT1564			72.9	61.5	154.3	28.4	12.4
MTS1573		20.1	72.9	61.5	155.9	29.9	13.2
Bearpaw	Montana, 2011	19.7	72.8	60.5	156.9	29.0	13.4
Loma	Montana, 2016	18.8	72.7	60.5	158.0	28.6	13.5
PSB13NEDH-7-140			71.9	62.1	155.5	31.5	13.3
MT1540			71.8	60.7	156.3	30.4	13.3
MT1465			71.3	60.8	157.1	28.4	13.0
MT1444			71.0	60.1	157.7	31.1	13.3
MTW1491			70.8	60.3	157.6	29.9	12.8
MT1471			69.9	59.4	157.9	30.6	14.4
MTCL1131			69.8	60.0	158.3	32.6	13.0

Table 1 continued on next page

Table 1 continued

Variety and Class	Source	Solid Stem score*	Yield[1] (bu/ac)	Test[1] weight (lb/bu)	Heading Date (Julian)	Plant height (in)	Seed Protein (%)
BZ9WM09-1620			69.7	61.5	156.4	31.8	12.3
MT1547			69.4	60.5	157.0	30.7	13.3
MTF1432			69.3	57.3	159.9	36.1	13.0
MT1565			69.0	60.7	155.4	28.5	13.8
BZ9W09-2216		16.5	68.5	62.8	158.4	30.2	12.9
WB4623CLP	WestBred, 2015		68.0	60.4	157.2	29.5	13.4
WB4483	WestBred, 2016	18.1	67.6	61.3	158.7	29.5	14.5
Decade	MT/ND, 2010		67.3	62.0	156.6	29.8	13.0
MTF1435			67.2	60.4	159.3	35.9	12.8
MTF1559			66.7	56.2	161.4	35.4	12.9
Warhorse	Montana, 2013	20.4	66.0	59.5	157.3	27.7	13.4
Warhorse #2			64.2	59.4	157.4	27.7	13.1
WB-Quake	WestBred, 2011	20.0	63.5	62.5	158.9	30.4	13.4
MT1488			54.8	57.5	159.1	29.7	13.4
Mean		16.3	73.7	60.8	156.8	30.1	13.0
LSD (0.05)		1.2	10.3	1.5	1.0	2.2	0.6
C. V. (%)		4.2	8.1	1.4	0.4	4.3	2.7
P-value (Varieties)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Planted: 09/26/2016 & 09/27/2016 on chemical fallow and harvested on 07/21/2017.
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 03/24/2017. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: pre-plant sprayed with 20 oz RT3/ac and 0.6 oz Olympus/ac. Huskie at 11.0 oz/ac and Axial XL at 16.4 oz/ac applied on 05/16/2017.
* 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, 2013 – 2017, 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	-	96.6	62.2	30.5	160.0	12.5	3
Northern	MSU	-	94.9	60.4	33.3	164.0	13.5	3
SY Clearstone 2CL	SY/MSU	-	93.1	59.7	34.8	163.0	12.5	3
Loma	MSU	18.8	89.0	59.6	31.0	165.1	13.0	4
Decade	MSU/ND	-	87.0	61.6	32.3	160.5	13.6	4
Bearpaw	MSU	19.7	83.2	60.6	31.8	161.5	13.1	2
Judee	MSU	18.5	80.5	62.1	32.3	161.3	13.2	2
WB-Quake	WestBred	20.0	76.1	59.6	30.8	163.0	13.2	3
Warhorse	MSU	20.4	76.1	61.0	32.4	164.2	13.1	4
Mean		19.5	86.3	60.7	32.1	162.5	12.9	

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

Table 3. 2017 Advanced Yield Nursery, Western Triangle Ag. Research Center, Conrad, MT.

ID or Variety	Yield (bu/ac)	Test weight (lb/bu)	Heading Date (Julian)	Plant height (in)	Seed Protein (%)
MT16101	74.2	59.9	155.7	30.7	13.2
MT1642	73.4	57.4	159.3	34.7	13.3
MTS1606	72.1	60.8	156.0	28.0	14.1
SY Wolf	70.7	60.5	156.3	30.3	13.9
MT1670	70.4	57.1	159.7	31.3	14.0
MTCS1601	68.8	59.8	157.7	30.0	14.0
MTW1644	68.7	61.7	155.3	29.0	13.6
MT1668	68.4	60.0	158.0	28.3	13.6
Judee	67.0	58.9	157.3	30.0	13.9
MT1688	67.0	60.4	154.7	28.0	13.9
MT16104	66.9	57.5	157.0	27.0	14.1
mixture	66.6	57.6	158.0	29.0	13.9
MT1695	66.3	59.1	154.0	28.3	13.1
MT16102	66.3	58.6	156.0	26.3	13.8
MTS1613	66.3	58.4	158.3	28.7	14.1
MT1683	65.2	58.2	157.0	29.7	13.4
MT1638	65.1	61.0	155.0	29.7	13.0
MT1646	64.8	61.0	155.3	27.3	13.7
MTCL1636	64.4	58.6	157.3	29.0	14.0
MT1694	64.2	59.4	156.7	30.3	13.4
MT1641	64.0	58.8	157.3	27.0	13.9
MTS1602	63.4	61.1	155.3	26.3	13.6
MT1647	62.8	57.5	160.3	29.0	13.3
MT1687	61.5	59.3	155.0	28.0	14.3
MT1654	60.8	58.2	154.0	25.3	13.8
MTS1622	60.7	58.0	156.7	26.0	13.5
MTS1621	60.4	59.4	157.0	24.7	13.7
MTV1681	60.2	58.7	156.7	29.7	13.9
Decade	59.8	59.6	156.7	28.0	13.5
MT1684	59.2	60.7	159.0	27.0	12.6
MT1648	59.1	61.1	156.0	25.3	13.8
Warhorse	58.9	58.8	157.7	26.7	13.7
MTCL1632	58.2	61.2	158.0	29.7	13.8

Table 3. Continued on next page

Table 3 Continued

ID Or Variety	Yield (bu/ac)	Test weight (lb/bu)	Heading Date (Julian)	Plant height (in)	Seed Protein %
MTF1631	57.8	59.9	158.7	30.3	13.4
MT1658	56.4	58.4	158.3	28.7	14.0
MT1672	50.0	60.3	153.3	28.7	13.6
Mean	64.2	59.3	156.8	28.5	13.7
LSD (0.05)	ns	1.7	1.2	3.7	0.7
C.V. (%)	12.7	1.7	0.5	8.0	2.9
P-value (Varieties)	0.4158	<0.0001	<0.0001	0.0022	0.0049

Planted: 09/26/2016 on chemical fallow and harvested on 07/21/2017.
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 3/24/2017. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: pre-plant sprayed with 20 oz RT3/ac and 0.6 oz Olympus/ac. Huskie at 11.0 oz/ac and Axial XL at 16.4 oz/ac applied on 05/16/2017.
[1] Yield and test weight are adjusted to 13% seed moisture.

Table 4. 2017 Preliminary A Variety Nursery, Western Triangle Ag. Research Center, Conrad, MT.

Variety	Yield (bu/ac)	Test weight (lb/bu)	Heading Date (Julian)	Plant height (in)	Seed Protein (%)
SY Wolf	86.7	63.6	157.1	30.5	12.7
MT1776	86.2	61.7	156.9	31.3	12.9
MTCL1737	85.9	59.9	160.2	30.1	13.2
MT1763	85.5	61.3	157.3	29.2	12.8
MT1790	81.4	62.3	158.6	27.7	12.9
MT1764	81.0	61.9	156.0	29.2	12.3
MT1747	80.8	63.9	158.2	28.3	12.8
MT1776	80.7	63.0	155.8	27.4	12.0
MT1742	80.3	63.3	156.9	31.4	13.5
MT1761	80.3	61.7	158.4	30.7	13.0
MT1765	79.8	61.4	156.7	28.9	13.1
MT1789	79.0	60.4	159.3	26.4	12.9
MT1783	79.0	63.8	156.6	28.6	12.9
MT1768	78.9	62.6	157.4	29.6	13.0
MT1787	78.6	61.2	159.6	28.0	12.5
MT1771	78.5	61.3	159.3	32.6	12.7
MT1745	77.0	62.6	159.8	30.5	12.7
MT1749	76.9	62.5	159.4	27.1	12.4
MT1767	76.9	61.5	157.8	30.3	12.9
MT1780	76.9	59.4	157.4	30.6	12.6
MT1772	76.3	60.7	160.3	32.4	14.1
MTCL1736	76.0	60.5	160.2	29.6	12.8
MT1758	75.8	61.7	158.6	27.8	12.7
MT1773	75.2	61.7	157.9	30.4	13.0
Yellowstone	74.4	59.7	159.1	32.8	12.7
MT1777	74.3	62.9	159.5	32.1	12.9
MT1762	74.2	61.2	156.8	27.3	12.6
MT1746	74.2	62.7	157.5	28.2	12.7
MT1775	74.2	62.1	159.1	31.6	12.4
MT1760	73.5	61.3	158.9	28.0	13.1
MT1739	73.4	62.0	157.4	30.1	13.9
MT1788	73.1	61.9	155.3	27.2	12.9
MT1748	72.8	62.2	157.7	26.0	12.6
MT1782	72.7	64.1	156.7	27.1	11.7

Table 4 continued on next page

Table 4 continued

Variety	Yield (bu/ac)	Test Weight (lbs/bu)	Heading Date Julian	Plant Height Inch	Protein (%)
MT1791	72.3	61.3	157.0	30.3	13.3
MT1784	72.0	61.8	160.2	31.1	12.4
MT1752	71.8	61.4	156.9	29.4	11.8
MTCL1733	71.4	61.1	158.1	27.9	13.1
MT1741	71.2	64.0	156.3	28.9	12.7
Decade	71.2	62.2	155.9	29.5	13.1
MTW1753	70.5	62.2	156.0	27.8	13.5
MT1779	70.5	61.9	157.7	27.7	12.4
MT1785	70.3	62.3	158.5	30.2	13.5
MT1754	70.1	61.9	157.1	26.8	13.4
MT1744	69.9	63.6	157.3	28.2	12.5
MT1756	69.8	59.6	161.1	31.9	13.3
MT1769	69.6	62.3	159.0	30.3	12.9
MTCL1732	69.5	60.4	158.5	27.5	12.5
MT1774	69.3	61.4	157.8	29.6	13.1
MT1740	69.2	63.4	157.1	29.2	13.0
MT1743	68.4	63.5	157.2	29.3	13.6
MT1751	67.9	63.8	159.6	27.3	12.9
MT1750	67.3	64.2	158.8	26.5	12.7
MT1757	67.2	61.9	158.3	30.4	13.2
MT1778	66.8	61.7	158.4	27.9	12.7
MTW1755	66.3	62.4	157.0	28.0	13.1
MTCL1734	66.2	62.6	156.5	29.1	13.6
Judee	65.9	63.4	158.1	29.0	13.9
MT1770	65.6	58.9	160.0	31.0	12.9
MT1738	64.4	62.5	158.9	30.8	13.9
MT1781	64.4	63.3	158.2	27.8	14.4
MTF1759	60.3	61.7	160.4	37.8	13.2
MTF1786	56.2	61.6	160.4	39.7	12.9
MTCL1735	52.9	62.5	158.9	28.2	12.5
Mean	73.1	62.0	158.1	29.5	12.9
LSD (0.05)	NS	1.8	1.7	0.0	NS
C. V. (%)	9.1	1.3	0.5	4.6	4.3
P-value (Varieties)	0.0812	<0.0001	<0.0001	<0.0001	0.1504

Planted: 09/27/2016 on chemical fallow and harvested on 07/21/2017.
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 03/24/2017. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: pre-plant sprayed with 20 oz RT3/ac and 0.6 oz Olympus/ac. Huskie at 11.0 oz/ac and Axial XL at 16.4 oz/ac applied on 05/16/2017.
[1] Yield and test weight are adjusted to 13% seed moisture.

Table 5. Off-station Winter Wheat variety trial located near the Choteau. Teton County. Western Triangle Ag. Research Center. 2017.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Height (inch)	Lodging (%)	Protein (%)
MTW1491	63.1	59	30.9	79.1	13.5
MTS1573	59.8	60.5	29.1	47.1	13.4
Brawl CLP	59.4	61.6	28.4	39.4	12.8
Keldin	57.6	59.6	29.1	77.3	13.8
MT1465	56.8	57.9	29.5	75.4	13.9
SY Clearstone 2CL	56.0	56.3	33.4	79.7	13.3
MT1348	55.9	58.3	29.2	77.4	13.3
MTF1435	55.4	56.9	33.3	84.7	13.9
SY Monument	55.4	55.8	27.3	72.0	13.1
MT1444	54.9	57.9	33.3	65.9	14.1
MT1265	54.9	57.0	31.7	74.7	13.6
MTF1432	53.3	56.5	33.9	75.4	13.7
MTS1588	52.6	58.3	26.5	6.3	14.1
MT1471	52.5	57.0	28.3	74.8	14.8
SY Wolf	52.2	59.6	31.5	69.8	14.1
Northern	52.2	57.6	30.9	74.0	14.0
Warhorse	52.0	57.4	29.5	16.8	14.2
CDC Falcon	51.0	57.7	28.6	58.3	14.3
Yellowstone	50.6	56.1	27.4	62.1	14.3
Bearpaw	49.4	57.1	28.3	45.0	14.5
Loma	49.1	57.1	29.5	30.6	13.7
Judee	48.8	58.3	30.5	52.9	14.6
Decade	48.6	59.3	28.5	64.4	13.5
MT1488	47.4	56.8	30.2	64.2	14.0
WB Quake	40.7	56.9	31.1	17.8	14.3
Mean	53.2	57.9	30.0	59.4	13.9
LSD (.05)	8.5	1.6	2.6	22.8	0.8
C.V. (%)	8.9	1.5	4.8	21.7	3.3
P-Value	0.0061	<0.0001	<0.0001	<0.0001	0.0010

Cooperator and Location: Inbody Farms western Chouteau County.
Planted on 10/03/2016 on chemical fallow durum stubble. Harvested on 08/04/2017.
Fertilizer, actual lbs/ac: 11-22-0 with seed at planting, 40-0-20 broadcast while planting. Spring top dressing took place on 03/27/2017 with 96-0-0. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: Pre-plant sprayed with RT3 @ 16 oz/ac on 10/3/2016. Plots were sprayed on 06/13/2017 with Axiel XL @ 16 oz/ac and Vendetta @ 2 pints per acre.
Conducted by MSU Western Triangle Ag. Research Center.
** = Solid wheat 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, Choteau area, Teton County.
2012-2014, 2016, 2017.

Variety Or ID	**	5-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Height (inch)	Protein (%)
Yellowstone		60.3	58.0	31.1	14.8
SY Clearstone 2CL		58.0	58.0	32.2	14.8
Northern (MT0978)		56.6	58.4	30.3	15.2
Judee	**	56.3	57.5	29.8	15.0
CDC Falcon		55.9	58.1	29.2	14.7
Decade		55.2	59.5	29.7	15.0
Bearpaw	**	54.6	59.2	29.4	14.8
Warhorse	**	54.2	58.4	29.1	14.8
WB-Quake	**	49.5	58.6	29.4	14.9
Mean		55.6	58.6	30.0	14.9

** = 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 7. Off-station Winter Wheat variety trial located north of Cut Bank, MT. Glacier County. Western Triangle Ag. Research Center. 2017.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Height (inch)	Protein (%)	Lodging (%)
Keldin	98.0	63.2	32.3	9.6	3.3
SY Monument	94.1	61.1	33.0	9.4	1.7
MT1465	91.5	62.4	32.0	9.6	1.7
MT1265	91.4	61.6	37.3	9.8	3.3
MT1444	90.5	62.1	37.0	9.7	0.0
Northern	87.3	61.7	35.3	10.0	6.7
MTS1588	86.7	63.2	30.0	10.0	0.0
MT1348	86.7	62.7	34.7	9.8	0.0
MT1488	86.0	62.8	34.3	10.6	1.7
SY Clearstone 2CL	85.4	60.9	37.7	10.1	0.0
Yellowstone	84.9	61.5	35.0	9.6	3.3
MTW1491	84.3	62.4	35.0	9.7	3.3
MTF1432	82.8	60.5	39.0	9.3	1.7
SY Wolf	82.4	64.4	31.7	10.5	0.0
CDC Falcon	82.0	62.5	32.3	9.8	0.0
Loma	80.9	62.1	33.0	9.7	1.7
Judee	79.9	63.8	33.7	10.1	1.7
MT1471	79.9	62.9	33.0	10.6	3.3
Warhorse	79.7	62.5	34.7	10.4	0.0
Brawl CLP	79.7	63.9	30.3	10.8	3.3
MTF1435	78.6	61.3	43.3	9.9	1.7
Decade	78.2	62.7	33.7	10.1	3.3
MTS1573	77.1	63.4	32.7	10.6	0.0
Bearpaw	75.0	63.0	33.0	10.1	0.0
WB-Quake	74.5	62.8	34.0	9.9	0.0
Mean	83.9	62.4	34.3	10.0	1.7
LSD (.05)	8.0	1.1	2.0	0.7	NS
C.V. (%)	5.3	1.0	3.5	3.9	160
P-Value	<0.0001	<0.0001	<0.0001	0.0018	0.2529

Cooperator and Location: Bradley Farms, northern Glacier County.
Planted on 09/30/2016 on chem-fallow. Harvested on 08/18/2017.
Fertilizer, actual lbs/ac: 11-22.5-0 with seed at planting, topdressed with 100-0-20 on 03/28/2017. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: Sprayed with Discover NG @ 16 oz/ac and Axial XL at 16.4 oz/ac on 05/02/2017.
** = 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. Four-year means, Winter Wheat varieties, Cut Bank area, northern Glacier County. 2014-2017.

Variety Or ID	**	4-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Height (in)	Protein (%)
SY Wolf		76.2	59.9	31.1	12.7
Yellowstone		74.2	58.6	32.8	12.9
Northern (MT0978)		73.2	59.1	31.9	12.7
Loma		72.1	59.0	29.7	12.4
CDC Falcon		69.9	57.6	30.1	12.7
SY Clearstone CL2		69.3	58.4	33.5	13.1
Decade		68.0	58.6	30.7	12.6
Bearpaw	**	67.2	58.0	30.9	12.8
Judee	**	69.7	59.9	30.5	12.6
WB-Quake	**	61.9	59.1	31.4	12.5
Warhorse	**	60.7	58.9	30.5	12.6
Mean		69.1	58.8	31.1	12.7

** = 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 9. Off-station Winter Wheat variety trial located near the Devon. Toole County. Western Triangle Ag. Research Center. 2017.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Height (inch)	Lodging (%)	Protein (%)
MTW1491	75.2	61.5	26.6	23	12.7
MT1348	72.9	60.9	24.9	18	12.7
MT1265	70.4	60.2	28.9	28	12.6
SY Monument	69.4	59.5	24.9	15	12.5
Loma	67.7	61.4	23.8	13	12.8
MTS1588	67.7	61.6	24.9	0	12.5
SY Clearstone 2CL	67.6	60.3	28.9	26	12.5
MT1444	67.5	61.3	24.0	27	12.6
CDC Falcon	66.6	60.6	23.5	20	13.0
Yellowstone	66.5	60.7	26.2	13	13.0
Keldin	65.5	61.1	24.2	26	12.9
MTF1432	65.3	58.7	28.9	38	12.9
MT1488	65.1	61.8	23.8	24	12.4
SY Wolf	65.0	62.9	23.5	38	12.4
Northern	64.7	60.9	25.8	24	13.4
MT1465	64.3	61.7	24.1	43	12.8
MTS1573	64.2	62.0	23.9	10	12.6
Brawl CLP	63.9	63.3	23.8	26	13.2
Bearpaw	63.2	61.8	22.0	11	12.9
Decade	62.5	60.6	24.5	14	12.6
Judee	62.4	61.3	25.7	6	12.8
WB-Quake	62.1	61.4	27.0	7	13.1
Warhorse	61.8	61.4	23.7	6	13.3
MTF1435	59.8	60.4	30.7	28	12.8
MT1471	58.4	60.8	25.4	30	13.7
Mean	65.6	61.1	25.3	20.6	12.8
LSD (.05)	NS	0.9	2.5	16.8	NS
C.V. (%)	9.6	0.8	5.5	45.3	4.3
P-Value	0.5007	<0.0001	<0.0001	0.0003	0.5443

Cooperator and Location: Brian Akelstad, Toole County.
Planted on 09/28/2016 on chem-fallow. Harvested on 08/02/2017.
Fertilizer, actual lbs/ac: 11-22-0 with seed at planting, 30-0-20 broadcast while planting. Spring topdressing took place on 03/28/17 with 77-0-0. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: Pre-plant sprayed with and RT3 @ 16 oz/ac on 9/28/2016. Sprayed with Huskie @ 11 oz/ac and Axial XL @ 16.4 oz/ac on 05/01/17.
** = 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 10. Five-year means, Winter Wheat varieties, Devon area, Toole County, MT. 2012-2014, 2016 and 2017.

Variety Or ID	**	5-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Height (in)	Protein (%)
Northern (MT0978)		66.8	60.4	26.8	12.3
Yellowstone		66.8	60.0	28.9	12.2
Decade		65.0	61.0	27.6	12.2
CDC Falcon		63.0	59.9	25.9	12.4
SY Clearstone 2CL		62.9	59.9	29.4	12.0
Bearpaw	**	61.5	60.4	25.6	12.8
WB-Quake	**	61.3	60.4	27.4	12.3
Warhorse	**	59.3	60.6	26.6	12.6
Judee	**	59.0	60.8	26.4	12.9
Mean		62.8	60.4	27.2	12.4

** = 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 11. Off-station Winter Wheat variety trial located near the Knees. Chouteau County. Western Triangle Ag. Research Center. 2017.

Variety or ID	Yield (bu/ac)	Test Wt. (lb/bu)	Height (inch)	Lodging (%)	Protein (%)
Brawl CLP	90.2	64.1	29.5	19.4	11.5
SY Monument	90.0	59.8	27.5	43.7	11.4
Keldin	89.9	61.9	29.3	53.4	11.8
Loma	88.2	60.9	28.8	25.8	11.9
MTS1573	86.1	62.8	28.5	37.2	12.1
MTW1491	85.6	60.4	30.0	23.0	11.9
SY Wolf	85.3	63.2	27.6	37.2	12.2
Yellowstone	84.9	60.7	28.9	33.8	11.9
MT1265	82.9	59.6	31.5	45.3	12.3
MT1348	82.3	60.1	28.0	54.8	12.4
MTS1588	82.1	62.0	26.4	8.5	12.4
MT1444	81.4	60.2	29.9	34.4	12.1
SY Clearstone 2CL	80.3	60.1	31.9	40.0	11.9
MTF1432	80.2	58.8	34.8	28.8	12.1
Northern	79.9	60.4	29.0	38.9	12.5
MT1471	78.5	61.2	29.5	66.0	12.8
Warhorse	77.1	61.0	26.4	28.9	12.6
MT1465	76.2	60.8	27.4	59.3	12.1
Bearpaw	75.5	61.3	27.1	43.9	12.6
MTF1435	74.7	59.7	35.1	27.5	12.4
Judee	72.9	61.9	29.2	41.7	12.4
CDC Falcon	71.8	60.6	27.1	36.5	12.5
Decade	71.6	61.3	27.7	29.0	12.6
MT1488	70.3	60.1	29.5	19.7	11.8
WB-Quake	65.0	62.1	27.6	43.7	12.5
Mean	80.1	61.0	29.1	36.8	12.2
LSD (.05)	10.7	0.8	1.8	1.3	0.5
C.V. (%)	7.6	0.8	3.5	31.4	2.3
P-Value	0.0004	<0.0001	<0.0001	0.0003	<0.0001

Cooperator and Location: Aaron Killion, western Choteau County.
Planted on 09/29/2016 on chem-fallow. Harvested on 07/29/2017.
Fertilizer, actual lbs/ac: 11-22-0 with seed at planting, 30-0-20 broadcast while planting, spring fertilized 3/27/17. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: Pre-plant sprayed with Olympus @ 0.6 oz/ac and RT3 @ 16 oz/ac on 09/29/2016. The plots were sprayed on 05/12/2017 with Huskie @ 11 oz/ac and Discover NG @16 oz/ac
Conducted by MSU Western Triangle Ag. Research Center.

Table 12. Five-year means, Winter Wheat varieties, Knees area, Chouteau County, MT. 2013-2017.

Variety Or ID	**	5-Year Mean Yield (bu/ac)	Test weight (lbs/bu)	Height (inch)	Protein (%)
SY Clearstone 2CL		78.3	59.6	32.5	12.4
Yellowstone		77.8	59.8	30.4	12.2
Northern (MT0978)		74.9	60.0	29.7	12.6
Judee	**	73.9	61.7	29.2	12.9
Decade		70.3	60.8	29.1	12.7
Warhorse	**	68.5	60.6	28.1	12.7
CDC Falcon		65.8	60.1	26.9	12.9
WB-Quake	**	63.2	60.8	28.5	12.9
Bearpaw	**	60.3	60.1	27.8	12.8
Mean		70.4	60.4	29.1	12.7

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

Table 13. 2017 Winter Cereal Forage, Western Triangle Ag Research Center, Conrad, MT.

Treatment	Head Date Cal.	Head Date (Julian)	Plant Height (in)	Dry Yield (ton/ac)	Forage Moisture (%)	Test Wt (lb/bu)	Grain Yield (bu/ac)
WCF1060	6/8	158.7	53.7	7.3	54.4	49.9	48.7
WCF1440	6/7	157.7	52.3	7.2	51.2	53.6	54.1
T1310-221	6/7	158.3	50.0	6.9	51.3	54.4	50.0
T1310-218	6/6	156.7	48.7	6.7	52.8	57.3	57.8
Trical 102	6/7	158.0	49.0	6.7	53.5	52.1	59.0
Flex 719	6/6	156.7	44.7	6.3	50.8	52.4	54.1
MTF1631	6/11	160.3	39.3	6.1	54.7	61.7	63.3
WCF0013	6/6	157.0	49.7	5.7	51.6	54.9	40.1
MTF1786	6/11	161.7	42.3	5.6	55.8	62.4	57.1
MTF1559	6/7	169.3	40.3	5.5	64.5	58.4	71.4
MTF1432	6/11	162.0	36.0	5.4	52.2	59.4	62.6
MTF1435	6/9	160.0	34.7	5.1	53.5	58.5	48.1
Willow Creek	6/12	163.0	45.0	4.9	60.3	60.5	33.4
MTF1775	6/7	157.7	28.0	4.2	52.5	62.5	56.5
Mean	6/9	159.8	43.8	6.0	54.2	57	54.0
CV%	-	1.4	11.2	20.1	6.4	2.6	18
LSD(0.05)	-	3.6	8.2	NS	5.8	2.8	977.9
P-Value	-	<0.0000	<0.0000	0.1070	0.0024	5.17	0.0088

Planted: 09/27/2016 on chemical fallow and harvested on 06/26-06/29/2017.
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 3/24/2017. For fertilizer rates a yield goal of 70 bu/ac was used.
Herbicide: pre-plant sprayed with 20 oz RT3/ac and 0.6 oz Olympus/ac. Huskie at 11.0 oz/ac and Axial XL at 16.4 oz/ac applied on 05/16/2017.
[1] Yield and test weight are adjusted to 13% seed moisture.

Table 14. Soil test values for off-station and on-station plots, 2017.

Location	N (lbs/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	39.6	17	385	7.5	2.7	0.39
Devon	12.0	14	221	7.2	0.8	0.15
Knees	21.1	28	482	6.9	2.4	0.55
Choteau	44.5	7	412	8.1	2.3	0.82
WTARC Fall	15.5	20	318	7.8	2.6	0.56
WTARC Spring	15.9	30	528	7.4	2.6	0.36
Sweetgrass Hills	3.5	27	336	6.7	2.5	0.23

[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.

<u>Accipiter</u> (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.

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

<u>Bearpaw</u> (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.

<u>Big Sky</u> (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.

<u>Bond</u> (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.

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

<u>Bynum</u> (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.

<u>Carter</u> (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.

<u>Colter</u> (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.

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

<u>Decade</u> (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.

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

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

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

Hatcher (CO 2004): Winterhardiness = 2. Strong straw, semidwarf height, medium coleoptile. Early maturity. Low protein. Resistant to biotype 1 Russian wheat aphid and Great Plains biotype Hessian fly. Very low quality.

Jagalene (AgriPro, 2002): Winterhardiness = 2. Semidwarf, stiff straw, medium coleoptile. Early maturity, 1 day earlier than Rocky. Shatter resistant. Average yield. Very high test weight. Avg protein, but higher than Rocky. Good milling quality. Good disease resistance package (stem & stripe rust, tan spot and Septoria).

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

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

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

Loma (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.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Hard White Winter Wheat

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

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

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

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

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

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

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

NuSky (MSU, 2001): Hard white, low PPO. (Sister line to the hard red var BigSky). Good dual purpose quality for noodles & bread. Winterhardiness 4. Height and straw strength similar to Nuwest & Rocky, med-stiff. Short coleoptile. Heading similar to Nuwest, Tiber & Neeley; and 3 days later than Rocky. Shatter resistant. Average yield. Test weight similar to Nuwest. Medium to high protein. Quality similar to Nuwest. High level of post-harvest dormancy (similar to Tiber), and thus does not have the sprouting problems common to some of the other hard white wheats. NuSky is a public release.

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

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

Spring wheat and durum variety evaluations

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

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

Personnel: John H. Miller, Research Scientist, Julie Prewett, Research Assistant, WTARC, Conrad, MT, and 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 threetimes. 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 or a Wintersteiger Classic 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 13. AYT is represented in Tables 1 and 2. The Irrigated off-station spring wheat nursery was mowed out by a well-intentioned farmhand. 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 Table 9 and 10 representing the ‘Knees’ location. The Cut Bank data are presented in Tables 5 and 6. Durum data are in Table 11 and 12. Table 13 is the soil test results from each location.

Overall, the crop year temperatures where much warmer than 31 year average at the research center, July was 4.9 degrees warmer than the average. But the overall average temperature for the year from September to August was 1 degree cooler than the 31 year average. The winter temperature was well below average, with the exception of November being about 7 degrees warmer than usual. December and January were 10 and 6 degrees colder than the 31 year average while May thru August were warmer than the 31 year average. July was 5 degrees warmer than the normal. Precipitation was generally above the average from September to April, then below normal from May to August. Overall, precipitation was average for the year.

The spring wheat plots were seeded into soil that had good soil moisture storage from the previous years' fallow period. Overall, considering the lack of moisture and heat this past summer, the spring wheat did quite well.

The AYT yields ranged from 73.5 to 48.5 bu/ac, with an average of 60.3 bu/ac and 15.1 % seed protein. The 5 year yield and protein average for selected varieties in the AYT is 66.1 bu/ac and 13.9 % seed protein. Seed protein was 1 % higher this year when compared to the 5 year average for selected varieties. The top yielding varieties were all Montana State University experimental entries. They are MT 1509, MT 1621, and MT 1651 with Reeder being fourth on the list.

Top yielding varieties at Choteau were Duclair, Vida, and Montana State University line MT 1525. The yields of the top three varieties at Choteau were 52.7, 52.5, and 50.7 bu/ac, respectively (Table 1). Reeder was again the top yielder at Devon with WB Gunnison and Duclair the other high yielding varieties at, 41.7, 37.7, and 37.0 bu/ac (Table 5). The 'Knees' high yielders at 44.3, 44.3, and 43.0 bu/ac, were Duclair, Montana State University line MT 1525, and LCS Pro (Table 7). The best yielding varieties, at the Cut Bank location were Vida, Reeder, and Montana State University line MT 1525 (Table 3) Yields at Cut Bank were 60.8, 55.9, and 54.7 bu/ac (Table 3).

At Devon the 2017 yield was about the same as the five year average; with slightly higher grain protein and a half pound lower test weight (Tables 5 and 6). The 'Knees' location had higher yields by about 2 bu/ac, 1% higher grain protein and 2 lb/bu higher test weight when compared to the five year mean (Tables 7 and 8). When compared to the five year averages, yields at Cut Bank ranged from 53.4 to 37.7 bu/ac, with average protein for the year, with slightly higher test weights (Tables 3 and 4). When comparing the five year means at Choteau the yields were 3.7 bushels higher, seed protein was about one half percent lower and the test weights were about 2 lbs/bu lower. Spring wheat at Choteau had lodging in all varieties, with some being much worse than others. With the exception of Devon, there was some lodging at the other off station sites.

Durum yields ranged from 56.1 to 43.8 bu/acre (Table 11). With MTD16007, Divide, and MTD16010 being the top three yielding varieties at 56.1, 55.7, and 54.0 bu/ac. The 2017 yields were about 13 bu/ac lower than the five year average (Table 12). Test weights were 2.6 pounds per bushel lighter than the long term average.

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.

MWBC FY2018 Grant Submission Plans: A similar project will be proposed for FY 2018. The continuation of on and off-station variety trials help to elucidate researchers and farmers which varieties are better suited for that particular region in Montana.

Table 1. 2017 Spring Wheat Advanced Yield Nursery, Western Triangle Ag. Research Center, Conrad, MT.

ID or Variety	Yield[1] (bu/ac)	Test[1] weight (lb/bu)	Heading Date (Julian)	Plant height (in)	Seed Protein (%)
MT 1509	73.5	58.0	174.6	26.1	14.8
MT 1621	69.3	59.3	171.9	28.2	15.0
MT 1651	67.8	59.1	171.5	26.7	15.3
Reeder	67.8	58.6	172.7	28.8	15.1
MT 1451	67.2	58.4	171.1	27.4	14.0
Alum	67.2	58.7	172.9	28.0	14.1
MT 1348	67.1	58.8	171.2	27.3	14.5
MT 1653	66.3	58.2	171.6	29.1	14.1
NS Presser CLP	65.5	56.9	174.1	29.3	14.2
LCS Rebel	65.2	59.2	171.5	27.8	15.1
MT 1617	65.1	56.7	172.6	27.4	15.1
MT 1455	64.9	58.5	171.2	26.3	15.0
MT 1619	64.9	59.9	171.7	26.0	15.8
WB 9879 CLP	64.7	59.3	172.3	27.1	15.1
MT 1664	64.3	59.4	170.7	27.7	14.9
MT 1320	64.0	59.1	171.7	28.7	14.4
MT 1401	63.9	60.7	170.2	26.5	14.5
MT 1659	63.8	59.7	169.3	25.5	14.8
MT 1635	63.7	59.6	171.9	26.4	15.4
WB 9719	63.3	60.5	172.3	26.6	14.5
MT 1542	62.9	60.0	170.6	27.3	14.7
MT 1601	62.9	58.0	171.8	26.5	15.3
WB Gunnison	62.0	59.2	171.5	27.0	14.0
MT 1625	61.9	60.1	171.1	27.5	15.8
MT 1442	61.1	58.7	171.6	27.5	15.4
Duclair	60.9	56.9	170.3	27.5	15.0
MT 1673	60.9	57.0	170.7	26.2	15.8
MT 1525	60.8	60.6	171.2	26.0	15.1
MT 1666	60.4	57.1	174.8	28.6	15.6
MT 1570	60.4	58.9	170.5	24.7	15.0
SY Tyra	60.1	61.7	171.2	27.7	13.8
Choteau	60.0	58.2	171.6	27.8	15.4
MT 1636	59.9	59.8	171.6	26.1	15.2
MT 1630	59.7	59.6	170.8	28.1	16.0
MT 1622	59.5	56.9	171.6	26.6	16.5
SY Soren	59.1	59.9	172.8	26.3	15.2
MT 1668	58.7	58.9	169.8	26.0	15.6
Lanning	58.7	57.3	171.4	27.1	15.4

Table 1. Continued on next page

Table 1 Continued

ID or Variety	Yield[1] (bu/ac)	Test[1] weight (lb/bu)	Heading Date (Julian)	Plant height (in)	Seed Protein (%)
WB 9616 CLP	58.3	57.7	176.9	29.4	15.1
LCS Prime	58.3	59.7	170.4	27.7	14.0
MT 1624	58.3	59.1	168.4	27.4	15.6
Corbin	58.1	58.1	171.0	27.7	15.3
MT 1514	57.9	56.0	173.6	27.1	15.6
Vida	57.7	57.8	172.5	26.8	14.1
SY Valda	57.4	58.5	171.3	27.4	14.8
MT 1643	57.1	60.2	170.0	25.5	15.6
MT 1645	57.0	59.3	171.3	26.3	15.9
McNeal	56.7	56.5	173.8	29.1	14.4
MT 1627	56.5	59.5	172.2	29.0	15.6
HRS 3530	56.3	56.2	173.6	28.6	15.0
MT 1543	56.1	58.0	170.8	26.6	15.1
MT 1672	56.0	57.3	172.2	28.1	15.9
LCS Pro	56.0	57.9	170.3	28.9	15.3
Egan	55.7	57.3	171.6	27.4	15.7
HRS 3504	55.4	56.3	173.2	25.1	14.0
WB 9590	54.9	59.6	170.5	24.2	15.9
MT 1607	54.9	57.9	171.6	27.0	15.8
AgriPR	54.6	58.5	174.6	25.9	14.5
Fortuna	54.6	58.5	172.6	32.3	14.7
MT 1512	54.4	57.7	171.0	25.8	15.5
SY Ingmar	53.7	59.2	170.9	26.1	15.7
Brennan	51.6	61.1	171.1	26.0	16.0
HRS 3616	51.0	58.6	171.3	27.4	15.5
Thatcher	48.5	55.3	176.0	34.4	15.4
Mean	60.3	58.6	171.8	27.3	15.1
LSD (0.05)	9.4	0.9	1.5	1.9	0.7
C.V. (%)	9.0	0.9	0.5	4.1	2.7
P-value (Varieties)	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Planted: 04/19/2017 on chemical fallow barley stubble and harvested on 08/14/2017.
Fertilizer: actual pounds/ac. of N-P-K: 11-22.5-0 applied with seed and a 208-0-20 blend of urea and potash was double shot at planting. Fertilizer rates are based on a yield goal of 70 bu/ac.
Herbicide: Sprayed with 11 oz/ac Huskie and 16.4 oz/ac Axial XL on 06/18/2017.
Precipitation from seeding to harvest: 4.81 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, 2013 - 2017.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Head date (Julian)	Height (in)	Protein (%)
Reeder	72.0	60.4	31.5	176.1	14.0
McNeal	69.9	59.3	31.0	177.8	13.8
SY Tyra	69.7	61.0	27.6	176.2	12.9
Vida	68.7	59.4	30.9	176.8	13.3
SY Soren	67.2	60.6	28.5	176.4	14.3
Corbin	66.7	60.3	29.9	174.8	13.8
Duclair	65.8	58.2	30.2	173.7	14.0
WB9879CLP	65.3	59.8	29.4	176.6	14.3
WB Gunnison	64.2	60.9	29.6	175.2	13.2
Egan	63.7	59.3	30.3	176.1	15.0
Brennan	63.5	62.1	28.0	174.8	14.5
Fortuna	61.5	60.3	35.6	176.6	13.9
Choteau	61.0	58.7	28.9	176.1	14.0
Means	66.1	60.0	30.1	175.9	13.9

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

Table 3. Off-station spring wheat variety trial located north of Choteau, MT. Teton County. Western Triangle Ag. Research Center. 2017.

Variety	Class	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (in)	Lodging (%)	Protein (%)
Duclair	**	52.7	54.4	27.7	23.3	15.3
Vida	*	52.5	56.8	27.3	40.0	14.0
MT 1525	-	50.7	58.1	27.0	20.0	14.8
Alum	-	50.3	57.3	26.3	60.0	14.0
WB Gunnison	*	50.2	56.3	24.3	8.3	14.2
MT 1543	-	50.0	55.1	26.0	23.3	14.6
WB9879CLP	CL	49.1	54.9	27.0	11.7	15.6
NS Presser 2 CL+	CL	48.2	55.4	26.0	53.3	14.3
Fortuna	**	48.0	57.2	33.7	40.0	15.0
LCS Pro	-	47.7	55.9	29.0	76.7	14.7
Choteau	-	46.9	56.1	27.0	30.0	15.2
MT 1570	-	46.3	55.1	27.0	16.7	14.9
Lanning (MT 1316)	-	46.1	55.1	27.0	91.0	15.6
Corbin	-	46.1	55.2	25.0	40.0	15.4
SY Soren	-	43.0	56.1	22.3	68.3	15.2
Egan	-	43.0	55.1	25.7	87.7	15.4
Brennan	-	42.1	56.9	25.3	63.3	15.2
SY Ingmar	-	41.9	55.9	26.3	65.0	15.6
Reeder	-	40.4	55.0	25.3	86.0	15.7
ONeal	-	37.7	55.3	26.3	43.3	15.9
Mean		46.6	55.7	26.6	47.4	15.0
LSD (.05)		NS	NS	3.1	26.3	NS
C.V. 1 (%) (S/mean)*100		10.5	2.5	7.0	33.5	5.3
P-Value		0.0227	0.1710	<0.0001	<0.0000	0.1079

Cooperator and Location: Inbody Farms, Teton County.
Planted on 05/05/17 on chemical fallow. Harvested on 08/29/17.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and 0-0-20 was applied through the opener while seeding. Fertilizer rates are based on a yield goal of 50 bu/ac.
Herbicide: The plots were sprayed with Roundup RT3 at 40 oz/ac and Sharpen at 1 oz/ac on 05/06/2017
** = 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. Five-year means, Spring Wheat varieties, Choteau, Teton County. 2013-2017.

Variety or ID	5-Year Mean			
	Yield (bu/ac)	Test weight (lb/bu)	Height (in)	Protein (%)
Duclair	46.7	56.1	28.1	15.4
Vida	45.1	57.4	26.9	15.1
WB9879CLP	44.7	56.8	26.8	15.4
WB Gunnison	44.6	58.2	26.8	14.7
Corbin	44.1	57.8	27.1	15.7
Egan	43.5	56.9	26.5	16.4
Choteau	42.6	56.9	26.9	15.7
ONeal	42.0	57.1	28.1	15.9
Brennan	41.9	59.3	25.3	15.5
Reeder	41.4	57.8	27.1	15.7
SY Soren	40.3	58.8	24.8	15.6
Fortuna	37.8	58.6	33.7	15.5
Mean	42.9	57.6	27.4	15.6

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

Table 5. Off-station spring wheat variety trial located at the Cut Bank, MT. Glacier County. Western Triangle Ag. Research Center. 2017.

Variety	Class	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (in)	Lodging (%)	Protein (%)
Vida	*	60.8	58.8	32.7	3.3	13.0
Reeder	-	55.9	58.8	32.3	1.7	14.8
MT 1525	-	54.7	61.5	28.7	0	13.9
Duclair	**	52.3	56.6	30.3	1.7	13.7
Lanning (MT 1316)	-	52.1	58.0	30.0	1.7	14.9
Choteau	**	51.8	58.7	30.3	3.3	14.1
ONeal	*	51.4	58.4	30.1	0	13.8
Brennan	-	49.4	60.8	28.0	0	14.1
SY Soren	-	49.0	57.9	28.3	0	15.0
Alum	-	48.4	58.8	30.1	0	13.4
Corbin	*	48.4	57.9	31.7	5	13.5
NS Presser	-	47.8	56.3	32.0	1.7	14.2
SY Ingmar	-	47.2	58.3	28.3	3.3	15.8
WB Gunnison	*	46.6	57.4	27.3	3.3	13.9
WB 9879 CLP	CL	44.7	57.9	28.7	1.7	15.1
Egan	-	44.3	56.9	28.3	0	15.7
MT 1570	-	41.9	58.7	27.3	3.3	15.1
LCS Pro	-	41.4	57.1	34.3	6.7	15.2
MT 1543	-	40.2	56.9	27.7	3.3	15.1
Fortuna	*	36.2	58.9	39.0	5	14.7
Mean		48.2	58.2	30.3	2.3	14.4
LSD (.05)		9.32	2.1	2.3	NS	1.3
C.V. 1 (%) (S/mean)*100		11.7	2.2	4.5	112.3	5.4
P-Value		<0.0012	<0.0013	<0.0000	0.0565	<0.0013

Cooperator and Location: Bradley Farms, Glacier County.
Planted on 05/09/2017 on chemical fallow. Harvested on 08/06/2017.
Fertilizer: actual pounds/ac of N-P-K: 11-22.5-0 applied with seed and 11-0-20 was applied through the double shoot openers while seeding. Fertilizer rates are based on a yield goal of 50 bu/ac.
Herbicide: The plots were sprayed with Roundup RT3 at 32 oz/ac and Sharpen at 1 oz/ac on 05/08/17.
** = 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, Cut Bank, Glacier County. 2011-2016.

Variety or ID	5-Year Mean Yield (bu/ac)	Test weight (lb/bu)	Height (in)	Protein (%)
Duclair	53.4	57.0	34.1	14.2
Vida	50.8	57.6	36.3	13.6
WB Gunnison	50.6	57.8	32.5	13.3
Choteau	49.1	56.9	33.5	14.4
Reeder	49.1	57.7	35.6	14.8
Corbin	47.8	58.5	33.1	14.0
Brennan	47.4	59.4	31.9	14.7
WB 9879 CL	46.8	56.7	32.3	14.8
Egan	44.7	57.1	31.3	15.9
Oneal	42.9	55.7	34.2	14.5
SY Soren	42.5	56.8	32.6	14.2
Fortuna	37.7	57.9	35.5	14.5
Mean	46.9	57.5	33.6	14.4

Table 7. Off-station spring wheat variety trial located north of Devon, MT. Toole County. Western Triangle Ag. Research Center. 2017.

Variety	Class	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (in)	Protein (%)
Reeder	-	41.7	58.2	24.0	15.3
WB Gunnison	*	37.7	58.1	24.3	13.8
Duclair	**	37.0	57.1	23.3	13.8
NS Presser CLP	CL	36.5	57.8	24.7	14.7
Vida	*	36.4	57.7	24.0	14.6
Alum	-	35.3	59.0	23	13.9
ONeal	*	34.7	57.8	24.0	15.2
MT 1543	-	34.4	57.3	23.3	14.9
Corbin	*	34.0	57.6	24.3	14.8
Lanning(MT 1316)	-	33.3	58.0	23.3	15.8
SY Soren	-	32.8	58.7	23.7	16.0
WB9879CLP	CL	32.0	58.4	22.3	15.4
Choteau	**	30.7	57.3	22.3	15.6
Brennan	-	30.4	59.0	22.0	15.5
LCS Pro	-	30.4	58.7	23.3	15.1
Egan	-	29.4	55.9	24	17.2
MT 1570	-	28.9	58.9	22.0	15.1
MT 1525	-	28.8	60.2	22.7	14.6
Fortuna	**	28.2	57.2	27.7	14.6
SY Ingmar	-	25.2	58.3	23.3	15.6
Mean		32.9	58.1	23.6	15.1
LSD (.05)		5.9	1.2	1.6	0.8
C.V. 1 (%) (S/mean)*100		10.8	1.2	4.2	3.1
P-Value		<0.0003	<0.0000	<0.0000	<0.0000

Cooperator and Location: Brian Aklestad, Toole County.
Planted on 05/08/2017 on chemical fallow. Harvested on 08/22/17
Fertilizer: actual pounds/ac of N-P-K: 11-22.5-0 applied with seed and 11-0-20 was applied through the double shoot openers while seeding. Fertilizer rates are based on a yield goal of 50 bu/ac.
Herbicide: The plots were sprayed with Roundup RT3 at 32 oz/ac and Sharpen at 1 oz/ac on 05/04/2017.
** = 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, Devon, Toole County. 2013-2017.

Variety or ID	5-Year Mean			
	Yield (bu/ac)	Test weight (lb/bu)	Height (in)	Protein (%)
Reeder	35.8	59.4	25.2	14.4
Vida	34.8	58.5	24.5	14.0
Duclair	34.7	57.7	24.0	14.3
WB Gunnison	33.9	58.9	23.9	13.6
WB9879CLP	33.5	58.5	22.3	15.4
Egan	31.8	57.1	24.6	15.9
SY Soren	31.8	59.0	22.7	15.2
Brennan	30.8	59.7	22.2	15.3
Oneal	30.6	59.4	23.9	14.5
Choteau	30.5	58.1	23.0	14.9
Corbin	29.8	58.8	24.1	14.5
Fortuna	28.0	58.2	27.6	14.7
Mean	32.2	58.6	24.0	14.7

Table 9. Off-station spring wheat variety trial located at the Knees area, Chouteau County. Western Triangle Ag. Research Center. 2017.

Variety	Class	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Height (in)	Lodging (%)	Protein (%)
Duclair	**	44.3	58.6	24.7	0.0	14.6
MT 1525	-	44.3	61.1	25.0	0.0	15.3
LCS Pro	-	43.0	58.2	28.7	3.7	14.9
WB Gunnison	*	42.0	57.9	25.3	0.0	14.0
MT 1543	-	42.0	56.7	25.3	0.3	15.1
Lanning (MT 1316)	*	41.4	57.4	26.3	3.0	15.9
NS Presser 2 CLP	CL	41.4	57.8	26.7	1.7	14.5
WB9879CLP	CL	41.1	57.7	24.0	0.0	15.2
MT 1570	-	40.8	58.3	24.3	0.7	15.2
Vida	*	38.6	58.9	24.3	1	14.2
ONeal	*	37.9	58.8	27.0	0.7	14.9
Alum	-	37.2	60.4	25.7	0.7	14.4
Egan	-	37.1	56.1	25.3	4.7	16.6
SY Ingmar	-	36.8	57.8	23.0	1.3	15.5
Reeder	-	36.0	58.2	25.7	1.0	15.6
Corbin	*	35.9	58.8	26.0	0.3	15.0
Fortuna	-	34.4	58.3	30.7	0.7	15.5
Choteau	**	34.3	58.0	23.7	0.0	15.8
SY Soren	-	34.1	58.3	24.0	1.3	15.8
Brennan	-	32.8	59.2	25.7	0.7	15.9
Mean		38.8	58.3	25.6	.8	15.9
LSD (.05)		7.4	2.0	2.3	1.3	0.7
C.V. 1 (%) (S/mean)*100		9.4	1.7	5.5	75.9	2.2
P-Value		0.0024	<0.0003	<0.0000	<0.0000	<0.0000

Cooperator and Location: Aaron Killion, Chouteau County.
Planted on 05/05/2017 on chemical fallow. Harvested on 08/17/2017
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and 26-0-20 was applied through the double shoot openers while seeding. Fertilizer rates are based on a yield goal of 50 bu/ac.
Herbicide: The plots were sprayed with Roundup RT3 at 32oz/ac and Sharpen at 1 oz/ac on 05/06/2017
** = 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, Knees area, Chouteau County. 2011-2017.

Variety or ID	5-Year Mean Yield (bu/ac[1])	Test weight (lb/bu)	Height (in)	Protein (%)
Duclair	42.9	56.2	24.9	14.4
Vida	39.6	56.1	25.7	14.5
WB Gunnison	39.1	57.9	25.3	14.2
Choteau	38.3	56.6	24.1	14.8
Reeder	37.9	57.5	25.9	14.9
Egan	37.9	55.9	24.8	16.4
WB 9879 CL	36.9	56.2	25.1	13.8
Corbin	35.4	57.2	25.6	14.5
Brennan	35.3	57.5	24.3	15.9
SY Soren	34.6	56.5	23.8	15.7
Oneal	32.6	56.4	26.2	14.2
Fortuna	30.7	57.5	29.7	15.8
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 11. Durum Variety Trial located WTARC. Pondera County. Western Triangle Ag. Research Center. 2017.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Height (in)	Head Date	Protein (%)	Lodging (%)
MTD16007	56.1	57.8	27.0	174.3	14.7	10.0
Divide	55.7	58.2	28.7	174.3	14.6	5.0
MTD16010	54.0	58.2	29.0	175.0	14.9	11.7
Grenora	53.1	57.0	25.7	172.3	14.4	6.7
MTD16005	52.9	56.5	27.7	173.3	15.1	8.3
Carpio	51.6	56.9	27.0	176.0	14.2	5.7
Tioga	50.5	57.7	31.7	175.7	15.3	6.7
MTD16001	49.6	55.3	26.0	174.3	15.3	5.0
MTD112219	49.5	58.6	22.7	171.0	14.5	4.0
MTD16003	49.2	57.0	26.7	172.3	14.0	10.0
Alkabo	49.0	57.4	26.0	173.0	14.3	8.3
Precision	49.0	57.0	26.7	172.0	15.8	8.3
MTD16004	49.0	58.1	27.7	173.3	13.3	11.7
Dynamic	48.3	57.5	26.3	174.7	14.3	9.0
Mountrail	48.3	55.5	28.7	174.3	14.76	10.0
MTD16009	47.6	53.5	27.3	177.0	15.9	6.7
MTD16011	47.6	55.7	27.3	173.7	15.9	16.7
Joppa	47.3	58.0	26.7	173.3	14.1	11.7
MTD16002	46.3	55.6	29.3	177.3	15.3	6.7
Fortitude	46.1	56.3	26.0	175.0	16.3	3.0
MTD16006	46.1	56.2	27.3	173.0	14.8	6.7
Alzada	46.1	57.6	24.0	171.3	15.1	10.0
MTD16008	45.6	55.5	27.7	174.3	15.1	6.7
Vivid	43.8	56.9	27.0	173.7	15.9	4.0
Mean	49.3	56.8	27.1	173.9	14.9	8.0
LSD (.05)	8.3	1.5	1.8	1.3	1.4	6.3
C.V.	10.3	1.7	4.1	0.5	5.8	47.5
P-Value	0.2768	<0.0000	<0.0000	<0.0000	0.0162	0.0216

Cooperator and Location: WTARC Pondera County.
Planted 04/19/2017 on chem-fallow barley stubble. Harvested 08/14/2017.
Fertilizer, actual lbs/ac: 11-22.5-0 with seed at planting, 208-0-20 broadcast while planting
Herbicide: Sprayed with 11 oz/ac Huskie and 16.4 oz/ac Axial XL on 06/18/2017.
Precipitation: 4.81 inches
[1] Yield and test weight are adjusted to 13% seed moisture.
Conducted by MSU Western Triangle Ag. Research Center.

Table 12. Five-year means, dryland Durum varieties. Western Triangle Ag. Research Center Conrad, MT, Pondera County, 2012 – 2015 and 2017.

		5 year mean				
Variety	Source	Yield (bu/ac)	Test weight (lb/bu)	Height (in)	Head[1] date	Seed Protein (%)
Alkabo	N. Dak.	65.5	59.8	34.5	70.1	13.7
Alzada	N. Dak.	64.7	59.4	35.5	67.3	13.8
Grenora	N. Dak.	64.1	59.3	64.7	70.1	14.5
Silver	MSU	63.5	59.5	26.7	68.4	14.4
Divide	N. Dak.	61.2	59.7	33.5	69.5	14.4
Mountrail	N. Dak	69.9	57.9	31.4	71.0	14.4
Tioga	N. Dak	59.2	60.2	26.7	69.9	14.8
Nursery Mean		62.6	59.4	31.9	69.5	14.3

[1] Days from seeding to heading.

Table 13. Soil test values for off-station and on-station plots, 2017.

Location	N (lbs/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	39.6	17	385	7.5	2.7	0.39
Devon	12.0	14	221	7.2	0.8	0.15
Knees	21.1	28	482	6.9	2.4	0.55
Choteau	44.5	7	412	8.1	2.3	0.82
WTARC Fall	15.5	20	318	7.8	2.6	0.56
WTARC Spring	15.9	30	528	7.4	2.6	0.36
Sweetgrass Hills	3.5	27	336	6.7	2.5	0.23

[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.

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

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

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

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

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

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

Hanna (AgriPro): Fusarium Scab tolerant.

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

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

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

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

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

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

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

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

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

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

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

Hard White Spring Wheat

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

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

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

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

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

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

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

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

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

Durum

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

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

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

<u>Alzada</u> (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.

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

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

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

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

<u>Kyle</u> (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.

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

<u>Maier</u> (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.

<u>Mountrail</u> (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).

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

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

<u>Pathfinder</u> (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.

Barley

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

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

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

Cooperators: Bradley Farms, North of Cut Bank, MT
Brian Aklestad, North of Devon, MT
Aaron Killion, East of Brady, MT
Inbody Farms, Northeast of Choteau, MT

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

Methods: Off station barley nurseries consist of 16 entries replicated three times, seeded with a four row plot seeder on one foot spacing. All plots were planted on no-till chemical fallow. Plots were trimmed, measured for length, and then harvested with a Hege 140 or a Wintersteiger Classic plot combine. Spring barley seed was not cleaned prior to collecting yield data.

Results: Table 1 and 2 are data from the dryland intrastate malt/feed barley trial. Tables 3 and 4 are for the irrigated intrastate malt/feed barley nursery. Results are tabulated in Tables 1 thru 10. The irrigated off-station spring barley nursery data are presented in Tables 1 and 2. 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 Table 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 much warmer than 31 year average at the research center, July was 4.9 degrees warmer than the average. But the overall average temperature for the year from September to August was 1 degree cooler than the 31 year average. The winter temperature was well below average, with the exception of November being about 7 degrees warmer than usual. December and January were 10 and 6 degrees colder than the 31 year average while May thru August were warmer than the 31 year average. July was 5 degrees warmer than the normal. Precipitation was generally above the average from September to April, then below normal from May to August. Overall, precipitation was average for the year.

The spring barley plots were seeded into soil that had good soil moisture storage from the previous years' fallow period. Overall, considering the lack of moisture and higher than normal temperatures this past summer, the barley did quite well.

Yields for the dryland intrastate malt/feed nursery ranged from 74.2 to 116.4 bu/ac with an average test weight of 52.8 bu/ac. Plump average was 98.5 % with an average of 9.8 % seed protein (Table 1). Irrigated intrastate malt/feed nursery had a range of 85.1 to 136.3 bu/ac with an average test weight of 51.7. The nursery averaged 97.8% plump and 9.9 % seed protein (Table 2).

The hull-less dryland barley intrastate nursery had an average yield of 56.5 bu/ac with an average test weight of 58.0 lbs/bu and 11.4 % grain protein. Yields in the hull-less dryland barley ranged from 23.4 bu/ac for Purple Prairie and 69.9 bu/ac for the Montana State University entry MT110061 (Table 15). Irrigated hull-less barley trial had an average yield of 68.1 bu/ac and an average test weight of 57.1 lbs/bu and 12.3% average seed protein. Yields in the hull-less irrigated barley ranged from 39.0 bu/ac for Purple Prairie and 83.5 bu/ac entry X0626-T22 (Table 15).

Yields for the irrigated off station spring barley nursery, averaged 110.1 bu/ac, with Odyssey, Oreana, and MT124073 being the top yielders at 130.3, 124.6, and 122.1 bu/ac. There was an average kernel plumpness of 94.2%, a mean protein of 9.0%, and an average test weight of 51.3 lb/bu (Table 1). Five year means for the irrigated off station nursery are tabulated in (Table 2).

Grain yields averaged 74.1 bu/acre at the Knees, 60.0 bu/ac north of Devon, 81.8 bu/ac at the Choteau site, and 73.7 bu/ac at the site north of Cut Bank. Kernel plumpness averaged 79.6 % and test weight averaged 47.1 lbs/bu at the Devon site while kernel plumpness averaged 69.9% and test weight averaged 46.0 lbs/bu at the Knees. Choteau kernel plumpness was 67.0 % and test weight averaged 45.0 lbs/bu. The nursery at Cut Bank averaged 48.2 lb/bu, 80.8% plumps, with 10.5 % seed protein (Tables 3 thru 10).

Top yielding varieties at the Knees were Oreana, Champion, and Haxby, yields were 85.6, 81.2, and 79.7 bu/ac. Whereas the top yielding barleys north of Devon were Oreana, Champion, and Lavina they yielded 77.5, 75.5, and 69.8 bu/ac. Yielding highest at the Choteau site were Oreana, Champion, and Bill Coors 100 with yields of 94.4, 91.0 and 87.2 bu/ac. High yielding varieties at Cut Bank were Montana State University experimental entry MT124128, 90.5 bu/ac, Champion, 83.6 bu/ac and Oreana, 82.8 bu/ac (Tables 3 thru 10). This being the first year Oreana was in the off station barley nurseries, it was the top yielding variety at three locations and the third yielding barley at one location.

The hot dry weather this past summer gave the barley varieties the opportunity to show what they can do with respect to malt quality barley when conditions are not ideal. In general, the Montana State University experimental entries, MT124128 and MT 090190 held their plumps well and did not have as high a seed protein as other entries in the off station dryland plots during our hotter and drier than usual summer.

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 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. Intrastate barley, malt/feed variety trial, WTARC, Conrad 2017.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Plump (%)	Thin (%)	Protein (%)	Head Date	Height (in)	Lodging (%)
MT124659	104.2	51.9	84.0	4.7	9.5	170.0	19.0	8.3
10WA-106.18	100.3	47.6	45.5	20.1	10.1	174.3	21.3	16.7
Harrington	100.3	48.6	74.8	8.8	11.6	175.0	23.3	16.6
MT124677	99.9	50.3	90.6	2.4	9.2	171.0	20.7	6.7
MT124007	99.8	49.5	80.1	7.4	10.9	173.0	24.0	16.7
MT124071	98.8	49.3	83.9	7.3	10.6	171.7	25.3	11.7
Hockett	97.6	50.8	80.3	6.8	11.0	173.7	23.3	18.3
2Ab08-X05M010-65	96.1	46.8	63.2	15.2	10.6	176.7	22.7	16.7
11WA-107.58	94.0	51.1	81.4	5.1	10.9	174.3	23.0	15.0
Odyssey	93.1	45.7	85.3	5.4	11.0	175.7	20.3	8.3
MT090182	93.1	48.7	72.3	9.5	10.2	174.7	24.3	10.0
Copeland	92.4	47.0	76.4	8.7	11.1	174.7	24.3	11.7
MT124688	91.6	49.3	83.1	6.0	10.0	173.0	24.0	10.0
Balster	90.3	45.7	72.7	10.7	11.1	174.3	22.3	11.7
MT124645	90.3	50.0	79.8	7.5	10.5	172.7	22.3	20.0
MT100120	89.8	49.5	81.6	6.0	9.8	177.0	24.3	11.7
MT124134	89.4	50.3	84.9	5.6	10.5	168.7	20.3	20.0
MT124112	89.3	50.9	86.6	3.8	9.9	170.7	20.0	20.0
MT090184	88.7	49.5	79.4	8.2	10.6	177.3	25.0	10.0
MT124127	87.1	51.5	80.2	4.9	10.9	172.3	21.3	20.0
MT124128	86.9	50.2	81.7	6.9	10.9	170.3	20.0	20.0
MT124018	86.8	48.5	72.8	14.5	11.6	172.0	23.0	18.3
Genie	86.0	47.2	41.4	23.6	9.7	175.7	19.0	10.0
MT124016	85.8	46.6	73.8	9.2	10.9	174.7	22.3	18.3
MT124069	85.6	48.0	74.6	10.8	10.6	175.7	23.7	15.0
MT124118	83.9	49.7	78.4	7.3	10.8	172.7	23.3	13.3
MT124601	83.9	50.0	77.2	8.2	9.9	174.3	24.0	13.3
MT124555	83.0	49.8	82.6	6.8	11.7	173.3	23.7	13.3
MT124093	82.8	50.6	82.0	6.2	11.5	173.0	25.3	16.7
MT090193	82.0	48.3	71.9	8.5	10.0	176.7	22.3	15.0
MT124113	81.4	49.3	81.8	7.6	10.9	169.7	22.3	13.3
MT124164	81.1	49.2	62.5	13.3	10.0	173.0	22.0	13.3
MT124243	80.9	48.3	70.8	12.7	10.0	171.3	22.0	18.3
Synergy	80.7	46.9	69.3	11.9	11.5	173.7	22.0	11.7
10ARS191-3	80.2	46.9	33.8	20.5	11.5	175.3	22.3	13.3
MT124716	80.0	46.7	52.7	20.0	12.3	173.0	22.3	18.3
MT090169	79.9	49.8	73.3	12.1	10.1	170.7	20.3	15.0
MT124663	79.7	49.1	84.2	5.4	11.0	171.3	21.0	6.7

Table 1 continued on next page

Table 1. Continued

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Plump (%)	Thin (%)	Protein (%)	Head Date	Height (in)	Lodging (%)
MT124073	78.7	48.4	77.3	8.3	11.0	174.3	24.0	13.3
Craft	78.7	50.5	82.2	5.6	11.2	173.7	24.3	13.3
MT124673	78.7	50.4	83.7	5.0	10.2	172.7	20.3	5.0
MT090236	78.6	49.7	76.3	9.0	10.3	169.0	18.3	13.3
MT124664	78.0	51.3	83.4	5.0	10.2	173.0	20.7	6.7
MT124380	77.0	48.9	70.6	13.5	10.8	173.7	21.0	10.0
Growler	76.9	44.9	59.2	16.2	12.1	176.0	21.3	8.3
MT124370	75.0	47.7	69.6	12.6	10.9	175.3	20.0	10.0
Metcalfe	70.0	48.3	68.2	10.4	12.3	173.7	21.0	15.0
MT090025	69.9	46.8	42.9	36.9	9.5	170.7	18.0	11.7
Genesis	63.9	47.5	81.7	6.7	12.1	170.7	21.3	16.7
Mean	85.8	48.8	74.0	10.0	10.7	173.3	22.1	13.6
LSD (0.05)	19.1	2.2	14.7	6.7	1.3	2.1	2.2	6.8
C.V. (s/mean)*100	13.7	2.7	12.3	41.6	7.4	0.7	6.2	30.8
P-value (0.05)	0.0167	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000

Seeded 04/20/2017 on chemical fallow barley stubble. Harvested: 08/09/2017.
Fertilizer, actual (lbs/ac): 11-22.5-0 placed with seed at planting, 45-0-20 side banded while seeding. Fertilizer rates are based on achieving malt grade barley.
Growing season precipitation: 4.77 inches.
Herbicide: Pre-plant sprayed with RT3 at 32 oz per acre on 04/18/2017.
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 2. 5-year Means, intrastate barley (malt/feed) varieties, WTARC, Conrad, MT, 2013-2017.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Plump (%)	Thin (%)	Protein (%)	Plant height	Head date
Hockett	96.6	52.6	93.4	2.4	10.0	27.8	173.9
Harrington	93.0	50.4	89.1	4.2	10.0	27.7	175.5
Metcalfe	86.0	50.9	87.2	4.6	10.2	28.0	174.7
Mean	91.8	51.3	89.9	3.7	10.1	27.8	174.7

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

Table 3. Irrigated intrastate malt/feed barley variety trial, Conrad 2017.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Plump (%)	Thin (%)	Protein (%)	Head Date	Height (in)	Lodging (%)
11WA-107.58	135.8	53.3	97.2	0.7	11.0	185.7	31.3	23.3
MT124071	133.2	52.3	95.9	1.0	11.1	183.3	30.3	16.7
Genie	131.8	51.9	95.6	1.4	9.8	187.7	26.3	36.7
10WA-106.18	131.8	51.9	93.7	1.4	11.9	184.0	30.0	73.3
MT090193	131.6	51.8	97.4	0.8	9.7	187.3	32.3	27.0
MT124677	131.0	52.7	98.2	0.6	10.3	172.3	27.3	15.0
MT100120	130.3	52.5	97.2	0.9	9.9	187.3	31.3	20.0
Odyssey	130.1	50.4	96.6	0.6	9.3	187.0	23.7	43.3.
MT124007	129.6	52.5	98.5	0.5	9.5	184.0	31.3	16.7
10ARS191-3	129.5	51.9	96.7	0.8	9.3	187.0	31.0	16.7
MT124069	129.4	52.0	96.2	1.1	10.3	186.7	30.3	43.3
MT090182	129.2	52.2	95.5	1.4	10.2	187.3	30.7	50.0
MT124688	128.9	53.0	97.7	0.8	9.9	187.3	30.0	30.0
MT090169	128.5	52.3	97.2	0.9	9.2	184.0	28.3	20.0
MT124018	128.2	51.6	97.6	0.7	11.1	184.0	29.3	40.0
MT124555	127.7	53.0	98.4	0.5	10.7	188.0	28.3	10.0
MT124370	126.1	51.6	96.7	0.9	9.8	187.3	26.3	20.0
MT124380	125.8	51.9	96.9	1.0	10.1	185.7	26.0	40.0
MT090184	124.7	53.0	96.9	0.8	10.1	187.0	32.3	27.0
MT124164	124.7	50.4	92.4	2.6	10.8	185.0	28.0	76.7
MT124016	123.5	50.3	91.1	3.4	11.4	187.6	28.3	60.0
MT124243	123.1	51.8	97.4	0.7	9.3	187.7	31.0	26.7
MT124112	122.2	51.9	98.4	0.5	10.1	182.0	28.3	33.3
MT090236	121.8	52.3	89.5	1.4	10.3	179.3	27.3	33.3
MT124601	121.2	51.1	78.3	4.6	11.2	186.0	32.3	76.7
MT124118	121.1	53.0	98.4	0.3	10.3	183.3	29.7	36.7
Synergy	120.9	50.6	94.9	1.7	11.9	187.0	31.3	53.3
MT124073	120.7	52.4	97.7	0.7	10.2	187.0	31.7	30.0
Balster	120.0	50.3	94.2	1.4	10.5	187.7	26.0	46.7
MT124645	119.8	52.1	96.7	1.0	10.1	185.3	29.3	26.7
MT124716	117.3	51.4	95.3	1.3	11.5	173.3	28.0	56.7
Metcalfe	116.8	52.0	95.5	1.3	10.2	186.0	28.3	46.6
2Ab08-X05M010-65	116.8	50.0	92.9	2.0	10.3	187.7	27.7	30.0
MT090025	116.7	48.8	56.9	23.7	8.8	179.7	23.0	16.7
Growler	116.5	50.1	94.2	1.8	10.0	186.3	27.3	36.7
MT124663	115.8	52.3	98.3	0.6	10.2	181.7	27.7	23.3
MT124128	115.6	52.3	97.4	0.8	9.9	179.3	26.0	23.3
Hockett	114.8	51.7	95.4	1.7	11.3	184.0	28.3	73.3

Table 3 continued on next page

Table 3. Continued

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Plump (%)	Thin (%)	Protein (%)	Head Date	Height (in)	Lodging (%)
Copeland	113.7	51.6	97.6	0.8	10.2	187.3	30.7	36.7
MT124134	113.1	52.5	96.5	0.9	9.9	179.3	26.7	10.0
MT124127	112.3	53.1	98.0	0.4	10.6	183.0	26.7	20.0
MT124673	112.0	52.7	98.7	0.5	9.8	186.3	28.0	5.3
MT124664	109.9	52.8	98.6	0.5	10.7	181.7	27.0	7.0
Harrington	109.6	50.4	93.6	2.1	11.6	187.3	29.3	78.3
MT124113	109.0	52.1	94.2	1.8	10.7	179.7	28.7	20.0
Craft	105.4	52.2	96.1	1.0	10.7	187.3	30.3	35.0
MT124093	105.0	52.1	95.7	1.0	9.9	186.0	29.7	53.3
MT124659	101.1	57.3	96.7	1.1	10.7	179.3	26.3	5.0
Genesis	98.1	50.9	97.9	0.5	11.0	181.0	28.0	26.7
Mean	120.9	51.9	95.1	1.6	10.4	184.4	28.7	34.1
LSD	16.7	2.1	7.8	2.1	2.1	5.9	2.7	31.7
CV	8.6	2.4	5.0	78.9	10.2	2.0	5.7	57.4
P-value (0.05)	<0.0000	<0.0000	<0.000	<0.0000	0.1318	<0.0000	<0.0000	<0.0000

Planted 05/10/2017 on fallow. Harvested 09/01/2017.
Fertilizer, actual (lbs/ac): 11-22.5-0 place with seed at planting, 60-0-20 side banded while seeding. Fertilizer rates are based on a yield goal of 90 bu/a.
Growing season precipitation: 4.35 inches. Irrigation = 8.0 inches
Pre-plant sprayed with RT3 at 32 oz/ac on 05/01/2017. The plot was sprayed with Bison @ 4 pts/ac and 16.4 oz/ac of Axial XL on 06/03/2017.
[1] Yield and test weight are adjusted to 13% seed moisture
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 4. 5-year Means, Intrastate Irrigated Barley varieties, WTARC, Conrad, MT, 2013-2017.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Plump (%)	Thin (%)	Plant Height (in)	Protein (%)	Head date
Metcalfe	104.8	50.9	97.2	1.1	31.6	8.2	179.8
Hockett	103.0	51.8	96.7	1.3	28.7	11.1	181.3
Harrington	102.4	50.6	95.1	2.0	29.6	10.9	184.1
Mean	103.4	51.1	96.3	1.5	30.0	10.1	181.7

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

Table 5. 2017 Irrigated off station barley variety trial, Conrad, MT.

Variety	Yield (bu/ac[1])	Test Wt (lb/bu[1])	Height (in)	Head Date	Plump (%)	Thin (%)	Protein (%)	Lodging (%)
Odyssey	130.3	50.8	24.0	187.7	98.3	0.5	8.8	23.3
Oreana	124.6	51.8	23.0	187.3	94.4	1.6	8.8	7.0
MT124073	122.1	52.3	30.7	187.7	96.8	0.8	9.0	10.0
MT124027	122.0	51.8	27.7	187.7	97.2	0.6	8.9	23.3
Genie	120.3	52.3	23.7	187.7	98.7	0.6	9.2	13.3
Eslick	118.8	52.3	27.0	187.3	93.3	1.8	8.9	43.3
Merit 57	118.0	50.0	28.0	187.7	92.8	1.6	8.7	13.3
Claymore	116.9	51.4	28.7	187.0	93.5	1.3	8.3	10.0
Haxby	116.8	53.4	27.3	184.0	97.8	0.6	9.9	16.7
Champion	115.9	52.8	27.7	186.3	95.7	1.3	8.9	8.3
Conrad	115.6	51.1	25.3	187.7	97.7	0.8	9.1	13.3
Balster	111.0	49.6	26.0	187.7	95.2	1.8	8.6	10.0
MT090190	109.9	51.9	28.3	185.0	97.9	0.7	9.2	13.3
Copeland	107.0	51.6	30.0	187.7	97.3	1.2	9.0	20.0
Growler	106.9	50.1	26.0	187.7	94.6	1.5	8.8	7.0
Bill Coors 100	106.5	50.2	22.7	188.0	97.8	0.8	9.4	11.7
Synergy	106.2	49.6	28.3	187.0	97.5	0.8	8.8	28.3
Hockett	105.7	51.1	25.0	187.0	95.0	1.5	9.0	73.3
Lavina	105.3	47.8	30.7	187.3	86.6	3.1	8.9	16.7
Metcalfe	102.1	51.5	27.7	186.7	93.5	2.0	8.9	33.3
09WA9-265.12	101.8	61.0	29.3	186.7	83.1	4.7	9.2	36.7
Moravian165	100.3	50.6	28.7	187.0	97.5	0.7	9.5	26.7
Hays	98.9	48.8	28.0	187.3	91.7	2.5	8.9	16.7
MT124128	97.0	52.1	24.3	179.7	98.0	0.6	9.5	5.0
Haybet	72.6	47.5	31.3	185.7	73.0	5.3	9.9	73.3
Mean	110.1	51.3	27.2	186.7	94.2	1.5	9.0	22.2
LSD (.05)	12.1	0.9	2.5	2.2	3.0	1.0	0.9	18.8
C.V. (s/mean)*100	6.7	1.1	5.5	0.7	1.9	38.5	6.3	51.7
P-Value	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000

Planted on 06/2/2017 into chemical fallow barley stubble. Harvested on 09/02/ 2017.
Fertilizer, actual (lbs/ac): 11-22.5-0 place with seed at planting, 60-0-20 side banded while seeding. Fertilizer rates are based on a yield goal of 90 bu/a.
Growing season precipitation: 4.35 inches. Irrigation = 8.0 inches
Pre-plant sprayed with RT3 at 32 oz/ac on 05/01/2017. The plot was sprayed with Bison @ 4 pts/ac and 16.4 oz/ac of Axial XL on 06/03/2017.
[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, 2012, 2014-2017.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Plump (%)	Thin (%)	Protein (%)	Plant height (in)	Heading date
Champion	107.8	52.4	96.3	0.9	9.5	29.3	180.9
Haxby	105.9	52.2	96.6	1.2	10.1	29.4	108.1
Metcalfe	104.9	51.2	96.6	1.3	10.3	31.1	179.2
Hockett	101.1	51.7	96.6	1.3	10.6	28.1	180.7
Mean	104.9	51.8	96.5	1.2	10.1	29.5	180.2

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, 2017.

Variety	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Plump (%)	Thin (%)	Plant Height (in)	Lodging (%)	Protein (%)
Oreana	94.4	46.3	61.6	9.9	22.0	1.7	13.8
Champion	91.0	48.3	64.6	7.6	26.0	10.0	13.7
Bill Coors 100	87.2	43.9	74.1	7.9	21.0	4.0	14.5
MT124128	84.3	48.7	84.4	5.0	24.0	16.7	12.1
Genie	83.7	46.2	71.8	8.7	22.3	7.3	13.1
Odyssey	83.7	42.0	76.4	5.9	22.0	5.7	13.5
Haxby	83.3	48.2	54.7	11.1	25.3	13.3	13.7
Copeland	81.6	45.0	70.6	8.1	25.7	2.3	13.7
Lavina	81.2	39.9	23.0	32.3	26.7	11.7	14.8
MT090190	81.1	47.5	86.2	3.9	25.3	1.3	12.5
Hockett	80.9	45.6	72.0	9.2	23.0	15.0	13.0
Moravian165	80.7	46.0	78.0	6.3	26.0	15.0	13.7
Balster	75.5	42.8	63.4	14.5	24.0	5.7	14.3
Synergy	74.7	44.9	73.2	7.7	23.7	15.0	12.7
Metcalfe	74.5	45.2	62.4	10.8	24.3	10.0	13.9
Growler	70.4	39.9	55.4	14.0	23.7	0.7	15.9
Average	81.8	45.0	67.0	10.2	24.1	8.5	13.7
LSD (.05) =	10.4	2.5	18.0	6.5	2.3	8.9	1.4
C.V. =	7.6	2.4	16.1	38.2	5.7	63.0	6.3
P-Value (0.05)	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000

Cooperator and Location: Inbody Farms, Teton County.
Planted: 06/06/2017 on chem-fallow. Harvested: 08/29/2017.
Fertilizer, actual lbs/a: 11-22.5-0 with seed at planting. 17-0-20 was applied as a side band while seeding.
Herbicide: Pre-plant sprayed with RT3 at 32 oz/ac and 1 oz/ac Sharpen on 05/06/2017.
[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 2013-2017.

Variety Or ID	5 Year Mean					
	Yield (bu/ac)	Test weight (lb/bu)	Plump (%)	Thins (%)	Height (in)	Protein (%)
Champion	80.1	50.5	76.6	6.8	27.3	13.8
Haxby	73.9	50.9	81.2	7.8	26.6	14.1
Hockett	71.9	49.0	81.9	9.4	26.6	14.4
Metcalfe	70.8	48.5	80.6	7.5	26.0	14.8
Mean	74.2	49.7	80.1	7.9	26.6	14.3

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, 2017.

Variety	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Plump (%)	Thin (%)	Plant Height (in)	Protein (%)
MT124128	90.5	50.8	95.6	1.4	23.3	9.7
Champion	83.6	50.7	72.7	4.4	25.7	10.6
Oreana	82.8	49.4	80.4	4.1	21.7	10.2
Balster	79.3	46.6	83.1	4.7	24.0	10.3
Genie	76.6	48.9	83.2	3.7	22.3	10.5
Hockett	75.8	48.9	83.8	3.8	23.0	10.5
Metcalfe	75.4	48.6	79.8	4.5	24.7	11.3
Copeland	74.6	48.0	85.6	3.7	26.3	11.9
Lavina	74.1	44.7	49.8	13.9	25.7	11.5
Odyssey	72.3	46.8	90.0	1.9	22.3	9.9
Synergy	71.3	47.2	85.4	3.4	24.7	10.7
Bill Coors 100	69.9	47.2	92.7	1.9	20.7	10.5
Moraviana165	68.7	46.9	78.7	5.1	25.0	10.8
Haxby	67.2	51.5	70.7	5.7	22.7	9.6
MT090190	63.9	49.7	86.6	2.1	26.3	10.2
Growler	53.6	44.6	74.8	6.4	23.3	10.6
Average	73.7	48.2	80.8	4.4	23.9	10.5
LSD (.05) =	21.1	0.9	8.5	2.2	1.8	1.0
C.V. =	17.1	1.1	6.3	30.2	4.4	6.0
P-Value (0.05)	0.2203	<0.0000	<0.0000	<0.0000	<0.0000	0.0375

Cooperator and Location: Bradley Farms, Glacier County.
Planted: 05/08/2017 on chemical fallow barley stubble. Harvested: 08/06/2017.
Fertilizer, actual lbs/a: 11-22.5-0 with seed at planting. 0-0-20 was applied as a side band while seeding.
Herbicide: Pre-plant sprayed with RT3 at 32 oz/ac and 1 oz/ac Sharpen on 05/08/2017.
[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 2013, 2015-2017.

Variety Or ID	4-Year Mean					
	Yield (bu/ac)	Test weight (lbs/bu)	Plump (%)	Thins (%)	Height (in)	Protein (%)
Champion	74.1	51.2	88.3	3.2	26.0	12.9
Haxby	62.9	51.5	89.6	2.6	25.8	12.7
Hockett	69.8	50.7	93.5	1.9	25.9	12.9
Metcalfe	63.8	50.2	91.5	2.4	26.1	13.4
Mean	67.6	50.9	90.7	2.5	25.9	13.0

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, 2017.

Variety	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Plump (%)	Thin (%)	Plant Height (in)	Protein (%)
Oreana	77.5	49.5	86.9	3.9	18.3	11.9
Champion	75.5	50.2	83.1	5.6	20.3	12.3
Lavina	69.8	45.7	68.6	10.3	20.3	12.3
Odyssey	68.6	48.5	95.4	1.4	18.3	11.0
Genie	62.4	47.7	78.2	6.9	19.0	12.4
MT124128	62.1	49.4	89.6	2.7	19.0	11.0
Copeland	58.0	46.3	87.5	3.3	22.3	13.3
Hockett	57.4	45.7	71.9	8.6	20.3	12.5
Bill Coors 100	56.7	47.7	91.4	2.5	17.7	13.5
MT090190	56.2	47.9	82.6	5.3	21.7	11.2
Haxby	54.8	47.9	55.1	14.9	19.3	13.1
Growler	54.6	44.1	75.8	7.3	20.0	12.1
Balster	54.1	44.5	68.8	11.4	19.0	12.4
Moravian165	53.7	46.4	79.4	6.2	20.3	13.3
Synergy	49.6	44.9	78.4	6.2	21.3	12.7
Metcalfe	41.5	46.2	75.8	7.5	21.0	13.4
Average	60.0	47.1	79.6	6.4	19.9	12.4
LSD (.05)	14.8	3.3	13.8	5.3	2.7	
C.V. (%)	12.0	3.4	8.5	40.8	6.6	4.2
P-Value (0.05)	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000

Cooperator and Location: Brian Aklestad Farms, Toole County.
Planted: 05/04/2017 on chemical fallow winter wheat stubble. Harvested: 08/22/2017.
Fertilizer, actual lbs/a: 11-22.5-0 with seed at planting. 27-0-20 was applied as a side band while seeding.
Herbicide: Pre-plant sprayed with RT3 at 32 oz/ac and 1 oz/ac Sharpen on 05/04/2017.
[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 (in)	Protein (%)
Champion	63.2	50.2	83.8	6.3	21.1	12.1
Haxby	51.9	49.2	76.1	9.6	21.5	12.3
Hockett	51.9	48.2	84.0	5.9	21.6	12.3
Metcalfe	46.1	47.4	85.6	5.3	21.8	12.9
Mean	53.3	48.7	82.4	6.8	21.5	12.4

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. 2017.

Variety	Yield (bu/ac[1])	Test Wt (lb/bu[1])	Plump (%)	Thin (%)	Plant Height (in)	Lodging (%)	Protein (%)
Oreana	85.6	46.8	68.0	8.7	25.0	0	14.0
Champion	81.2	48.7	64.7	8.2	26.3	1.3	13.5
Haxby	79.7	49.5	58.7	9.2	28.0	3.0	13.8
Genie	78.4	47.7	75.4	7.3	26.0	0	13.0
Hockett	76.7	47.7	83.6	4.7	26.7	1.3	13.3
Balster	75.9	43.7	71.7	9.8	25.3	0	14.2
Synergy	75.9	45.1	72.7	7.0	27.7	0.7	14.0
Metcalfe	73.6	46.0	71.6	6.9	27.7	1.3	14.3
Bill Coors 100	72.5	44.4	74.6	7.2	24.3	0	14.7
MT090190	72.4	48.6	85.6	3.1	28.0	0	12.4
Copeland	72.2	45.7	77.4	6.2	27.3	0.3	14.2
Morivian165	69.6	46.0	71.0	8.1	27.3	2.7	14.3
Odyssey	69.1	43.7	75.4	7.3	23.7	0.7	13.7
Growler	68.6	41.3	62.1	13.0	26.3	0	15.7
MT124128	67.8	49.4	80.5	3.8	24.3	3.0	12.3
Lavina	66.3	41.7	26.0	28.7	27.0	2.0	14.1
Average	74.1	46.0	69.9	8.7	26.3	1.0	13.8
LSD (.05)	7.7	1.4	13.3	4.5	1.6	2.0	0.7
C.V.	6.2	1.8	11.4	30.8	3.6	120.1	2.9
P-Value (0.05)	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	0.0161	<0.0000

Cooperator and Location: Aaron Killion, western Chouteau County.
Planted: 05/06/2017 on chemical fallow winter wheat stubble. Harvested: 08/17/2017.
Fertilizer, actual lbs/ac: 11-22.5-0 with seed at planting. 8-0-20 was applied as a side band while seeding.
Herbicide: Sprayed with RT3 at 32 oz/ac and 1 oz/ac Sharpen on 05/06/2017.
[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 (lb/bu)	Plumps (%)	Thins (%)	Height (in)	Protein (%)
Champion	71.6	47.1	77.6	9.3	25.7	13.1
Hockett	71.7	48.4	87.6	4.7	25.8	12.9
Haxby	70.0	48.5	80.1	6.9	25.8	13.1
Metcalfe	69.9	46.4	84.5	5.1	25.7	13.9
Mean	70.8	47.6	82.5	6.5	25.8	13.2

Conducted by MSU Western Triangle Ag. Research Center.

Table 15. Hull-less dryland intrastate barley variety trial, Conrad 2017.

Variety	Yield (bu/ac)	Test Wt (lb/bu)	Protein (%)	Head Date
X0626-T22	100.8	49.9	14.8	175.3
09WA-265.12	76.5	56.9	12.4	177.3
Havener	71.8	58.0	13.1	176.6
MT110066	63.0	56.5	15.8	178.0
X07G30-T1	61.6	54.7	14.0	178.3
X05013-T1	58.7	56.5	13.9	178.0
MT110065	60.4	54.6	14.6	179.0
MT110061	58.7	55.9	15.3	177.7
2Ab09-X06F058HL-31	54.3	56.0	15.4	177.7
Transit	45.0	55.2	18.2	178.3
MT110009	44.9	53.4	15.5	179.0
MT110016	43.5	56.4	16.0	179.7
Falcon	31.9	55.8	19.0	179.3
Mean	58.4	55.5	15.2	177.9
LSD	16.7	2.2	2.0	1.9
CV (%)	13.8	1.9	6.2	0.06
P-value (0.05)	<0.0000	<0.0000	0.0000	0.0268

Seeded 04/20/2017 on chemical fallow barley stubble. Harvested: 08/09/2017.
Fertilizer, actual (lbs/ac): 11-22.5-0 placed with seed at planting, 45-0-20 side banded while seeding. Fertilizer rates are based on achieving malt grade barley.
Growing season precipitation: 4.77 inches.
Herbicide: Pre-plant sprayed with RT3 at 32 oz per acre on 04/08/2017.
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 16. Hull-less irrigated intrastate barley variety trial, Conrad 2017.

Variety	Yield[1] (bu/ac)	Test Wt[1] (lb/bu)	Protein (%)	Head (Date)	Height (in)	Lodging (%)
X0626-T22	102.8	53.7	13.7	187.0	27.3	13.3
Falcon	95.3	53.9	12.9	190.7	29.0	0.3
Havener	94.0	59.7	12.3	187.0	30.0	46.7
09WA-265.12	90.0	61.4	11.9	186.7	29.0	40.0
X05013-T1	89.9	59.5	13.4	187.3	29.3	26.7
MT110065	81.5	58.6	14.6	187.7	32.7	50.0
MT110009	75.4	56.8	15.3	188.3	32.0	3.7
Transit	75.2	85.0	16.0	187.0	32.0	34.0
MT110061	74.5	58.6	14.5	187.7	27.0	0.7
X07G30-T1	72.7	58.3	15.3	187.7	30.0	10.3
2Ab09-X06F058HL-31	71.7	60.5	15.4	187.0	29.3	7.0
MT110016	69.2	56.4	14.6	188.0	26.7	7.0
MT110066	64.3	59.2	15.5	187.0	28.3	3.3
Mean	81.3	58.0	14.4	187.6	29.4	18.7
LSD	15.8	2.3	2.5	1.2	3.0	26.2
CV (%)	11.5	2.4	8.3	0.3	6.0	83.3
P-value (0.05)	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000	<0.0000

Planted 06/10/2016 on fallow. Harvested 09/01/2017.
Fertilizer, actual (lbs/ac): 11-22.5-0 place with seed at planting, 60-0-20 side banded while seeding. Fertilizer rates are based on a yield goal of 90 bu/a.
Growing season precipitation: 4.35 inches. Irrigation = 8.0 inches
Pre-plant sprayed with RT3 at 32 oz/ac on 5/1/2017. The plot was sprayed with Bison @ 4 pts/ac and 16.4 oz/ac of Axial XL on 06/03/2017.
[1] Yield and test weight are adjusted to 13% seed moisture
Location: MSU Western Triangle Ag Research Center, Conrad, MT.

Table 17. Soil test values for off-station and on-station plots, 2017.

Location	N (lb/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	39.6	17	385	7.5	2.7	0.39
Devon	12.0	14	221	7.2	0.8	0.15
Knees	21.1	28	482	6.9	2.4	0.55
Choteau	44.5	7	412	8.1	2.3	0.82
WTARC Fall	15.5	20	318	7.8	2.6	0.56
WTARC Spring	15.9	30	528	7.4	2.6	0.36
Sweetgrass Hills	3.5	27	336	6.7	2.5	0.23

[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 2010, 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.

Canola

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

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

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

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

Methods: 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 Hege 140 plot combine. Canola seed was cleaned prior to collecting data.

Results: The canola nursery averaged 24.5 bu/ac (Table 1). Test weight averaged 49.8 lbs/bu with mean seed oil content of 42.9%. There was no lodging or shatter to report in the canola nurseries. Highest yields in bu/ac (lb/ac) were HyClass 955 having 31.4 (1570.4), InVigor L252 at 29.6 (1477.9), DKL35-23R with 28.0 (1401.2), InVigor L230 at 27.9 (1394.3), and 11H4030 in the amount of 27.8 (1390.2), respectfully.

The combination of heat and dry at the end of June and into July at the time the canola was flowering and setting pods, affected yield making growing conditions very poor for canola. This past summer, the canola aborted the pods and flowers on the upper six inches of the plant. The canola nursery seed size and oil were lower than usual.

Overall, the crop year temperatures where much warmer than 31 year average at the research center, July was 4.9 degrees warmer than the average. But the overall average temperature for the year from September to August was 1 degree cooler than the 31 year average. The winter temperature was well below average, with the exception of November being about 7 degrees warmer than usual. December and January were 10 and 6 degrees colder than the 31 year average while May thru August were warmer than the 31 year average. July was 5 degrees warmer than the normal. Precipitation was generally above the average from September to April, then below normal from May to August. Overall, precipitation was average for the year.

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. 2017.

Variety	Herbicide System	Seed Yield[1] (bu/ac)	Seed Yield[1] (lb/ac)	Test Weight[1] (lb/bu)	Seed Oil (%)	Flowering Date (Julian)	Plant Height (in)
HyClass 955	RR	31.4	1570.4	49.3	44.4	170.3	37.3
InVigor L252	LL	29.6	1477.9	50.5	43.4	176.3	38.8
DKL35-23R	RR	28.0	1401.2	49.1	42.7	170.3	36.8
InVigor L230	LL	27.9	1394.3	49.9	42.7	175.5	38.3
11H4030	RR	27.8	1390.2	49.0	42.0	170.5	35.5
InVigor L140P	LL	26.6	1327.5	50.1	43.0	177.0	41.0
09H7763	RR	26.3	1313.4	49.8	45.7	180.0	40.5
DKL70-10R	RR	26.1	1303.8	50.3	42.0	172.2	36.5
5545 CL	CL	25.7	1282.7	50.9	44.1	174.8	40.8
InVigor L233P	LL	25.5	1273.5	50.3	43.6	175.5	39.0
HyClass 930	RR	25.2	1261.7	48.8	45.9	170..8	34.8
6074 RR	RR	24.3	1212.6	49.8	41.6	177.5	42.0
15MH6006	CL	23.6	1181.2	49.8	42.4	171.3	32.3
6080 RR	RR	23.2	1159.7	48.9	44.2	177.0	38.0
C5522	SU	22.9	1144.3	49.2	39.1	176.3	41.8
HyClass 970	RR	22.5	1127.4	49.6	42.2	171.8	38.8
11H4054	RR	20.6	1030.4	50.2	41.7	174.5	35.8
C5507	SU	20.4	1020.9	49.0	42.7	177.8	41.8
11H4009	RR	16.3	817.0	50.0	39.9	176.0	35.8
C5513	SU	15.4	769.7	50.6	39.1	177.5	38.8
Mean		24.5	1223.0	49.8	42.9	174.6	38.2
LSD (α = 0.05)		4.7	234.3	0.6	2.3	3.1	2.6
CV (%)		13.5	13.5	0.9	3.7	1.3	4.9
P-value (0.05)		<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

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: 05/01/2017 Direct cut harvested date: 08/15/2017
Fertilizer (actual lb/ac): 34-22-20-20(S), using 0-45-0, 24-0-0-21, 0-0-60, and 46-0-0
Pre-plant sprayed with Roundup RT3 at 40 oz/ac on 05/01/2017.
Previous crop: Chemical fallow barley stubble.
Location: MSU Western Triangle Ag. Research Center, Conrad, MT.

Pulses



Title: Spring Pea, Lentil and Chickpea Variety Evaluation.

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

Project Coordinators: Chengci Chen and Yesuf Mohammed, MSU/MAES, Eastern Ag. Research Center, Sidney, MT.

Project Personnel: Julie Prewett, MSU/MAES, Western Triangle Ag. Research Center, Conrad, MT.

Cooperator: Brian Aklestad, North of Galata, 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 pulse varieties under the local conditions with respect to yield, test weight, plant height, one thousand kernel weight 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 pulse varieties.

Methods: Statewide, Western Regional and one off station spring pulse variety trials were seeded for the 2017 growing season. Off station pea and lentil nurseries consisted of 6 entries replicated four times. Statewide pea nursery had 33 entries replicated four times, with the Western Regional pea trial having 12 entries replicated three times. Western Regional lentil nursery had 14 entries replicated three times and the Statewide lentil trial had eight entries replicated four times, while the Statewide chickpea trial had eight entries replicated four times and the Western Regional chickpea had eight 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 or a Wintersteiger Classic plot combine.

Results: Pulse variety data are summarized in Tables 1 thru 9, with Table 10 having soil test data. Tables 1 thru 4 are pea data, with Tables 5 thru 7 representing lentil data. Table 8 and 9 are a summarization of chickpea data.

Overall, the crop year temperatures where much warmer than 31 year average at the research center, July was 4.9 degrees warmer than the average. But the overall average temperature for the year from September to August was 1 degree cooler than the 31 year average. The winter temperature was well below average, with the exception of November being about 7 degrees warmer than usual. December and January were 10 and 6 degrees colder than the 31 year average while May thru August were warmer than the 31 year average. While we had the colder than normal temperatures in December and January, there was snow cover on the winter wheat. July was 5 degrees warmer than the normal. Precipitation was generally above the average from

September to April, then below normal from May to August. Overall, precipitation was average for the year.

The chemical fallowed soils generally had good moisture while seeding spring pulses during the spring of 2017. 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 1796 lb/ac for Earlystar and 3625 lb/ac for CDC Leroy. Yellow pea averaged 2723 lb/acre with an average test weight of 63.9 lb/bu and an average plant height at maturity of 75.7 cm (29.8 inches). The top three yielding yellow pea were: CDC Leroy, Spider, and Montech 4152 at 3625, 3492, and 3459 lb/ac.

Statewide green pea data are presented in Table 2. Green pea varieties grown at WTARC yielded from 2017 lb/ac for CDC Striker to 3674 lb/ac for Ginny. Green pea averaged 2723 lb/ac with an average test weight of 63.5 lb/bu and an average plant height at maturity of 69.4 cm (27.3 inches). Yielding well in the statewide trial were Ginny at 3674 lb/ac followed by Arcadia and Cruiser at 3346 and 3995 lb/ac.

Western Regional (WR) pea date are summarized in Table 4. 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 1744.3 lb/ac. Yields ranged from 1400 lb/ac for DS Admiral to 2130.4 lb/ac for PS1514B002. The difference in yield between the Statewide and WR pea nurseries is most likely due seeding the WR nursery about a month later than the Statewide pea nursery.

An off station pea variety nursery was seeded north of Galata. There were three yellow and three green peas in the trial. The trial mean was 1209.7 lb/ac with Banner (green pea) yielding 1428.5 lb/ac and Hyline (yellow pea) yielding 1280.6 lb/ac.

Statewide Lentil data are summarized in Table 5. The lentil nursery grown at WTARC yielded between 1174 lb/ac for Imi-Green and 2056 lb/ac for Viceroy (Table 5). 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 nine inches, with an average yield of 1682 lb/ac.

Western Regional lentil data are presented in Table 7. Avondale a medium green lentil, Pardina a small brown lentil, Eston a small green lentil and Merrit a large green 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 1528.1 lb/ac. Yields ranged from 1142.7 lb/ac for Merrit to 1773.0 lb/ac for LC09600476L. The difference in yield between the Statewide and WR pea nurseries is most likely due seeding the WR nursery about a month later than the Statewide lentil nursery.

An off station lentil variety trial was seeded north of Galata. There were three yellow and three green peas in the trial. The trial mean was 1262.2 lb/ac with the top three yielding lentil varieties being, Avondale (green), Viceroy (green), and Maxims (red) at 1369.9, 1363.0, and 1317.6 lb/ac.

Statewide chickpea data are summarized in Table 8. Chickpea entries in the Statewide nursery were mostly kabuli types with one desi type entered. The chickpea nursery grown at WTARC yielded between 2756 lb/ac for CDC Orion (kabuli) to 2267 lb/ac for Myles (desi) (Table 8). The top yielding varieties were CDC Orion, Royal, and Sierra at 2756, 2543, and 2502 lb/ac.

Western Regional chickpea data are presented in Table 9. CDC Frontier (large kabuli), Billy Beans (small kabuli) and Sierra (kabuli) chickpeas are included in the WR nursery as checks, otherwise the WR nursery is made up of experimental varieties. The WR chickpea trial had a mean of 2490.4 lb/ac. Yields ranged from 2214.5 lb/ac for CA0790B0034C to 2839.5 lb/ac for CDC Frontier.

Summary: A similar project will be proposed for FY 2018. The continuation of on and off-station variety trials help elucidate researchers and farmers which varieties are better suited for that particular region in Montana.

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. 2017.

Variety	Pea Color	Yield (lb/ac)	Test Weight (lb/bu)	Plant Height (cm)	1000 Kernel Weight (g)	Days to Flower
CDC Leroy	Yellow	3625	64.9	68	162.7	61
Spider	Yellow	3492	64.1	84	242.8	60
Montech 4152	Yellow	3459	65.1	80	247.0	58
Abarth	Yellow	3228	63.7	78	272.3	58
Jetset	Yellow	3225	63.9	83	237.3	60
SW Midas	Yellow	3216	64.1	74	219.3	59
Korando	Yellow	3182	63.2	67	238.0	55
Pro 793	Yellow	3138	64.0	55	275.0	57
Pro127-2	Yellow	2992	64.1	76	263.8	59
Agassiz	Yellow	2876	63.7	76	229.0	60
CDC Treasure	Yellow	2876	64.4	87	224.7	59
Nette	Yellow	2867	63.9	77	215.0	58
DS Admiral	Yellow	2795	63.4	74	244.0	58
Navarro	Yellow	2492	62.7	72	270.3	54
Mystique	Yellow	2281	63.0	84	235.0	59
Bridger (LL7020)	Yellow	2212	64.3	70	217.5	58
Montech 4193	Yellow	2209	63.4	74	250.8	58
Salamanca	Yellow	2157	63.7	80	239.0	60
Earlystar	Yellow	1796	63.9	81	219.8	58
Yellow pea means		2723	63.9	75.7	238.2	58.2
P-Value		0.2898	<0.0001	<0.0001	<0.0001	<0.0001
LSD (0.05)		NS	0.57	9.5	22.1	0.7
CV (%)		32.53	0.63	8.89	0.56	0.27

Seeding Date: 04/05/2017.
Harvested Date: Different based on cultivars, 07/16-23/2017.
Precipitation: 6.21 inches.
Fertilizer (actual): 11-22-0 was applied with the seed with 0-0-20 being broadcast while planting.
Herbicide: Pre-plant sprayed with Spartan at 3 oz/ac and RT3 at 32 oz/ac on 04/02/2017.
Located at Western Triangle Ag. Research Center, Conrad, MT.

Table 2. Statewide Dry Pea Variety Evaluation. Green pea. Western Triangle Ag. Research Center. 2017.

Variety	Pea Color	Yield (lb/a)	Test Weight (lb/bu)	Plant Height (cm)	1000 Kernel Weight (g)	Days to Flower
Ginny	Green	3674	63.8	71	206.5	58
Arcadia	Green	3346	63.7	55	208.0	60
Cruiser	Green	2995	62.2	62	205.8	58
Bluemoon	Green	2827	62.9	70	236.0	60
Viper	Green	2707	62.7	78	232.5	59
Banner	Green	2651	64.1	74	219.3	56
K2	Green	2619	63.2	69	209.5	59
Aragorn	Green	2597	62.4	67	218.8	58
Greenwood	Green	2473	64.9	70	216.5	59
Majoret	Green	2469	64.0	77	234.3	60
Daytona	Green	2148	63.9	73	253.3	60
CDC Striker	Green	2017	63.9	69	241.8	60
Green Pea Means		2723	63.5	69.4	222.9	58.7
P-Value		0.3342	<0.0001	0.0224	0.0224	<0.0001
LSD0.05 (by t)		NS	0.83	11.1	20.6	1.1
CV% (s/means)		30.7	0.92	11.38	11.38	0.43

Seeding Date: 04/05/2017.
Harvest Date: Different based on cultivars, 07/16-23/2017.
Precipitation: 6.21 inches.
Fertilizer (actual): 11-22-0 was applied with the seed with 0-0-20 being broadcast while planting.
Herbicide: Pre-plant sprayed with Spartan at 3 oz/ac and RT3 at 32 oz/ac on 04/02/2017.
Located at Western Triangle Ag. Research Center, Conrad, MT.

Table 3. Off-station pea variety trial north of Galata, MT. Toole County. Western Triangle Ag. Research Center. 2017.

Variety	Color	Yield[1] (lb/ac)	Test Wt[1] (lb/bu)	TKW[1] (grams)	Height (inch)
Banner	green	1428.5	63.3	177.7	23.0
Hyline	yellow	1280.6	63.2	214.5	21.8
Ginny	green	1253.5	62.5	188.4	21.5
Aragorn	green	1197.8	61.8	196.6	21.5
Montech 4193	yellow	1181.3	61.7	217.5	20.8
Lacombe	yellow	916.5	60.7	223.5	20.8
Trial Mean		1209.7	62.2	203.0	21.5
LSD (.05)		199.4	1.2	21.4	NS
C.V. 1 (%) (S/mean)*100		10.9	1.2	8.6	5.9
P-Value		<0.0021	<0.0016	<0.0116	<0.1997

Cooperator and Location: Brian Aklestad, Toole County.
Planted on 05/08/2017 on chemical fallow. Harvested on 07/25/2017.
Fertilizer: actual pounds/ac of N-P-K: 11-22-0 applied with seed and 0-0-20 was broadcast at planting.
Herbicide: The plots were sprayed pre-plant with RT3 at 32 oz/ac by the farmer.
[1] Yield, test weight and thousand kernel weight (TKW) are adjusted to 13% seed moisture.
Conducted by MSU Western Triangle Ag. Research Center.

Table 4. Western Regional Pea Variety Evaluation. Western Triangle Ag. Research Center. 2017.

Variety	Pea Type	Yield[1] (lb/ac)	Mature Canopy Height (in)	Test[1] Weight (lb/bu)	1000 Kernel Weight (g)	Flower Date (Julian)
PS1514B002	-	2130.4	15.3	59.1	212.3	176.3
PS07100925	-	1957.9	14.0	60.6	237.0	176.7
Hampton	green	1855.2	16.3	61.0	207.7	180.0
PS08101004	-	1786.8	15.7	61.5	229.0	177.0
PA1514B0095	-	1759.8	19.0	61.2	180.3	179.0
PS1410B0073	-	1742.7	17.7	60.8	185.0	180.3
PS14100018	-	1742.6	16.0	60.6	180.7	177.0
PS1514B0400	-	1727.4	15.0	61.0	226.7	179.7
PS10100207	-	1636.6	18.7	58.6	222.7	174.0
PS08101022	-	1607.7	13.7	58.9	222.0	174.0
PS1410B0064	-	1584.2	16.0	57.7	207.7	176.0
DS Admiral	yellow	1400.0	16.0	58.2	208.7	177.0
Means		1744.3	16.1	59.9	210.0	177.3
$LSD_{0.05}$ (by t)		325.9	3.7	3.9	17.3	2.2
CV% (s/means)		11.0	13.7	3.9	4.9	0.7
P-Value		0.0183	0.1467	0.4799	<0.0000	<0.0000

Seeding Date: 05/02/2017 Harvest Date: 08/14/2017
Fertilizer (actual): 11-22.5-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 4.09 inches
Herbicide: Pre-plant sprayed with Roundup RT3 at 40oz/ac on 05/01/2017.
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Table 5. Statewide Lentil Variety Evaluation. Western Triangle Ag. Research Center. 2017.

Variety	Lentil Color and size	Yield (lb/a)	Mature Canopy Height (in)	Test Weight (lb/bu)	1000 Kernel Weight (g)	Vine Length (in)
CDC Greenland	lg	1768	6.5	55.9	65.8	17.3
Merrit	lg	1744	7.8	55.4	67.0	15.8
Riveland	lg	1616	9.0	47.1	109.3	18.0
CDC Richlea	mg	1752	6.8	54.2	68.0	15.5
Impress CL	mg	1799	7.0	54.9	59.0	14.3
Imi-Green	mg	1174	9.8	53.2	104.3	19.3
Viceroy	sg	2056	6.5	59.5	44.0	17.0
Eston	sg	2020	8.5	58.3	63.8	14.8
Essex	sg	1865	6.0	58.2	46.3	14.8
CDC Redberry	sr	1869	14.3	57.8	45.0	19.5
Red Coats	sr	1630	8.5	57.9	58.0	16.5
Crimson	sr	1590	5.0	61.2	33.3	13.8
CDC Impact	sr	1514	7.5	59.5	47.0	13.5
Morena	sb	1633	8.8	57.8	64.8	15.8
Pardina	sb	1259	4.5	59.2	67.5	12.8
Avondale	tr	1597	9.0	52.7	60.5	15.0
Means		1682	7.8	56.4	62.7	15.8
$LSD_{0.05}$ (by t)		NS	2.3	4.8	29.7	2.3
CV% (s/means)		23.6	21.0	6.0	33.4	10.1
P-Value		0.1820	<0.0000	<0.0001	0.0003	<0.0001

Seeding Date: 04/05/2017. Harvested Date: 08/03/2017.
Fertilizer (actual lbs/ac): 11-20-20. 11-20-0 was applied with the seed and 0-0-20 being broadcast while planting.
Precipitation: 6.21 inches.
Herbicide: Pre-plant sprayed with Roundup RT3 at 32oz/ac, Prowl H2O at 32 oz/ac, and Sharpen at ¾ oz/ac on April 2, 2017.
Lentil color: Small Green = sg; Medium Green = mg; Large Green = lg; Small Red = sr; Spanish Brown (Pardina) = sb
Western Triangle Ag. Research Center, Conrad, MT.

Table 6. Off-station Lentil Variety trial north of Galata, MT. Toole County. Western Triangle Ag. Research Center. 2017.

Variety	Color	Yield[1]	Test Wt[1]	TKW[1]	Height	Shatter
		(lb/ac)	(lb/bu)	(grams)	(inch)	(%)
Avondale	Green	1369.9	58.8	43.4	12.0	8.0
Viceroy	Green	1363.0	60.0	28.2	12.8	6.1
Maxims	Red	1317.6	60.5	33.3	11.7	3.0
Invincibles	Green	1236.3	60.0	29.6	12.0	8.0
Richlea	Orange Red	1232.6	56.2	42.5	11.7	5.4
CDC Redcoat	Red	1060.2	59.7	34.8	12.8	2.2
Trial Mean		1262.2	59.2	35.1	12.2	5.6
LSD (.05)		NS	1.9	2.3	NS	NS
C.V. 1 (%) (S/mean)*100		11.7	1.8	3.7	6.3	67.8
P-Value		<0.0904	<0.0020	<0.0000	<0.2677	<0.2099

Cooperator and Location: Brian Aklestad, Toole County.
Planted on 05/08/2017 on chemical fallow. Harvested on 07/25/2017.
Fertilizer: actual lb/ac of N-P-K: 11-22.5-0 applied with seed and 0-0-20 was broadcast at planting.
Herbicide: The plots were sprayed pre-plant with RT3 at 32 oz/ac by the farmer.
[1] Yield, test weight and thousand kernel weight (TKW) are adjusted to 13% seed moisture.
Conducted by MSU Western Triangle Ag. Research Center.

Table 7. Western Regional Lentil Variety Evaluation. Western Triangle Ag. Research Center. 2017.

Variety	Lentil Type	Yield[1] (lb/ac)	Mature Canopy Height (in)	Test[1] Weight (lb/bu)	1000 Kernel Weight (g)	Flower Date (Julian)
LC09600476L	-	1773.0	11.3	58.7	66.7	173.3
LC08600005E	-	1758.4	11.0	61.2	45.0	177.7
LC14600023P	-	1701.3	9.3	61.8	41.0	178.0
LC10600494P	-	1692.9	10.7	61.6	40.7	176.3
Avondale	Medium/ green	1642.4	9.7	59.3	50.0	177.7
LC14600017P	-	1605.9	11.0	61.1	41.0	177.7
LC01602273E	-	1605.6	9.7	60.5	35.7	177.7
LC09600507P	-	1552.7	9.7	60.6	43.0	175.7
LC09600410L	-	1541.5	11.3	57.2	73.3	177.3
LC11600342R	-	1442.7	11.3	58.1	51.7	170.7
Pardina	Small/ brown	1399.7	9.7	61.4	38.7	177.3
LC14600031P	-	1376.7	9.7	62.1	45.0	178.0
Eston	Small/ green	1158.5	9.7	61.3	36.3	176.0
Merrit	Large/ green	1142.7	10.7	56.7	62.7	170.7
Means		1528.1	10.3	60.1	47.9	176
$LSD_{0.05}$ (by t)		NS	1.3	0.5	4.9	3.9
CV% (s/means)		20.2	7.7	0.5	6.1	1.3
P-Value		0.2872	0.0028	<0.0000	<0.0000	0.0023

Seeding Date: 05/02/2017 Harvested Date: 08/14/2017
Fertilizer (actual): 11-22.5-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 4.09
Herbicide: Pre-plant sprayed with Roundup RT3 at 40oz/ac on 05/01/2017.
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Table 8. Statewide Chickpea Variety Evaluation. Western Triangle Ag. Research Center. 2017.

Variety	Chickpea Type	Yield[1] (lb/ac)	Mature Canopy Height (in)	Test[1] Weight (lb/bu)	1000 Kernel Weight (g)	Flower Date
CDC Orion	Large Kabuli	2756	14.3	58.3	486.5	161.5
Royal	Café Kabul	2543	16.8	58.5	582.3	171.3
Sierra	Kabul	2502	15.5	58.9	534.5	168.7
Nash	Café Kabul	2390	16.0	57.8	624.0	173.5
Sawyer	Café Kabul	2375	14.3	60.0	469.0	168.8
CDC Frontier	Large Kabuli	2349	15.3	59.6	410.7	171.8
CDC Alma	Med/Large Kabuli	2305	12.0	59.1	394.5	171.3
Myles	Desi	2267	15.5	54.8	212.6	-
Means		2435	14.9	58.4	464.3	169.5
$LSD_{0.05}$ (by t)		NS	1.3	2.5	45.6	3.3
CV% (s/means)		13.33	6.0	2.9	6.7	1.3
P-Value		0.4832	<0.0000	<0.0102	<0.0000	<0.0000

Seeding Date: 04/19/2017 Harvest Date: 08/30/2017
Fertilizer (actual): 11-22-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 4.81 inches
Herbicide: Pre-plant sprayed with Roundup RT3 at 32 oz/ac and Sharpen at 1 oz/ac on 04/19/2017.
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Table 9. Western Regional Chickpea Variety Evaluation. Western Triangle Ag. Research Center. 2017.

Variety	Chickpea Type	Yield[1] (lb/ac)	Mature Canopy Height (in)	Test[1] Weight (lb/bu)	1000 Kernel Weight (g)	Flower Date (Julian)
CDC Frontier	Large Kabuli	2839.5	13.7	176.7	373.0	176.7
CA0790B0547C	-	2763.9	13.0	176.7	503.3	176.7
Billy Beans	Small Kabuli	2707.7	14.3	172.0	328.7	172.0
CA0890B0531C	-	2479.2	13.3	173.7	519.7	173.7
CA0890B0429C	-	2338.5	13.3	174.0	508.7	174.0
CA0790B0043C	-	2298.3	15.7	172.0	481.0	172.1
Sierra	Kabul	2281.5	13.0	176.3	504.3	176.3
CA0790B0034C	-	2214.5	14.3	177.3	505.3	177.3
Means		2490.4	13.8	57.7	465.5	174.8
$LSD_{0.05}$ (by t)		334.3	1.4	1.2	49.0	2.8
CV% (s/means)		7.7	5.6	1.2	6.0	0.9
P-Value		0.0052	0.0117	0.0033	<0.0000	0.0029

Seeding Date: 05/02/2017 Harvest Date: 09/05/2017
Fertilizer (actual): 11-22-20. 11-22-0 was applied with the seed with 0-0-20 being broadcast while planting.
Precipitation: 4.09 inches
Herbicide: Pre-plant sprayed with Roundup RT3 at 40 oz/ac on 05/01/2017.
Conducted by Western Triangle Ag. Research Center, Conrad, MT.

Soil Test Values

Soil test values for off-station and on-station plots, 2017.

Location	N (lb/ac)[1]	Olsen-P (ppm)	K (ppm)	pH	OM (%)	EC (mmhos/cm)
Cut Bank	39.6	17	385	7.5	2.7	0.39
Devon	12.0	14	221	7.2	0.8	0.15
Knees	21.1	28	482	6.9	2.4	0.55
Choteau	44.5	7	412	8.1	2.3	0.82
WTARC Fall	15.5	20	318	7.8	2.6	0.56
WTARC Spring	15.9	30	528	7.4	2.6	0.36
Sweetgrass Hills	3.5	27	336	6.7	2.5	0.23

[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

Montana Wheat and Barley

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Screening for low phosphorus tolerance in 99 spring wheat genotypes adapted to Montana ecosystems

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Investigators: Kenedy Etone Epie, Maral Etesami, and John H. Miller

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Background

Phosphorus (P) is one of the non-renewable essential macronutrients of plants that plays a critical role in improving wheat productivity but remains generally unavailable. Considering the important role of P in growth and yield of grain crops, identifying genetic variability for low P tolerance will be critical for increasing crop productivity. Defficiency of P retards growth, reduced numbers of tillers and reproductive structures in plants. It may be abundant in some soils but less readily available due to low solubility and mobility of its phosphate forms. In the Northern Great Plains including Montana, P availability is heavily influenced by soil pH and even when applied as inorganic fertilizer, only about 20% is used by crops and the rest is converted into insoluble forms in acid and alkaline soils (Rodriguez and Fraga, 1990). Excessive amounts of expensive artificial soluble P fertilizers are therefore used in crop production which reduce profit margins and also accumulate in water bodies, causing water pollution and eutrophication.

To look for answers to the P crisis, the development of P efficient spring wheat genotypes, which are adapted to low P soils, would be a promising solution. Wheat genotypes exhibit considerable genetic diversity in response to P and screening of spring wheat genotypes for P deficiency tolerance could help to identify contrasting genotypes for low P tolerance that can be included in spring wheat improvement programs. An understanding of the relationship of growth traits and grain yield will further help to improve productivity. More so, most research attention is focused on the responsiveness of wheat genotypes to increasing P fertilization, and information is therefore lacking on responsiveness of genotypes to low or deficient P conditions.

Objectives

The objectives of this research were to characterize genetic variability and screen for P deficiency tolerance in ninety nine spring wheat genotypes that can be adapted to Montana ecosystems.

Materials and Methods

The spring wheat genotypes classified by source were AM which included elite spring wheat lines from several regional breeding programs (Table 1), 2016 off-stations and NAM (nested association mapping) originating from 30 countries, developed by crossing landraces to a common parent (Table 2). The genotypes were obtained from the Department of Plant Science and Plant Pathology, Montana State University.

Table 1. Spring wheat genotypes from AM source screened for phosphorus deficiency tolerance.

TID	Source	Genotype	Origin	TID	Source	Genotype	origin
1	AM PANEL	KEISE	WSU	26	AM PANEL	AC CADILLAC	MANITOBA
2	AM PANEL	MACON	WSU	27	AM PANEL	AC SPLENDOR	MANITOBA
3	AM PANEL	OTIS	WSU	28	AM PANEL	SUPERB	MANITOBA
4	AM PANEL	SCARLET	WSU	29	AM PANEL	IDO440	UI
5	AM PANEL	SD4265	SD	30	AM PANEL	PEACE	MANITOBA
6	AM PANEL	TARA2002	SWSU	31	AM PANEL	WHITEBIRD	UI
7	AM PANEL	9249	CIMMYT	32	AM PANEL	AC ANDREW	SASKATCHEWAN
8	AM PANEL	92161	CIMMYT	33	AM PANEL	AC DOMAIN	SASKATCHEWAN
9	AM PANEL	BERKUT	CIMMYT	34	AM PANEL	BW947	ALBERTA
10	AM PANEL	9258	CIMMYT	35	AM PANEL	CULTER	ALBERTA
11	AM PANEL	9259	CIMMYT	36	AM PANEL	LASER	ALBERTA
12	AM PANEL	9260	CIMMYT	37	AM PANEL	CDC ALSASK	SASKATCHEWAN
13	AM PANEL	9253	CIMMYT	38	AM PANEL	CDC GO	SASKATCHEWAN
14	AM PANEL	TREASURE	UI	39	AM PANEL	CDC KERNEN	SASKATCHEWAN
15	AM PANEL	JEROME	UI	40	AM PANEL	MNO1333-A	UMN
16	AM PANEL	ID0702	UI	41	AM PANEL	MNO2072-7	UMN
17	AM PANEL	JEFFERSON	UI	42	AM PANEL	MNO2255	UMN
18	AM PANEL	ALTURAS	UI	43	AM PANEL	MNO7098-6	UMN
19	AM PANEL	LASSIK	UCD	44	AM PANEL	MNO8013-2	UMN
20	AM PANEL	UC1682	UCD	45	AM PANEL	MNO8106-6	UMN
21	AM PANEL	SUMMIT515	UCD	46	AM PANEL	SD4112	SDSU
22	AM PANEL	BLANCA FUERTE	UCD	47	AM PANEL	SD4165	SDSU
23	AM PANEL	HARVEST	MANITOBA	48	AM PANEL	SD4178	SDSU
24	AM PANEL	UNITY	MANITOBA	49	AM PANEL	SD4250	SDSU
25	AM PANEL	MN07338	MN	50	AM PANEL	BERKUT	CHECK??

TID=Trial ID number

Table 2. Spring wheat genotypes from off-station and NAM parent source screened for phosphorus deficiency tolerance.

TID	source	Genotype	Origin	TID	Source	Genotype	origin
51	2016 OFF-STATION	FORTUNA	MSU	76	NAM PARENTS	PI 8813	IRAQ
52	2016 OFF-STATION	MCNEAL	MSU	77	NAM PARENTS	PI 9791	UZBEKISTAN
53	2016 OFF-STATION	REEDER	MSU	78	NAM PARENTS	PI 43355	URUGUAY
54	2016 OFF-STATION	CHOTEAU	MSU	79	NAM PARENTS	PI 61693	MALAWI
55	2016 OFF-STATION	VUDA	MSU	80	NAM PARENTS	PI 70613	CHINA
56	2016 OFF-STATION	DUCLAIR	MSU	81	NAM PARENTS	PI 82469	KOREA, NORT
57	2016 OFF-STATION	NITT	MSU	82	NAM PARENTS	PI 94567	ISRAEL
58	2016 OFF-STATION	CORBIN	WB	83	NAM PARENTS	PI 153785	BRAZIL
59	2016 OFF-STATION	ONEAL	WB	84	NAM PARENTS	PI 166333	TURKEY
60	2016 OFF-STATION	WB9879CLP	MSU/WB	85	NAM PARENTS	PI 185715	PORTUGAL
61	2016 OFF-STATION	WB GUNNISON	WB	86	NAM PARENTS	PI 192001	ANGOLA
62	2016 OFF-STATION	BRENNAN	SYNGENTA	87	NAM PARENTS	PI 192147	ETHIOPIA
63	2016 OFF-STATION	SY TYRA	SYNGENTA	88	NAM PARENTS	PI 192569	SWEDEN
64	2016 OFF-STATION	SY SOREN	SYNGENTA	89	NAM PARENTS	PI 210945	CYPRUS
65	2016 OFF-STATION	EGAN	MSU	90	NAM PARENTS	PI 220431	EGYPT
66	2016 OFF-STATION		MSU	91	NAM PARENTS	PI 262611	TURKMENIST
67	2016 OFF-STATION	GLENN/MT0747	MSU	92	NAM PARENTS	PI 278297	GREECE
68	2016 OFF-STATION		MSU	93	NAM PARENTS	PI 283147	JORDAN
69	NAM PARENTS			94	NAM PARENTS	PI 366716	AFGHANISTAN
70	NAM PARENTS			94	NAM PARENTS	PI 382150	JAPAN
71	NAM PARENTS	CLTR 4175	PHILIPPINES	96	NAM PARENTS	PI 470817	Algeria
72	NAM PARENTS	CLTR 7635	RUSSIAN FED	97	NAM PARENTS	PI 477870	Peru
73	NAM PARENTS	CLTR 11223	CROATIA	98	NAM PARENTS	PI 565213	BOLIVIA
74	NAM PARENTS	CLTR 15134	PAKISTAN	99	NAM PARENTS	PI 572692	GEORGIA
75	NAM PARENTS	CLTR 15144	SAUDI ARABIA				

TID=Trial ID number

This research was conducted in a high tunnel facility (greenhouse) of the Western Triangle Agricultural Research Center, Montana State University, Conrad, MT. Plants were grown in cylindrical plastic pots in potting mix of peat, vermiculite and sand in the ratio of 1:1:1. During mixing, sufficient P treatment received 25 ppm of MAP and low P with a residual P of 5 ppm received no P fertilizer. Therefore, the two levels of P maintained in the trial were 5 ppm P (designated as P5) and 30 ppm P (designated as P30). Other required nutrients were sufficiently supplied. All nutrients were mixed thoroughly with growing media before potting with 10 kg of the mixture per pot. The treatments were performed in triplicate and arranged in a completely randomized design. Twelve seeds of each genotype were sown at 4-cm depth in each pot in April 2017. Plants were irrigated every other day to maintain a soil moisture level per pot of 60% of the field capacity during growth of the plants by weighing and adding water to make up loses.

After emergence, plants were thinned to eight plants per pot at the 2-leaf stage. The greenhouse was monitored daily by a temperature recording device, Onset Hobo Data Loggers, (Onset Computer Corporation, MA). Mean temperatures ranged from 10°C at night to 25°C during the day. Plants were harvested at 106 DAS. Height, tiller number, and head number of all 99 varieties were recorded shortly before harvest. Plant height was determined as the distance between potting mix surface level and the tip of the last head. Harvested shoots in each pot were collected and oven dried at 70 °C until a constant dry weight (g/pot). Grain yield and 1000 seed weights were determined. Grains from a subset of 20 genotypes selected based on grain yield after ranking the yields of P5 plants from highest to lowest were selected, milled and the ground samples were sent to Agvise Laboratory to analyze for grain P and N concentrations. Grain protein content was determined, and grain P uptake (mg/pot) was calculated.

Results

Table 3. Grain yields and protein content of 20 genotypes selected based on grain yield after ranking the yields of low P plants from highest to lowest. Values are means ± standard deviations.

	TID	Genotype	Grain yield (g pot^{-1})		Grain protein content	
Highest 20			P5	P30	P5	P30
	24	UNITY	13.9±1.8	15.4±2.3	14.6±0.3	15.3±0.7
	30	PEACE	13.6±4.4	12.8±3.0	14.7±1.0	16.7±0.4
	55	VIDA	13.6±3.7	17.6±3.2	14.6±0.3	15.2±0.8
	53	REEDER	13.0±1.2	17.8±1.3	14.2±0.5	15.0±0.5
	74	CLTR 15134	12.2±0.7	12.6±0.8	13.4±0.4	17.1±1.0
	59	ONEAL	12.1±0.7	16.9±2.0	14.2±0.3	15.5±0.5
	51	FORTUNA	12.0±2.6	15.4±5.5	14.1±0.5	14.7±1.0
	48	SD4178	12.0±3.7	14.3±4.3	14.2±0.6	15.2±0.6
	31	WHITEBIRD	11.9±2.3	18.3±7.0	13.3±0.6	13.9±1.0
	23	HARVEST	11.8±0.4	16.0±2.1	13.6±0.2	16.2±0.6
	17	JEFFERSON	11.7±2.3	19.5±6.0	13.2±0.3	14.6±0.8
	34	BW947	11.7±4.1	16.1±5.1	14.6±0.4	16.1±0.7
	99	PI572692	11.7±1.4	12.8±1.3	13.0±0.8	16.4±2.0
	57	NITT	11.6±2.4	18.8±3.8	14.7±0.4	15.4±0.8
	64	SY SOREN	11.4±1.3	8.3±2.9	14.2±0.4	16.4±0.3
	90	PI220431	11.4±3.1	13.9±4.4	12.7±0.9	13.9±1.3
	77	PI9791	11.4±3.6	15.5±1.0	14.3±0.3	16.0±0.8
	88	PI192569	11.3±3.3	16.4±5.2	13.9±0.5	14.1±0.9
	39	CDC KERNEN	11.2±1.7	19.3±1.5	14.2±1.0	14.3±0.2
	6	TARA 2002	11.2±2.9	12.5±4.9	13.7±1.0	15.6±1.2
	Mean		12.1	15.5	14.1	15.4

TID Trial ID number.

Significance of results and recommendations
This study confirms the possibility of departing from rectifying P deficiencies in soils by commercial chemical fertilizers. It highlights an approach whereby the inherent genetic differences with respect to P deficiency tolerance can be exploited to partially, at least, tackle the intractable problem of P deficiency as a factor in crop production. In this study, Unity, Peace, Vida, Reeder and CLTR 15134 spring wheat genotypes showed substantial tolerance in their growth response, grain yield and protein content under a P-deficient conditions. The genetic variability identified in this research for grain yields offers useful information for spring wheat improvement programs for choosing genotypes with low P tolerance characteristics. These results could also be used to select interesting genotypes for organic spring wheat production in Montana.

This study should be repeated in the greenhouse only for the selected genotypes and field evaluations are recommended to confirm their P tolerance abilities. Detailed findings of this research project is being prepared into a manuscript for possible submission to an international peer reviewed journal.

Project Challenges
This project was well implemented except that the top of the hoop house (greenhouse) was ripped apart by strong winds in the middle of the trial. Minimal bird and rodent damage was also recorded.

Acknowledgements
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Effect of water regime on evapotranspiration, grain and protein yields of pea, lentil, barley, spring wheat followed by winter wheat crop sequence

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Background

Primarily due to low annual quantity and poor distribution of precipitation, the risk of crop production in dryland Montana is high. Available water in dryland agriculture is the most important factor controlling crop function and a decline in available water increases the physiological stress and vulnerability of plants (Guoju et al. 2013). There is no doubt that increasing soil moisture will favor crop productivity. Winter wheat-fallow agricultural systems have been widely adopted to reduce the risk of crop failure. Montana farmers believe that leaving land fallow after a cropping season is required to store soil moisture rather than continuously growing crops. This perception stems from cases of pulse failure across the state attributed to severe drought conditions. Based on soil water dynamics, farmers may predict when to skip fallow and adopt a pulse-winter wheat and barley-winter wheat cropping systems to increase profitability of their farmlands. In addition, this research examines the role of evapotranspiration and water use efficiency as related to yields and protein content. Considering the urgent need to develop a sustainable dryland cropping system, the Montana Wheat and Barley Committee renewed the funding of this research project in January 2017.

Objectives

The overall goals of this project were to determine the effect of soil water regime on evapotranspiration, grain yields and protein contents of lentil, pea, barley, spring wheat and the profitability of following these crops with winter wheat crop sequence.

Materials and Methods

Field trial was established in spring 2017 at the Western Triangle Agricultural Research Center. Soils in this area are described as Scobey clay loam with a soil surface pH of 7.7 and an organic matter content of 2.4%. Because of their yields and market popularity in North Central Montana, Vida, Hockett, Richlea and Banner varieties were respectively chosen for spring wheat, barley, lentil and pea. After initial soil testing, seeding was done with a total soil N (residual + fertilizer) rate of 50 lbs per acre. Fertilization was based on recommendations and expected yields and was kept to a minimum to avoid dilution and the masking of water regime effect on the crops. Four water regime treatments were set up through a differential line irrigation system aimed at providing 18 (high), 12 (medium), 6 (low) and zero (only precipitation) inches of water from seeding to flowering. Irrigation treatments were assigned to the main plots of 75 x 50 feet and crops and a fallow plot were randomly assigned to the sub plots with four replications in a randomized complete block design. Weeds were effectively controlled using appropriate herbicides.

Soil samples were collected at 1-3 ft depths before seeding and after harvesting in each plot to determine change in soil water content. Evapotranspiration or water use was calculated by adding total precipitation and change in soil water content. Water loss through drainage was assumed as negligible. Water use efficiency (WUE) was computed as the ratio of yield to evapotranspiration.
After harvest, grain yield was determined. Protein content and test weight was analyzed by Perten NIR. Data was subjected to analysis of variance and Pearson's correlation and significance of means was determined at 5% level of probability using Tukey b test.

Research results, Significance and Recommendations
Results showed water regime significantly influenced evapotranspiration and water use efficiency of the crops (Table 1-4). Evapotranspiration increased with increasing water application throughout the growing season. Grain or seed yields of lentil, barley and spring wheat were significantly influenced by water regime. Grain or seed protein content of pea, barley and spring wheat generally increased with increasing water application but test weights were not significantly affected (Table 2-4). Except lentils, the crops used water more efficiently at lower water applications and evapotranspiration. Evapotranspiration generally had significant correlation with yield and water use efficiency (Table 5). Grain or seed yields showed significant positive correlation with evapotranspiration and WUE in lentil. WUE was positively correlated with grain or seed yields in pea, barley and spring wheat but significantly so only in barley. Significance in correlation is an indication that two variables have a strong association. A change in one variable can be used to predict the response of the associated variable with some degree of certainty.

There was wide variation in yields of the crops compared to the average yields for Montana in 2015. According to the USDA (2016) average yields for lentil, dry pea, barley and spring wheat for Montana State in 2015 was 1100 lb ac^{-1}, 1450 lb ac^{-1}, 52 bu ac^{-1} and 31 bu ac^{-1} respectively. Lentils and spring wheat responded well with high yields in increased irrigation plots compared to pea and barley. Barley and pea proved to be sensitive to soil moisture by yielding more in dryer conditions. These results indicate that genotypic differences exists between these crops in their response to different water regime conditions. This study proves that there is need to continue to look into better and more accurate understanding of different crops and their response to soil water dynamics in semi-arid agri-systems and Montana farmers must continue to be prudent in making soil and crop management decisions in this era when rainfall is erratic and unpredictable. The information from this study could be used to help farmers formulate strategies for ensuring effective and efficient use of stored soil water for sustainable production of irrigated lentil, pea, barley and spring wheat in dryland agro-ecological environment. Under irrigated conditions, the highly mobile nitrates move out of the root zone before plants can take them up (Inskeep et al. 1992). Therefore, further studies are necessary to investigate these crops at different water regimes and N fertilizer rates to determine a proper combination of applied water and fertilizer N that will meet a realistic yield goal while minimizing leaching of fertilizers.

Table 1. Effect of water regimes on evapotranspiration, seed yield and water use efficiency of lentil. Values are means of 4 replicates.

Water regime	Evapotranspiration (mm)	Seed yield (lb ac^{-1})	Water use efficiency (kg ha^{-1} mm^{-1})
High	429d	2645c	6.9a
Medium	332c	2721c	9.2b
Low	233b	1322b	6.4a
Control	132a	775a	6.6a
P value	***	***	*

*,*** P<0.001, P<0.05 respectively. ns not significant.
Means followed by different letters are significantly different.

Table 2. Effect of water regimes on evapotranspiration, test weight, protein content, seed yield and water use efficiency of pea. Values are means of 4 replicates.

Water regime	Evapotranspiration (mm)	Seed yield (lb ac^{-1})	Water use efficiency (kg ha^{-1} mm^{-1})	Test weight	Protein content
High	428d	827a	2.2a	60a	19.5ab
Medium	332c	912a	3.1a	61a	17.1a
Low	233b	998a	4.8b	61a	20.8b
Control	131a	970a	8.3c	61a	17.5a
P value	***	ns	***	ns	*

***, *, P<0.001, P<0.05 respectively. ns not significant.
Means followed by different letters are significantly different.

Table 3. Effect of water regimes on evapotranspiration, test weight, protein content, plumps, seed yield and water use efficiency of barley. Values are means of 4 replicates.

Water regime	Evapotranspiration (mm)	Seed yield (bu ac^{-1})	Water use efficiency (kg ha^{-1} mm^{-1})	Test weight	Protein content	Plumps
High	427d	33.0a	4.2a	54	11.7b	91
Medium	339c	43.5b	7.1b	53	10.3a	94
Low	229b	42.8b	10.1c	54	10.7ab	96
Control	130a	47.0b	19.5d	53	9.7a	91
P value	***	***	***	ns	**	ns

***,** P<0.001, P<0.01 respectively. ns not significant.
Means followed by different letters are significantly different.

Table 4. Effect of water regimes on evapotranspiration, test weight, protein content, seed yield and water use efficiency of spring wheat. Values are means of 4 replicates.

Water regime	Evapotranspiration (mm)	Seed yield (bu ac^{-1})	Water use efficiency (kg ha^{-1} mm^{-1})	Test weight	Protein content
High	425d	33.5b	5.3a	64a	10.5b
Medium	330c	27.6a	5.6a	64a	10.0ab
Low	228b	31.2b	9.2b	64a	10.3ab
Control	130a	26.8a	13.8c	64a	9.5a
P value	***	***	***	ns	*

***,* P<0.001, P<0.05 respectively. ns not significant.
Means followed by different letters are significantly different.

Table 5. Pearson correlation coefficients between evapotranspiration (ET), water use efficiency (WUE) and grain or seed yield (Y) and associated P values of lentil, pea, barley and spring wheat.

Crop	ET x Y	ET x WUE	WUE x Y
Lentil	0.917**	0.292ns	0.628**
Pea	-0.280ns	-0.916**	0.485ns
Barley	-0.762**	-0.943**	0.744**
Spring Wheat	0.602*	-0.946***	0.454ns

*,**,*** Correlation is significant at the 0.05, 0.01,0.001 level (2-tailed) respectively. ns, not significant.

Project Challenges and problems
Water for irrigation was released into the canal (source) at the end of May 2017. For this reason, there was delay in irrigation initially planned to start as early as seeding. Therefore, instead of eight weeks planned irrigation, plots received six weeks of irrigation water. Yields of pea and barley were severely affected by the feeding damage of a swarm of birds at the juicy dough stage of the pods and grains respectively.

Next phase of the project into 2018
In September 2017, winter wheat was seeded into previously cropped and fallowed plots and grains will be harvested in summer 2018. The benefits of pulse-winter wheat rotation and profitability will be determined taking into consideration the yields and estimated fertilizer cost of each cropping sequence.

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United States Department of Agriculture
National Institute of Food and Agriculture

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Montana Wheat and Barley

Managing wheat stem sawfly using synthetic plant defense elicitor chemicals

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Aim of the Study

The aim of this study was: 1) to determine the effects of three synthetic plant defense elicitor chemicals (Acitgard, Cis-Jasmone and Neem) treatment application on wheat stem sawfly management.

Materials and Methods

Insect

Wheat stubbles containing wheat stem sawfly (WSS) diapausing larvae were collected from winter wheat fields in Pondera County, Montana from October 2016 to February 2017. Infested, 'WSS-cut' stems were stored in plastic deli round containers and maintained in a climate cabinet (5 ± 1ºC) for nearly three months in the dark to facilitate completion of obligatory larval diapause (Holmes, 1977). Afterwards, WSS infested stems were transferred in new deli containers. However, the half of these containers were first filled with garden soil, stem base placed beneath the soil and positioned in standing situation. About 50-60 stems were kept in each container, placed in insect cages (12 × 10 × 10 cm), and held at a laboratory temperature (19-21 ºC, 50–60% RH, 16:8 L: D) at Western Triangle Agricultural Research Center (WTARC), Montana State University, USA.

Containers were lightly moistened twice weekly with tap water to minimize the desiccation of the larvae. The insect cages were opened daily, and the emerged WSS adults were held in new insect cages with cotton pad pieces moistened with a solution of 10 % of honey in water until they were used for experiments. . In each insect cage, about 100 WSS adults were placed with about female and male ratio of 60:40. To minimize the host deprivation time, the laboratory bioassay experiments were performed with WSS female adults within 48 h of emergence. In our rearing system, adults emerged in three-four weeks from WSS infested stems.

Plants

Winter wheat variety '*Yellowstone*' was selected as a source of plant material for both the lab and the field experiments. This variety is one of the most common winter wheat variety in Montana because of high yielding, excellent qualities (baking and noodle), and moderately resistance to plant diseases (dwarf smut and stripe rust), but; very susceptible to WSS damage. Winter wheat plants require a period of exposure to cool temperatures to trigger its stem elongation and reproductive induction. For the laboratory bioassay experiments the winter wheat seedling nursery plot was established at WTARC. Winter wheat seeds were seeded at the rate of

194 live seeds per m^2 in September 2016.The nutrient and irrigation management tactics were as per the normal standard grower's agronomic practices.
When the vernalization completed naturally in the next year spring 2017, the seedlings (two unfolded leaves) were transplanted into tapered square pots (13 × 13 × 13.5 cm) a density of three plants per pot. Plants were maintained in a greenhouse at 18-20 ^{0}C, 50–60% RH and natural light conditions until used for experiments. Each pot contained 1.62 kg of prepared soil mixture. The soil mixture has an equal proportion of sand, vermiculite, and peat moss, and N, P and K fertilizer at 17.13, 11.49 and 8.10 g/100 kg soil mixture respectively. Plants were watered four to five times weekly, and fertigated with Peters General Purpose Fertilizer (J. R. Peters, Allentown, PA) at 100 ppm in aqueous solution at fortnight interval. Nutrient application initiated when the plants reached the third leaf stage (Zadoks et al. 1974). Plants used for the laboratory experiments were at a developmental stage of Zadoks 33 when 2–3 nodes are visible. This stage was considered for experiments since WSS female adults preferred this wheat plant stage for oviposition, as reported by Holmes and Peterson (1960).

Synthetic plant defense elicitor (SPDE) chemicals source and rates
Actigard 50WG® was obtained from Syngenta (Fargo, ND) as a water-dispersible granular formulation containing 50 % active ingredient. Cis-Jasmone was obtained from Sigma-Aldrich (St. Louis, MO) as a soluble liquid formulation with 85 % purity. Azadirachtin (extracts from neem) containing 1.2 % emulsifiable concentration was obtained from Gowan Company (Yuma, AZ). For both the laboratory and field experiments, the chemicals were applied at the concentrations of 0.75 ml/L (Actigard), 0.5 ml/L (Cis-Jasmone) and 2.88 ml/L (Azadirachtin), which correspond to the doses recommended by the manufacturers for agricultural practices.

Lab experiments
WSS adult settling preference experiments
The bioassay experiments were performed to determine the WSS female adults settling preference for wheat plants (control) or wheat plants treated with SPDE chemicals as aforementioned. For the application of SPDE chemicals, potted wheat plants established in the greenhouse were transported to a spraying room. Spray application was made to individual plants using a 750 ml hand-held sprayer, with a spray volume of 20 ml per plant. After spraying, plants were allowed to dry for 1 h, and then transported to the collapsible cages. Plants treated with tap water served as a control treatment.

Four wheat plants were placed inside a cage. Two of the plants were SPDE chemicals treated and two were control to facilitate choice in the experiment. Each group of plants were further placed separately inside a cage. Subsequently, 10 female adults (48 hr old) were released at the center of the cage and allowed to settle overnight. However, insects were released five days after the Actigard treatment application to allow to induce resistance against insect pests in plants. Following day, the position of each WSS adult (either on the SPDE chemicals treated, the water treated plants or elsewhere) was recorded in the morning (9:00-10:00 am) and the afternoon (15:00-16:00 pm) local time.

A similar procedure was followed to determine the WSS female adults settling behavior under no-choice condition. Except, one plant treated with each SPDE chemical or water (control) was placed in an insect cage and the number of insect released per cage was seven. The cages were maintained in a room at 19-21 ºC, 50–60% RH, 16:8 L: D. Both choice and no-choice experiments have four replications (each insect cage = one replicate) and conducted on two times.

Field experiments

Locations of winter wheat field trials

The experiments were conducted at three locations: Knees (N 48°00'08.5 W 111°21'51.8), Conrad (N 48°18'29.0 W 111°55'23.1) and Choteau (N 47°59'36.0 W112°06'49.9), in the Golden Triangle area of Montana, USA. All experimental locations were known to have moderate to high WSS infestation levels for many years. The experimental plots were seeded between the first and second week of September 2016 with a seeding 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) before to the seeding to control weed growth. Fertilizer N, P, and K ratio at 224.2, 0, and 22.4 kg/ha was broadcasted while planting, and an additional application of 12.3, 25.2, and 0 kg/ha of these three nutrients were placed through seed plot drill.

A randomized complete block design (RCBD) with four replicates per treatment was used. Plots were 3.6 × 1.2 m separated by 0.60 m buffer zones to avoid cross contamination of treatments.

Monitoring of WSS adults

WSS adults usually begin to deposit eggs in developing wheat stems when the stem elongation is initiated during the spring season. Estimating the ideal application time for synthetic pesticides or SPDE chemicals, could be one of the critical factors for WSS management. Currently, no degree-day model has been established for determining WSS adult emergence (Knodel et al. 2011). In this study, two methods were used: 1) dissection of WSS infested stubble for monitoring the immature stages of WSS (Nansen et al. 2005) and 2) sweep netting the winter wheat fields for monitoring the adult emergence (Knodel et al. 2010). Based on these two methods, experimental plots and their adjacent winter wheat fields were scouted at a weekly interval from last week of April to until mid-June, 2017.

Application of SPDE chemicals

The field experiments consisted of three treatment types: 1) application of SPDE chemicals before to WSS egg laying, 2) after egg laying, and 3) before and after egg laying inside wheat plants. The considerations for multiple treatment categories were to determine the most vulnerable insect stages and wheat plants response to the spraying timing of SPDE chemicals.

All SPDE chemicals were applied on the same date (treatment 1: May 29, 2017; and treatment 2 & 3: June 6, 2017) at Knees and Choteau field trial locations. However, for Conrad location, the spraying activity started ten days later because of the late emergence of WSS adults. Treatments were applied using a SOLO backpack sprayer (SOLO, Newport News, VA). The sprayer was calibrated to deliver ca. 150 L mixture/ha based on nozzle flow and walking speed. Plants treated with water served as control. At all field trail locations, SPDE chemicals were applied between 4-6 wheat nodules stages.

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, and 10, 20, 30 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.

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

This study examined that SPDE chemicals had the ability to repel WSS adult populations and further impacts on its associated parasitoid species. A sweep net was used to estimate the insect populations. Sweeping was performed with a standard sweep net, and 15 sweeps were made from each treatment plot. The sampling was performed the 3 days before treatment and, 10, 20 and 30 days after treatments application. The samples will be stored in the freezer until to diagnosis under the lab conditions.

Stem lodging level at harvest

WSS larval feeding in stems weakened stems, lodge and cause difficulty during harvesting (Holmes 1977). This experiment examined whether SPDE 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 9. The rating of 1 indicates that all plants in a plot were vertical and 9 for all plants in a plot were horizontal.

Yield and quality

A Hege 140 plot combine was applied to harvest the wheat grains from treatment plots. The precaution was used to avoid 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 SPDE chemicals treatments on WSS adults settling behaviour, WSS infestation level, WSS diapausing larval body weight, WSS diapausing larval mortality, 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 ($\alpha = 0.05$). Paired t-test was used to assess the WSS adult settling behavior when adults were exposed to SPDE chemicals and water sprayed plants together under choice conditions. The data was analyzed using the software statistical package R 2.15.1 (R Development Core Team, 2017).

Results

Laboratory experiments

WSS adult settling preference

In a no- choice situation, the SPDE chemicals treatments had not shown any effect on WSS adults settling behavior (df = 3, 56; F = 1.20; P = 0.32) although there was a tendency towards the low numbers of adults located on the Neem treated plants as compared to control (water sprayed) plants (Fig 1). In addition, time had not any effect on WSS adults settling behavior (df = 1, 56; F = 1.49; P = 0.22). However, in the choice situation, there was significantly higher WSS adults settling on control than Neem treated winter wheat plants both at the morning (t = -5.79; df = 7; P = 0.0006712) and evening (t = -3.0; df = 7; P = 0.01935) observation periods. WSS adults also preferred significantly to the control compared to the Actigard treated plants group at the evening (t = -3.66; df = 7; P = 0.007999), but without an effect at the morning (t = -1.47; df = 7; P = 0.1834) observation period (Fig 2). In contrast, there was no significant difference between in adults settling number between the control and Cis-Jasmone treated plants groups morning (t = -0.11; df = 7; P = 0.9079) and evening (t = 0.28; df = 7; P = 0.7849) observation periods (Fig 2).

Field experiments

WSS infestation level

WSS infestation levels at different sampling time are presented at Table 1. Overall, there was high variability in infestation levels at different time of sampling. Treatments, particularly, the application of Actigard or Cis-Jasmone appeared to have some effect on infestation level at 10 days after the treatments application (Table 1)

Table 1. Effects of synthetic plant defense elicitor chemicals treatments application on WSS infestation levels in winter wheat at the three study locations of Montana, 2017.

	Wheat stem sawfly Mean Infestation Level (%)				
Treatment	**PT**	**10 DAT**	**20 DAT**	**30 DAT**	**50 DAT**
Knees					
Water-BEL	23	38	55	67	75
Neem-BEL	22	23	38	60	85
Actigard-BEL	25	32	38	60	82
Cis-BEL	22	35	57	70	81
Actigard-AEL	10	25	57	53	74
Water-BAEL	20	42	65	71	72
Neem- BAEL	18	25	50	55	78
Cis- BAEL	20	17	48	55	81
Actigard- BAEL	22	27	35	35	62
Neem-AEL	18	33	48	63	77
Cis- AEL	22	37	47	67	72
Water-AEL	25	40	52	77	82

Choteau					
Water-BEL	17	57	67	77	93
Neem-BEL	22	48	60	78	93
Actigard-BEL	20	37	55	80	95
Cis-BEL	26	53	53	72	97
Actigard-AEL	11	35	55	78	82
Water-BAEL	25	48	61	82	97
Neem- BAEL	15	55	52	62	72
Cis- BAEL	10	24	77	82	97
Actigard- BAEL	18	33	58	83	79
Neem-AEL	22	35	47	77	100
Cis- AEL	22	63	70	85	99
Water-AEL	15	58	66	87	97
Conrad					
Water-BEL	10	25	33	57	83
Neem-BEL	15	27	38	58	66
Actigard-BEL	10	15	45	60	82
Cis-BEL	8	15	40	57	78
Actigard-AEL	16	13	33	50	60
Water-BAEL	27	28	45	58	79
Neem- BAEL	12	15	33	53	56
Cis- BAEL	17	37	32	52	57
Actigard- BAEL	9	17	30	58	70
Neem-AEL	10	23	45	68	84
Cis- AEL	13	20	55	60	71
Water-AEL	10	26	48	53	73

BEL: WSS Before egg laying; AEL: WSS Before egg laying; BAEL: WSS Before and after egg laying. PT: Pre-Treatment; DAT: Days after treatments.

Body weight of diapausing WSS larvae

Higher body weight of diapausing larvae were usually found at the Conrad followed by Choteau and Knees locations. Mean larval body weight recorded for SPDE chemicals including controls plots ranged from 12.66-19.00 mg, 11.88-16.90 mg and 9.67-13.46 mg for Conrad, Choteau and Knees locations, respectively. This study reported that SPDE chemicals treatments had significant impact on larval body weight at the two study locations: Knees (df = 11, 36; F = 3.35; P = 0.002) and Conrad (df = 11, 35; F = 4.89; P = 0.0001), but no significant effect at the Choteau location (df = 11, 35; F = 1.85; P = 0.08) (Fig 3).

At the Knees location, among the treatment plots, significantly lower larval body weight was observed when wheat plots were treated with one time (before egg laying) or two times (before and egg laying) applications of Actigard when compared to the water (control) sprayed plots (Fig 3). There were no significant differences in larval body weights with other treatments applications. Similarly, at the Conrad location, wheat plots treated with one time application of

Actigard before to WSS egg laying had lower larval body weight in comparison to the control (water sprayed) plots. Other treatments had no significant effects on larval body weight (Fig 3).

WSS diapausing larval mortality

Normally, higher diapausing WSS larval mortality was observed at the Knees followed by Conrad and Choteau locations, regardless of the treatment. Total mean larval mortality ranged 11-65 %, 12-58 % and 2-24 % for Knees, Conrad and Choteau locations, respectively. The results indicated that SPDE chemicals treatments had a significant influence on diapausing WSS larval mortality at each study location: Knees (df = 11, 36; F = 4.78; P = 0.001), Choteau (df = 11, 36; F = 3.45; P = 0.003) and Conrad (df = 11, 35; F = 2.61; P = 0.01).

Actigard treatment applications generally inflicted higher WSS diapausing larval mortality when compared to other treatments including controls, irrespective of locations. At the Knees location, wheat plots treated with one time (before or after egg laying) or two times (before and after egg laying) applications of Actigard, and one time Cis-Jasmone (after egg laying) applications were found to cause higher larval mortality when compared to the control treatments. However, one time (after egg laying) or the two times application of Actigard had only inflicted significantly higher mortality in comparisons to the water control treatments (Table 2). Similarly, at the Choteau and Conrad locations, significantly higher WSS larval mortality was recorded for the treatment with two times applications of Actigard as compared to the water control. In contrast, WSS larvae were found to be the least susceptible to Neem applications at all three locations, with no significant differences in larval mortality compared to control treatments (Table 2).

Wheat stem lodging at harvest

To assess the influence of SPDE chemical treatments on wheat stem lodging at harvest, the recorded visual rating stem lodged data of each SPDE chemical treatment plot was compared with the control (water) sprayed treatment plots. The results reported that the application of SPDE chemical treatments had a significant impact on wheat stem lodging at two locations: Knees (df = 11, 36; F = 3.02; P = 0.006) and Choteau (df = 11, 36; F = 4.20; P = 0.0005), but without a significant effect at the Conrad location (df = 11, 36; F = 1.78; P = 0.09).

Generally, at the Knees location, all SPDE chemical treatments were able to maintain lower stem lodging levels when compared to control treatment application. However, the stem lodged for a treatment with the two times application of Actigard was only significantly lower than the water controls (Fig 4). There was no significant differences in the lodging of the three SPDE chemicals treated wheat plots.

Regarding lodging results from Choteau location, on time (before or after WSS egg laying) or two times (before and after WSS egg laying) Actigard application provided lower lodging rating over the other treatments including controls. However, two times application of Actigard (before and after WSS egg laying) had only significantly minimal lodging rate when compared to the wheat plots treated with control (water) treatments (Fig 4).

Table 2. Effects of synthetic plant defense elicitor chemicals treatment application on total mortality of diapausing larvae (Mean ± SE), recorded in dissected stem at final harvest in winter wheat at the three study locations of Montana

Treatment	Diapausing Larval Mortality (Mean ± SE)

	Knees	Choteau	Conrad
Water-BEL	23 ± 2.75cd	2 ± 1.79bc	19 ± 4.38abc
Neem-BEL	21 ± 9.77cd	8 ± 9.48ab	25 ± 12.12abc
Actigard-BEL	34 ± 5.99bc	14 ± 3.78ab	34 ± 4.37abc
Cis-BEL	18 ± 4.26cd	13 ± 1.80ab	23 ± 9.29abc
Actigard-AEL	46 ± 1.79abc	11 ± 4.71ab	13 ± 5.32abc
Water-BAEL	17 ± 3.5cd	10 ± 2.25bc	12 ± 2.16bc
Neem- BAEL	20 ± 4.55cd	16 ± 2.50bc	17 ± 0.71bc
Cis- BAEL	26 ± 7.79cd	12 ± 4.43ab	25 ± 13.25abc
Actigard- BAEL	65 ± 1.79ab	33 ± 1.88a	54 ± 7.28a
Neem-AEL	32 ± 4.55bc	19 ± 3.53ab	10 ± 2.78bc
Cis- AEL	36 ± 7.79abc	23 ± 7.44ab	27 ± 15.14abc
Water-AEL	17 ± 3.54cd	11 ± 3.54bc	25 ± 5.13abc

Mean values within columns bearing the same letters within each location are not significantly different (One-way-ANOVA followed by Tukey test, $P > 0.05$). BEL: WSS Before egg laying; AEL: WSS Before egg laying; BAEL: WSS Before and after egg laying.

Yield

Irrespective of treatment and location, wheat plots treated with Cis-Jasmone maintained numerically higher yield levels than the Actigard applications. However, no significant differences were found between treatments at any locations (Knees: $df = 11, 36$; $F = 0.635$; $P = 0.78$; Choteau: $df = 11, 36$; $F = 0.50$; $P = 0.89$; and Conrad: df = 11, 36; $F = 0.28$; $P = 0.98$). Average winter wheat grain yield level ranged from 54-61 bushel/acre, 55-62 bushel/acre, and 68-81 bushel/acre at the Knees, Choteau and Conrad locations, respectively (Table 3).

Quality

This study showed that treatments had no significant impact in a test weight at any studied locations: Knees ($df = 11, 36$; $F = 1.67$; $P = 0.12$), Choteau ($df = 11, 36$; $F = 1.09$; $P = 0.40$) and Conrad ($df = 11, 36$; $F = 1.53$; $P = 0.16$). The overall test weight was numerically higher at the Conrad location (61-64 lbs/bushel) followed by Knees (61-62 lbs/bushel) and Choteau (59-61 lbs/bushel) (Table 3). Similarly, there were no significant differences in protein % of SPDE chemicals treatments or controls at any study location: Knees ($df = 11, 36$; $F = 0.70$; $P = 0.73$), Choteau ($df = 11, 36$; $F = 1.49$; $P = 0.17$) and Conrad ($df = 11, 36$; $F = 0.73$; $P = 0.69$). Numerically, protein levels were generally higher at Choteau (13-15 %) and Conrad (13-14 %) locations, while lower at the Knees (11-12 %) location (Table 3).

Table 3. Effect of synthetic plant defense elicitor chemicals treatment application on yield and quality parameters of wheat stem sawfly infested winter wheat (cv. Yellowstone) at the three study locations of Montana, 2017

Treatment	Yield (bushel/acre)	Test Weight (lbs/bushel)	Protein Level (%)
Knees Location			
Water-BEL	58 ± 2.78a	61 ± 0.11a	11 ± 0.05a
Neem-BEL	60 ± 2.40a	61 ± 0.14a	11 ± 0.19a
Actigard-BEL	54 ± 3.66a	62 ± 0.09a	11 ± 0.18a
Cis-BEL	60 ± 2.24a	61 ± 0.22a	11 ± 0.33a
Actigard-AEL	57 ± 3.34a	62 ± 0.11a	12 ± 0.23a
Water-BAEL	59 ± 2.63a	61 ± 0.34a	11 ± 0.27a
Neem- BAEL	57 ± 3.33a	62 ± 0.07a	11 ± 0.21a
Cis- BAEL	61 ± 1.33a	61 ± 0.28a	11 ± 0.13a
Actigard- BAEL	55 ± 2.95a	62 ± 0.20a	12 ± 0.18a
Neem-AEL	58 ± 2.12a	61 ± 0.14a	11 ± 0.21a
Cis- AEL	57 ± 2.14a	61 ± 0.03a	11 ± 0.45a
Water-AEL	56 ± 1.90a	61 ± 0.48a	12 ± 0.36a
Choteau Location			
Water-BEL	54 ± 6.06a	60 ± 0.66a	14 ± 0.29a
Neem-BEL	55 ± 1.22a	59 ± 0.76a	14 ± 0.53a
Actigard-BEL	58 ± 6.30a	59 ± 0.41a	15 ± 0.40a
Cis-BEL	59 ± 5.69a	59 ± 0.59a	13 ± 1.03a
Actigard-AEL	59 ± 3.89a	60 ± 0.13a	15 ± 0.18a
Water-BAEL	57 ± 4.53a	60 ± 0.59a	13 ± 0.40a
Neem- BAEL	59 ± 2.98a	59 ± 0.63a	14 ± 0.31a
Cis- BAEL	62 ± 2.04a	60 ± 0.39a	13 ± 0.42a
Actigard- BAEL	58 ± 5.56a	61 ± 0.09a	14 ± 0.30a
Neem-AEL	58 ± 2.48a	60 ± 0.57a	14 ± 0.45a
Cis- AEL	55 ± 2.74a	59 ± 0.60a	15 ± 0.13a
Water-AEL	56 ± 2.30a	60 ± 0.64a	14 ± 0.40a
Conrad Location			
Water-BEL	65 ± 12.15a	62 ± 0.30a	13 ± 0.32a
Neem-BEL	74 ± 9.63a	62 ± 0.31a	13 ± 0.39a
Actigard-BEL	70 ± 7.14a	62 ± 0.60a	13 ± 0.32a
Cis-BEL	81 ± 9.73a	64 ± 1.09a	14 ± 0.95a
Actigard-AEL	76 ± 8.54a	61 ± 0.51a	13 ± 0.39a
Water-BAEL	67 ± 11.18a	62 ± 0.50a	13 ± 0.53a
Neem- BAEL	70 ± 8.74a	62 ± 0.43a	13 ± 0.47a
Cis- BAEL	74 ± 10.79a	62 ± 0.31a	13 ± 0.20a
Actigard- BAEL	69 ± 5.99a	61 ± 0.53a	13 ± 0.28a
Neem-AEL	72 ± 7.97a	61 ± 0.55a	13 ± 0.44a
Cis- AEL	78 ± 6.42a	61 ± 0.39a	13 ± 0.23a
Water-AEL	68 ± 4.72a	61 ± 0.19a	13 ± 0.23a

The number of replicates per treatment was four. Mean values within columns bearing the same letters within each location are not significantly different (one-way-ANOVA followed by Tukey test, P > 0.05). BEL: WSS Before egg laying; AEL: WSS Before egg laying; BAEL: WSS Before and after egg laying.

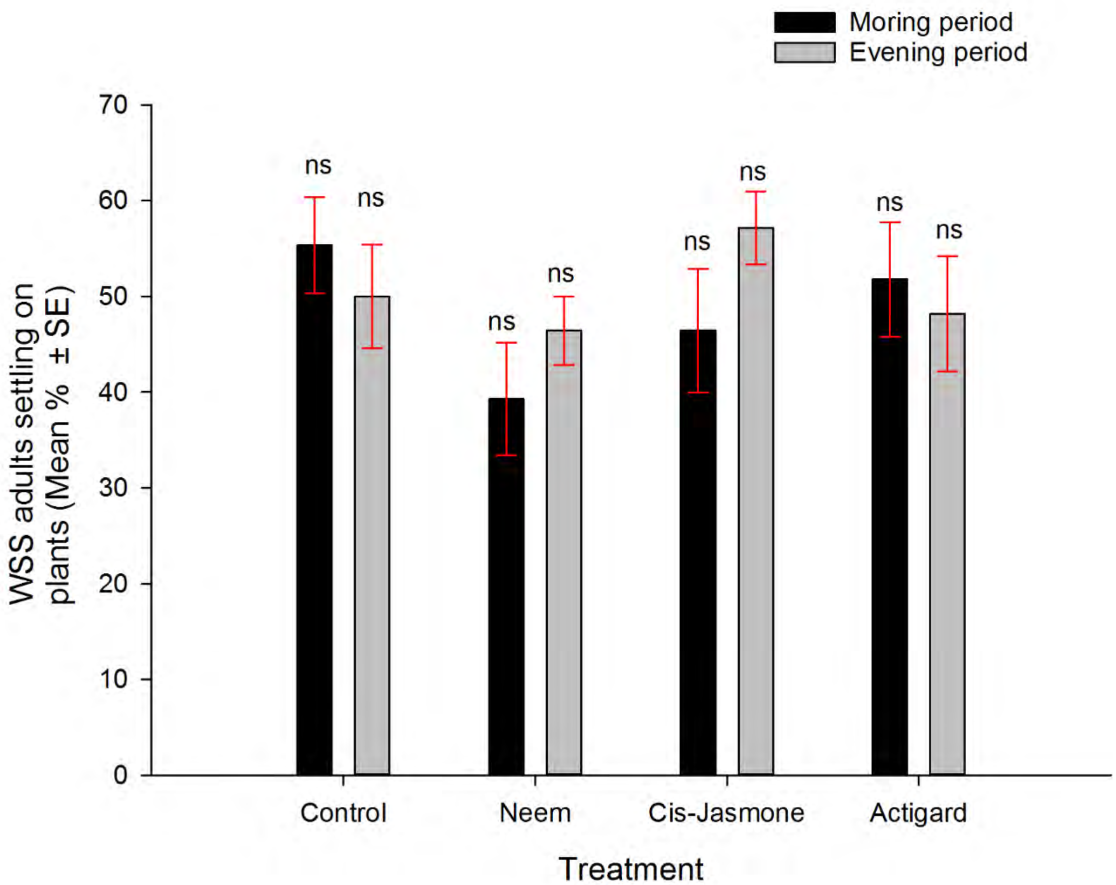

Figure 1. Effect of synthetic plant defense elicitor chemicals treatments application on wheat stem sawfly adults settling behavior under no-choice condition.

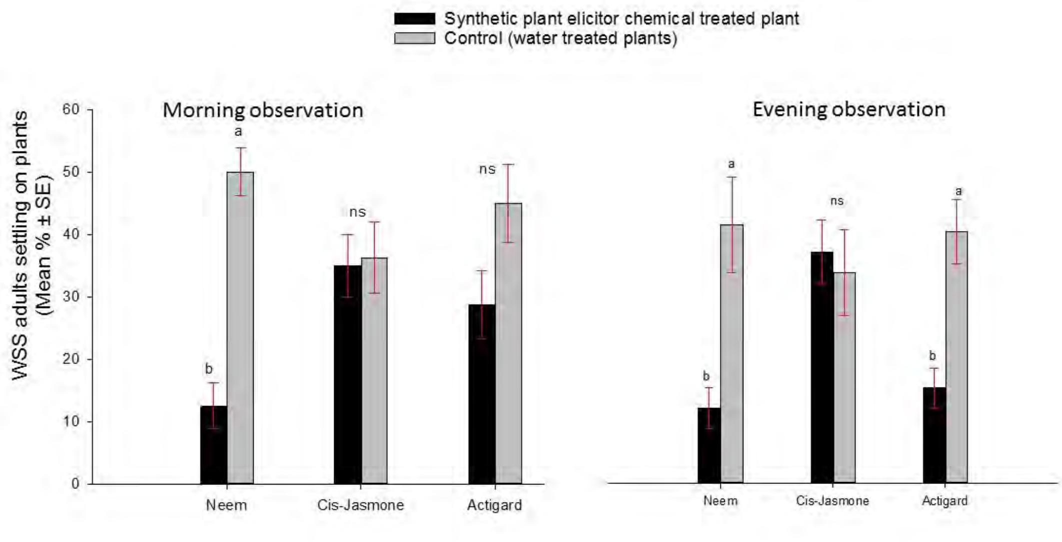

Figure 2. Effect of synthetic plant defense elicitor chemicals treatments application on wheat stem sawfly adults settling behavior under choice condition.

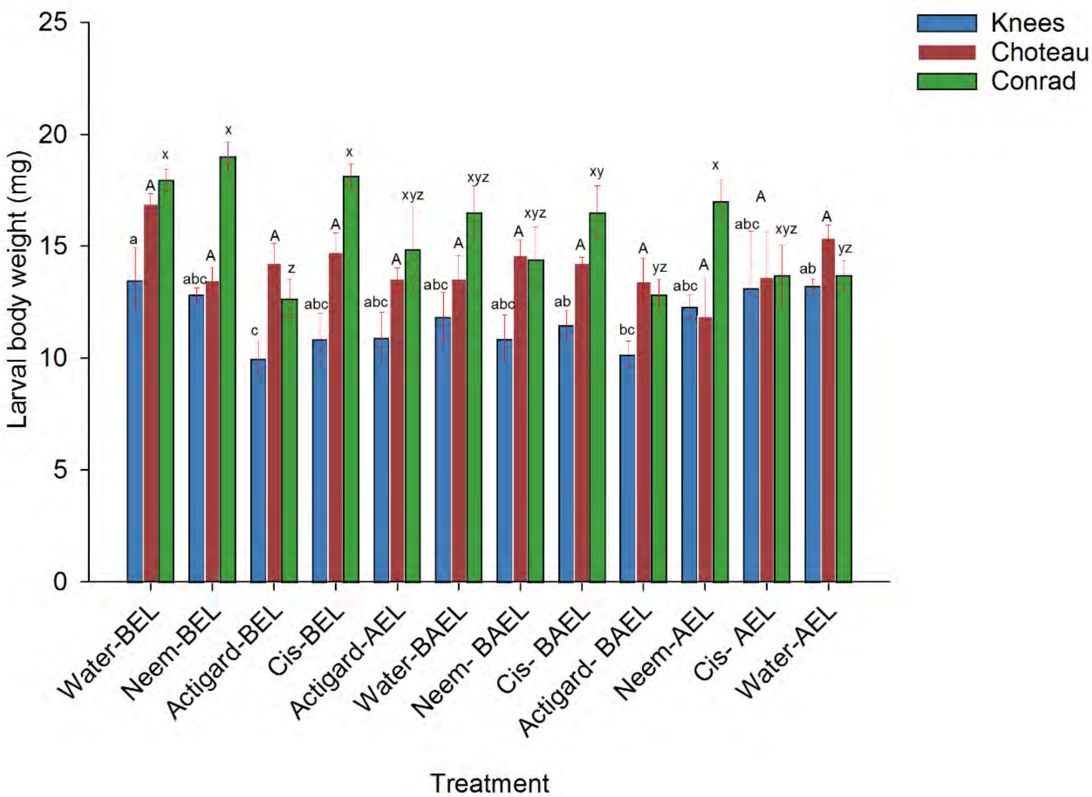

Figure 3. Effect of synthetic plant defense elicitor chemicals treatments applications on the body weight of diapausing WSS larvae. Bar of each color bearing the same letters are not significantly different (One-way- ANOVA followed by Tukey test, P > 0.05).

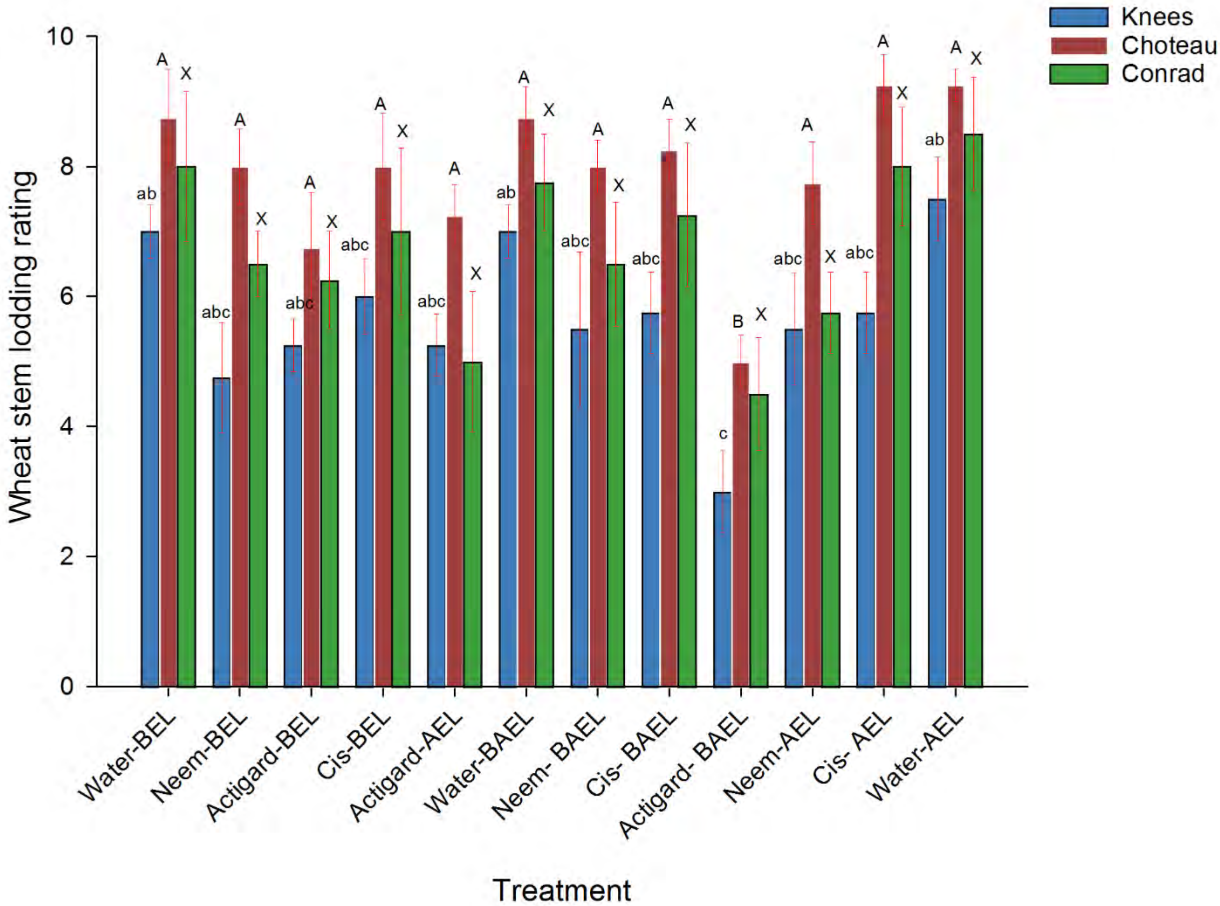

Figure 4. Effect of synthetic plant defense elicitor chemicals treatments applications on the wheat stem lodging recorded at the harvesting time. Bar of each color bearing the same letters are not significantly different (One-way-ANOVA followed by Tukey test, $P > 0.05$). BEL: WSS Before egg laying; AEL: WSS Before egg laying; BAEL: WSS Before and after egg laying.

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.

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Field efficacy of *Bacillus thuringiensis galleriae* strain SDS-502 for the management of alfalfa weevil and the impact on *Bathyplectes* spp. parasitization rate

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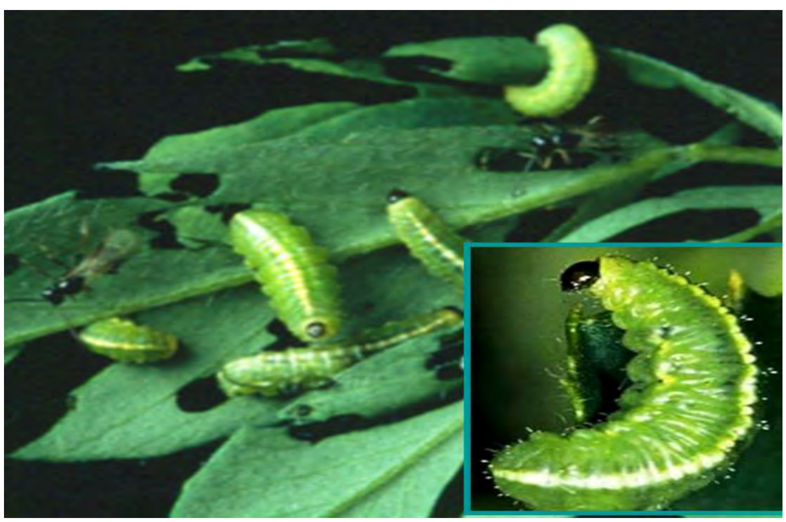
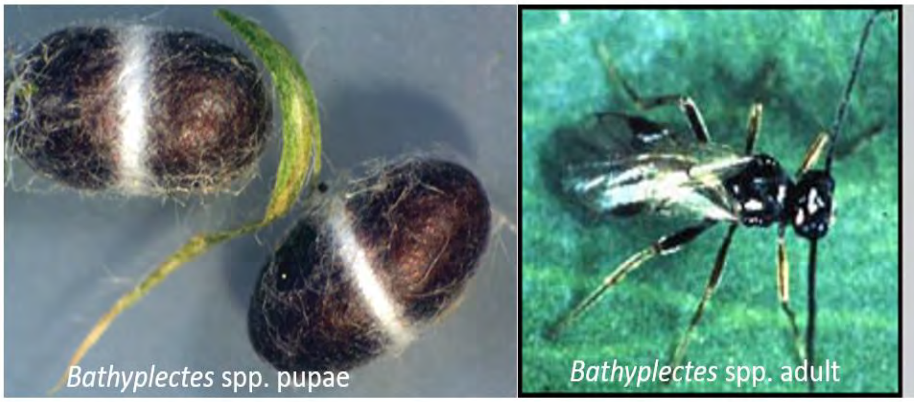
Aim of the Study

One of our goals was to determine the efficacy of a commercial formulation of SDS-502 against the *Hypera postica* under Montana conditions. Observations by Rand (2013) suggested that efficiency of *Bathyplectes curculionis* and *Oomyzus incertus*, the predominant parasitoids in Montana alfalfa, was somewhat inversely proportional to host numbers, parasitism being density independent. We, therefore, also wanted to determine if a partial reduction of larval *H. postica* populations with a *Bacillus thuringiensis* would yield to greater parasitoid efficiency, manifested as a greater percent parasitism among the surviving larvae. If there would be complementarity between the microbial and the parasitoids, overall *H. postica* population suppression would be greater.



Alfalfa weevil Larvae feeding on alfalfa leaves



Alfalfa weevil larval parasitoids

Materials and Methods

Locations of alfalfa field trials

The research reported here was conducted in 2016. The experiments were conducted at two locations: Valier (N 48º 35.192 W112º 21.169) and Conrad (N 48º 30.206 W112 º14.350), Pondera County, in the Gold Triangle region of Montana, USA. Both alfalfa fields had reached economic threshold level (1 larvae/stem), as determined by larval numbers prior to field selections. Ages of the crop ranged from 3 to 5 years and the area of the Valier and Conrad fields were 68 and 16 ha, respectively. Alfalfa was grown according to recommended industry standards and both were irrigated fields.

A randomized complete block design (RCBD), with four replicates per treatment, was used. Each treatment plot was 6 × 6 m, and separated from each other by 3 m buffer zones to avoid any overlap of treatment effects. Plots were situated at least 6 m inside from field edge.

Bacillus thuringiensis galleriae SDS-502 application

A commercial formulation of *B. thuringiensis galleriae STS-502* (BeetleGone®) (76.5% a.i., >$0.85x10^{10}$ CFU/g) was provided by Phyllom BioProducts Corporation, Oakland, California, USA. The low and high recommended application rates of BeetleGone corresponding to 2.2 and 4.4 kg, respectively, per hectare in 234 L ha^{-1} were used for experiments. NuFilm® 17 (Miller Chemical and Fertilizer, LLC) was added to each BeetleGone treatment (583 ml ha^{-1}) as a sticker. The spray suspension was prepared by mixing the product materials with water, followed by addition of the NuFilm17, and agitated well before spray application. The diluted NuFilm 17 served as a carrier control treatment.

Treatments were applied using a CO_2- pressurized backpack sprayer calibrated to deliver 252 L ha^{-1} through a two-person, 3.66 m, boom with TeeJet nozzles spaced 0.46 m apart. Each plot was sprayed in two swaths. The spraying activity was performed between 6-8 am.

Sampling

Alfalfa weevil larvae population

Hypera postica larvae were sampled in all plots to determine the treatment effects. Sampling was conducted 2 days before treatment application, and 3 and 7 days after applications. Ten samples were taken from each treatment plot, with 3 alfalfa stems/sample, and the sampling was performed along an N-shaped transect beginning 1 m into the plot. Alfalfa stems were detached from the base of plants with help of scissors, placed into one zipper-lock bag, and kept in a picnic cooler. The samples were returned immediately to the lab and larvae dislodged from foliage by vigorous shaking in a plastic bucket. The larvae were categorized into two age classes-'young' (L1-L2) and 'old' (L3-L4).

Parasitization rate of *Bathyplectes* spp.

Parasitism by *Bathyplectes* spp. in *H. postica* larvae was assessed in treatment plots with larvae collected at 7 days post application. Both stem-cut and sweep net sampling were used. Sweeping was conducted with a standard sweep net (180^{o} arc) with 20 sweeps in each treatment plot.

The larvae collected from each treatment plot were kept in plastic zipper-lock bags with some alfalfa foliage and transported immediately to laboratory. In the lab, *H. postica* larvae from each treatment plot were transferred into a large paper bag with a paper towel in the bottom. Fresh alfalfa foliage (1-2 healthy stems) was placed in each bag, and the top of the bag was folded multiple times and secured with a large binder clip. Fresh foliage was added every other day as needed and dried out foliage was left in a bag in order to avoid risk of losing insects. All bags were kept at room/lab temperature for 14 days at which time most insects had pupated or eclosed into adults. *Hypera postica* larvae parasitized by *Bathyplectes* spp. were determined by presence of dark brown, football-shaped cocoons with un-raised white band around the cocoon or with white equatorial band that is not raised (Tharp, 2015).

Data analysis

The data were analyzed with R 2.15.1 (R Development Core Team, 2011). For all data, a test with a normal quantile-quantile plot was performed to confirm normality of the data and equality of variance. Where appropriate, Tukey`s contrast pairwise multiple comparisons were used to test for significant differences in means (Hothorn et al., 2008). Furthermore, the data were subjected to angular transformation prior to statistical analysis.

Alfalfa weevil population

The percentage reduction of alfalfa weevil population was calculated relative to the initial larval population (assessed 2 days before spraying) as follows:

Alfalfa weevil density reduction (AWDR) (%)

$$= \frac{AWDRst0 - AWDRst1}{AWDRst0} \times 100;$$

Where $AWDR_{s}t_{0}$ represents the number of *H. postica* larvae recorded at each treatment plot before the BeetleGone application and $AWDR_{s}t_{1}$ is the number of *H. postica* larvae recorded at each treatment plot in each sampling time (3 days or 7 days after BeetleGone or carrier control treatments) (Shrestha et al., 2015).

The overall data were fitted to a linear mixed model with sampling time interval, SDS-502 rate and *H. postica* populations per replicate as fixed effects (categorical variables converted to factors), the variation in *H. postica* populations (1|Unit) as random effect and the mean *H. postica* populations per treatment as response variable using the function "lmer". The mean alfalfa weevil population per treatment was calculated using the "Summaryby" work package (doBy). The model was then simplified with stepwise removal of factors having no effect. The Kenward-Roger test was run using the function "KRmodcomp" to compare the models (Halekoh and Højsgaard, 2012). One-Way Analysis of Variance (ANOVA) was carried out to determine the effect on *H. postica* population across treatment levels at each sampling time.

H. postica percent control level due to SDS-502 rates was further calculated by using the formula given by Henderson and Tilton (1955):

$$= 100\left[1 - \frac{Ta \times Cb}{Tb \times Ca}\right]$$

Here T*b* is the number of *H. postica* larvae collected per sampling unit before treatment, T*a* the number collected after treatment, C*b* the number collected from the carrier control plot before treatment, and C*a* the number collected from the carrier control plot after treatment of test plots.

Parasitism

One Way-ANOVA was performed to evaluate whether the spray of SDS-502 had an effect on parasitism levels by *Bathyplectes* spp. The parasitism percentage was calculated as numbers of parasitoid pupae formed / total number of *H. postica* larvae reared from each plot × 100. Linear regression was further used to analyze the correlation between mean parasitism percentage and mean 7 days weevil larvae reduction percentage after the treatment application through stem-cut method. Data from Valier and Conrad locations were pooled for analysis.

Results

Effects on alfalfa weevil populations

The overall mean number (± SE) of *H. postica* larvae per 30 stems 2 days before the treatment applications at the Valier and Conrad locations ranged from 11.25 to 12.75 and 10.75 to 13.00, respectively, across all plots (Fig.1). Mean number of post-treatment *H. postica* larvae per 30 stems (± SE) for Valier location varied from 8.00 ± 0.40 to 13.00 ± 1.58 and 5.25 ± 0.85 to 11.75 ± 0.85 respectively, at the 3 days and 7 days post-applications. The corresponding values for Conrad location were 7.75 ± 0.25 to 11.75 ± 0.85 and 4.75 ± 0.95 to 9.50 ± 0.50 respectively. There were significant treatment effects for both SDS-502 rates (Valier: F = 13.19; df = 2, 18; P < 0.0001; Conrad: F = 15.20; df = 2, 18; P < 0.0001) and at both sampling times (Valier: F = 6.09; df = 1, 18; P < 0.05; Conrad: F = 5.66; df = 1, 18; P < 0.05). There were no interaction effects between treatments and sampling times (Valier: F = 0.10; df = 2, 18; P > 0.05; Conrad: F = 0. 06; df = 2, 18; P > 0.05).

Across the treatment levels, the significant difference in *H. postica* numbers occurred at 3 days post treatment (Valier: $F = 5.32$; $df = 2, 9$; $P < 0.05$; Conrad: $F = 6.78$; $df = 2, 9$; $P < 0.05$) and 7 days (Valier: $F = 8.93$; $df = 2, 9$; $P < 0.01$; Conrad: $F = 9.98$; $df = 2, 9$; $P < 0.01$). The percentage reduction of *H. postica* larval populations with the two SDS-502 treatments was rate-dependent. (Table 1). The SDS-502 provided 27-40% reduction in weevil numbers at the low label rate and 55-59 % for the high label rate (Table 1).

Based on the Henderson and Tilton correction (1955), mean alfalfa weevil control level ranged 12-32% for the low rate and 36-51% for the high rate of SDS-502 at the 3 days and 7 days post-applications at the Valier location. Similarly, at Conrad location, average weevil control level for low and high rate of SDS-502 varied from 25-40 % and 38-54% respectively at the 3 days or 7 days after treatments.

Parasitism level

Bathyplectes spp. were recorded in both alfalfa fields. The mean parasitism levels varied from 5-26% and 17-36% respectively at Valier and Conrad research sites (Table 2) There were no significant differences in rates of parasitism among treatments at both Conrad (stem cut: $F = 3.02$; $df = 2, 9$; $P = 0.09$ and sweep netting: $F = 0.87$; $df = 2, 9$; $P = 0.45$) and Valier (sweep net: $F = 2.20$; $df = 2, 9$; $P = 0.17$) with one exception. At Valier, in the stem-cut samples from high rate of SDS-502 plots only, there was a significantly lower mean parasitism rate (5.0% ± 5.00) compared to all other treatments (Table 2). No significant relationship between parasitism levels and *H. postica* reduction percentage at the 7 days post-application was recorded based on R^2 value (0.306) as predicted by a linear regression equation (Fig. 2).

Acknowledgements

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Table 1. Cumulative percentage reduction (mean ± SE) of *Hypera postica* larval population on alfalfa plants after *Bacillus thuringiensis* SDS-502 or carrier control application.

Location	Sampling time	Treatment		
		Carrier Control	Low Dose	High Dose
Valier	3 DAT	1.9 ± 1.92b	11.0 ± 6.88b (12.5 ± 7.65)	33.2 ± 2.07a (35.7 ± 1.99)
	7 DAT	9.2 ± 3.68b	26.8 ± 10.90b (31.9 ± 6.96)	55.1 ± 8.29a (51.0 ± 8.99)
Conrad	3 DAT	5.8 ± 5.77b	24.9 ± 5.07b (31.3 ± 4.64)	38.3 ± 5.96a (43.5 ± 5.44)
	7 DAT	14.2 ± 8.37b	39.6 ± 5.17a (31.6 ± 5.88)	59.5 ± 10.90a (54.2 ± 12.34)

Different letters within a row indicate significant differences between treatments (Tukey test, $p < 0.05$). The values in parentheses denote the mean *H. postica* control levels calculated based on Henderson and Tilton correction (Henderson and Tilton, 1955).

Table 2. Mean percent parasitism (± SEM) by *Bathyplectes* spp. in *Hypera postica* larvae 7 days after *Bacillus thuringiensis* SDS-502 or carrier control application.

Location	Sampling Method	Treatments		
		Carrier Control	Low Dose	High Dose
Valier	Stem cut	19.3 ± 1.68a	15.8 ± 2.17a	5.0 ± 5. 00b
	Sweep net	25.8 ± 3.05a	18. 2 ± 2.41a	24.1 ± 2.84a
Conrad	Stem cut	36.3 ± 5.54a	22.4 ±4.03a	17.5 ± 6.85a
	Sweep net	26.8 ± 5.28a	20.2 ± 2.53a	21.3 ± 3.62a

Different letters within a row indicate significant differences between treatments (Tukey test, $p< 0.05$).

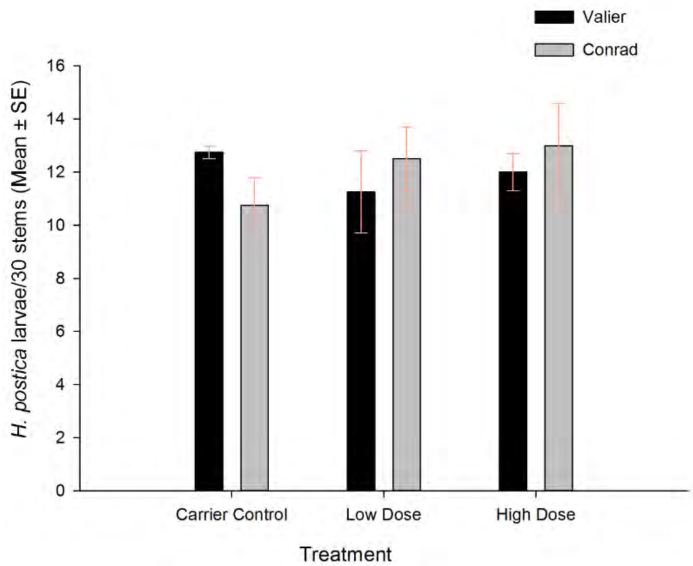

Figure 1. Average numbers (± SE) of *Hypera postica* larvae recorded 2 days before treatments at Valier and Conrad, Montana

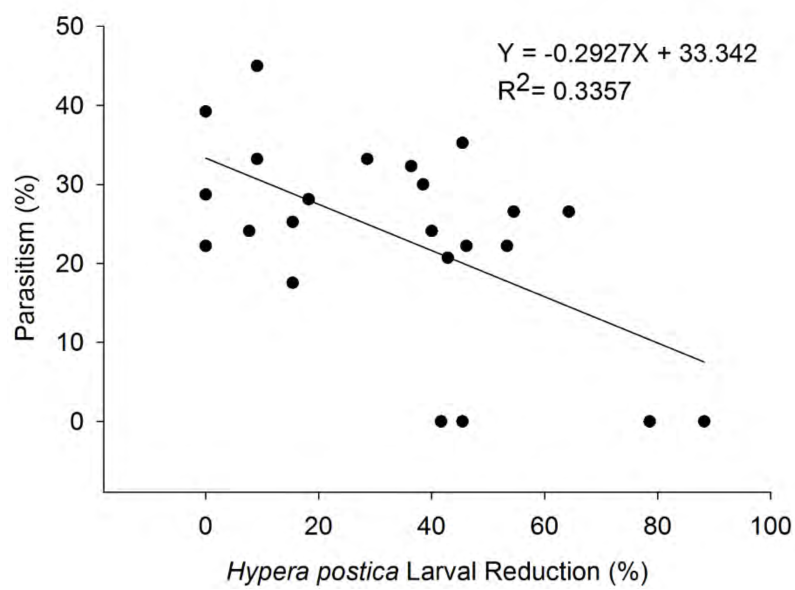

Figure 2. Relationship between *Bathyplectes* spp. parasitism and *Hypera postica* larval reduction levels, 7 days post-application. Valier and Conrad locations data were pooled for analysis.

Effect of nitrogen fertilization levels and insecticide seed treatment on the incidence of crucifer flea beetle and cabbage seedpod weevil on canola yield and quality

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Aim of the Study

1. To determine if N fertility at different rates and seed treatment affects flea beetle and cabbage seedpod weevil feeding patterns.
2. To study flea beetle and cabbage seedpod weevil feeding impacts on canola seed yield and quality with respect to N soil fertility.

Figure 1: Flea beetle damage symptoms on canola leaf, pods and stem stages of growth.

Material and Methods

Site description

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 Sweetgrass (48° 57.831'N, 111° 40.801' W), both representing dryland rain fed (i.e., non-irrigated) conditions of the West-Central region of Montana, USA in 2017. Previous crop before seeding canola was barley at the Sweetgrass while the field was maintained as chemical fallow at the Conrad location. Soil test from both locations were conducted in the spring of 2017 to calculate the rate of fertilizer applications while seeding canola. Based on the soil tests performed, residual N level was about 16 lbs/ac at Conrad compared to only 3.5 lbs/acre at the Sweetgrass location. Experimental plots were seeded on May 1st, 2017 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. Weed control was done by pre-plant application of herbicide RT3® (a.i. glyphosate) at a rate of 2.5 L/ha.

Air temperature (Figure 2 A) and precipitation data (Figure 2 B) for the period of study for Conrad and Sweetgrass were accessed from the USDA, NRCS weather station (NRCS, 2016) and Alberta Agriculture and Forestry weather station (Alberta Agriculture and Forestry, 2016), respectively. Average temperature at Conrad remained was slightly higher from April to September, 2017 than the Sweetgrass location (Figure 1 A). Both locations experienced low precipitation throughout the growing season especially from July to August when the dry spell prevailed until the crop harvest except for one time rain in the middle of July (Figure 1 B)

Treatments and field plot design

The treatment structure for this study consisted of four levels of N including: no external application of N (N1), 56 kg/ha (N2) (50 lbs/ac); 112 kg/ha (N3) (100lbs/ac) and 168 kg/ha (N4) (150lbs/ac) applied at the time of seeding canola. Further each level of nitrogen either received insecticide imidacloprid (Gaucho 600®) seed treatment or no treatment. All treatments (i.e. four N levels with or without insecticide seed treatment), received fungicide seed treatment prior to seeding of experimental plots. No foliar sprays of any pest control were applied to the research trials. The field experiments at both the locations were Randomized Complete Block Design (RCBD). Individual plots measured 3.6 m × 1.2 m in size. 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.

Data collection

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. *P. 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. Data is presented as percent infested pods per plot.
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.

Statistical analysis

PROC MIXED procedure (PROC MIX, SAS Institute 2017) was performed for determining the effects of insecticide, nitrogen levels and, their interactions on both flea beetle (*P. cruciferae*) and seedpod weevil (*C. obstrictus*) damage ratings and, yield and grain quality parameters including test weight, TKW and percent oil content. An alpha level of 0.05 was used for all tests. Since, interaction among N and insecticide was not significant, least square (LS) mean estimates and their SE are presented for main effects only which includes four N levels averaged over the seed treatment and, insecticide seed treatment (Treated versus Untreated averaged over the N levels).

Results

Flea beetle and seedpod weevil damage assessment

Overall comparisons among N levels, insecticide and their interactions are presented in table 1. In general, flea beetle feeding pressure based on crop injury ratings was very high throughout the canola growing season at Conrad as compared to the Sweetgrass location (Table 2). Injury rating recorded at different crop stages showed highest level of damage from flea beetle at the four leaf stage followed by the pod formation stage at Conrad whereas at Sweetgrass highest damage was noted at four leaf and pre-flowering stages of canola. (Table 2). More than 70% injury was recorded at four leaf stage in Conrad while the highest injury ratings were about 11% at four leaf and pre-flowering at the Sweetgrass location.

At Conrad, no significant differences were among the N levels at cotyledon (F =0.88; P = 0.22), four leaf (F =1.13; P = 0.36) and pod stage (F =0.66; P = 0.59) except for pre-flowering stage of canola (F =3.67; P 0.03) (Table 1). The effect of seed treatment on injury ratings at four leaf (F =30.00; P <0.0001), pre-flowering (F =9.81; P 0.01) and pod stage (F =33.1; P <0.0001) was significant, except for cotyledon stage (F =0.77; P= 0.09) (Table 1 and 2).

At Sweetgrass location where flea beetle feeding pressure was remained low during the growing season, injury ratings varied among the N levels only at cotyledon stage (F =3.89; P = 0.02) but not during the other crop growth stages. On the other hand, Insecticide significantly impacted the feeding injury ratings at cotyledon (F =7.81; P = 0.01), four leaf (F =26.40; P < 0.0001) and pre-flowering (F =47.40; P < 0.0001) but not at pod stage (F =1.02; P = 0.33).

Mean seedpod weevil percent infested pods were low at Conrad (range 5-13%) compared to Sweetgrass location where the percent infested pods were high and range 6-26%. No significant differences, however were among the N levels (Figure 3 A and B) and insecticide treatments at both the locations for the seedpod weevil percent infested pods.

Canola seed yield and quality parameters

Average canola seed yield ranged from to 887-992 and from 392-641 kg/ha respectively, at the Conrad and Sweetgrass locations (Table 2). Yield levels lower at Sweetgrass as compared to Conrad location. Although, yield levels increase slightly with the increase in N level, with the highest at 100 lbs/al level, differences were not significant among the N levels at Conrad location (Table 1 and 2). Similar trend of no significant differences were among the N levels for grain quality parameters. In contrast, insecticide averaged over the N levels, canola yield (F = 8.10; P = 0.01), TKW (F = 4.61; P = 0.04) and percent oil content (F = 10.70; P< 0.0001) were significantly higher in treated than the untreated plots except for the canola grain test weight (F = 0.99; P = 0.33).

At Sweetgrass location, significant differences were among the N levels for canola grain yield (F =9.55; P = <0.0001), test weight (F =3.70; P = 0.03) and oil content (F =4.55; P = 0.01) except for TKW (F =0.16; P = 0.92) (Table 1). Yield levels increase with the increase in N application at the time of seeding with highest mean yield (641 kg/ha) at the highest level of N (Table 2). Yield (F =30.00; P <0.0001) and percent oil content were significantly higher (F =9.81; P 0.01) in the insecticide treated than the untreated plots (F =33.1; P <0.0001). No significant impact of insecticide was observed for the other grain quality parameters.

At Sweetgrass location where flea beetle feeding pressure remained low during the growing season, injury ratings varied significantly among the N levels only at the cotyledon stage (F =3.89; P = 0.02). Insecticide on the other hand significantly impacted the feeding injury ratings at cotyledon (F =7.81; P = 0.01), four leaf (F =26.40; P < 0.0001) and pre-flowering (F =47.40; P < 0.0001) but not at pod stage (F =1.02; P = 0.33).

Mean seedpod weevil percent infested pods were low at Conrad (range 5-13%) compared to Sweetgrass location where the percent infested pods were in the higher (range 6-26%). There was no trend for the N levels and no differences were observed among the seed treated and untreated plots (Figure 3 A and B).

Conclusions

It is interesting to note here that flea beetle pressure was very high at the Conrad location throughout the canola growing season. Although, seed treatment with insecticide maintained lower feeding pressure than the untreated plots, it was well above the threshold level of 20-25% as established and reported in literature. This data clearly demonstrate that if dry and warm conditions prevail over the canola growing season considerable damage can occur even at the later stages of canola growth and exhibit considerable damage during the pod formation stage thereby impacting the yield and grain quality parameters. Although, yield was highest at the 100 and 150 pounds of N/ac treatment levels, flea beetle injury pressure likely masked the differences among the N levels at the Conrad location. Consequently, no significant differences were detected between the N levels. In contrast at the Sweetgrass location where feeding pressure was low, impact of N was more pronounced as significant differences were observed among the N levels. Seedpod weevil infested pods were higher at Sweetgrass location. However, no relationship of Seedpod weevil to N levels and seed treatment were observed. No significant differences among insecticide treated and untreated plots for Seedpod weevil likely indicate that the effects of seed treatment with insecticide did not last long enough to impact this pest at pod stage in Montana dry land conditions.

Acknowledgements

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Table1: Effect of nitrogen level, insecticide seed treatment and their interaction, on flea beetle (FB) leaf and pod injury percent rating and, canola yield and quality at two locations in Montana, 2017.

Parameter	Treatment effect[1]					
	Nitrogen		Insecticide		Nitrogen*Insecticide	
	F	*P*	*F*	*P*	*F*	*P*
Conrad						
FB Injury rating						
Cotyledon	0.88	0.22	0.77	0.09	0.82	0.31
Four leaf	1.13	0.36	30.0	**<.0001**	1.19	0.34
Pre-flowering	3.67	**0.03**	9.81	**0.01**	0.46	0.71
Pods	0.66	0.59	33.1	**<.0001**	0.90	0.46
Yield and quality						
Yield	0.31	0.82	8.10	**0.01**	0.29	0.83
Test Wt.	0.04	0.99	0.99	0.33	0.28	0.84
TKW	2.54	0.09	4.61	**0.04**	0.53	0.67
Oil Content	0.94	0.44	10.7	**<.0001**	0.55	0.65
Sweetgrass						
FB Injury rating						
Cotyledon	3.89	0.02	7.81	**0.01**	2.07	0.13
Four leaf	1.41	0.27	26.4	**<.0001**	0.92	0.45
Pre-flowering	2.98	**0.06**	47.4	**<.0001**	0.63	0.61
Pods	1.67	0.20	1.02	0.33	1.77	0.18
Yield and quality						
Yield	9.55	**<.0001**	22.2	**0.00**	1.60	0.22
Test Wt.	3.70	**0.03**	2.50	0.13	1.78	0.18
TKW	0.16	0.92	1.03	0.32	0.65	0.60
Oil Content	4.55	**0.01**	5.37	**0.03**	1.83	0.17

[1]: *F*- & *P*-values from type 3 tests.

Table 2: LS means estimates (±SE) for nitrogen levels and insecticide seed treatment, on flea beetle (FB) leaf and pod injury and canola yield and quality at two locations in Montana, 2017. *F*- and *P*-values are shown in table 1.

Treatment	***FB injury rating (%)***				***Yield and quality***				
	------------------------Canola growth stage---------------------				Yield		Test wt.	TKW	Oil content
	Cotyledon	Four leaf	Pre-flower	Pods	(kg/ha)	(bu/ac)	(lbs/bu)	(g)	(%)
Conrad									
Nitrogen level									
N1	13.1 ±2.6	74.8 ±2.1	27.5 ±1.4	47.7 ±2.8	887 ±149	15.8 ±2.7	51.2 ±0.7	2.7 ±0.2	47.3 ±0.4
N2	15.8 ±2.6	69.8 ±2.1	24.4 ±1.6	48.7 ±2.8	893 ±149	15.9 ±2.7	51.2 ±0.7	2.6 ±0.2	47.1 ±0.4
N3	13.6 ±2.6	73.1 ±2.1	20.7 ±1.4	46.7 ±2.8	992 ±149	17.5 ±2.7	51.2 ±0.7	3.0 ±0.2	47.1 ±0.4
N4	13.8 ±2.6	74.4 ±2.1	24.6 ±1.6	52.0 ±2.8	980 ±149	17.7 ±2.7	51.4 ±0.7	3.2 ±0.2	46.4 ±0.4
Insecticide									
Treated	14.5 ±1.8	67.2 ±1.5	21.9 ±1.0	40.7 ±2.0	1080 ±131	19.3 ±2.3	51.6 ±0.5	3.1 ±0.1	47.61 ±0.3
Untreated	13.7 ±1.8	78.9 ±1.5	26.7 ±1.1	56.9 ±2.0	795 ±131	14.2 ±2.3	51.0 ±0.5	2. 7 ±0.1	46.3 ±0.3
Sweetgrass									
Nitrogen level									
N1	2.0 ±1.1	5.3 ±2.3	11.3 ±1.4	2.0 ±0.7	392 ±53	7.0 ±0.9	52.1 ±0.4	4.2 ±0.3	49.5 ±0.6
N2	5.3 ±1.1	8.8 ±2.3	6.1 ±1.5	1.8 ±0.7	577 ±53	10.3 ±0.9	52.1 ±0.5	4.3 ±0.3	49.2 ±0.6
N3	7.6 ±1.2	8.3 ±2.3	7.0 ±1.4	1.25 ±0.7	591 ±53	10.6 ±0.9	51.8 ±0.3	4.4 ±0.3	49.0 ±0.6
N4	4.4 ±1.1	10.0 ±2.3	9.4 ±1.5	1.8 ±0.7	641 ±53	11.4 ±0.9	51.0 ±0.3	4.2 ±0.3	47.3 ±0.6
Insecticide									
Treated	3.2 ±0.8	3.8 ±1.9	3.7 ±1.0	1.1 ±0.5	633 ±46.5	11.3 ±0.8	52.0 ±0.2	4.5 ±0.2	49.3 ±0.5
Untreated	6.4 ±0.8	12.3 ±1.9	13.2 ±1.1	1.8 ±0.5	467 ±46.5	8.3 ±0.8	51.5 ±0.3	4.1 ±0.2	48.2 ±0.5

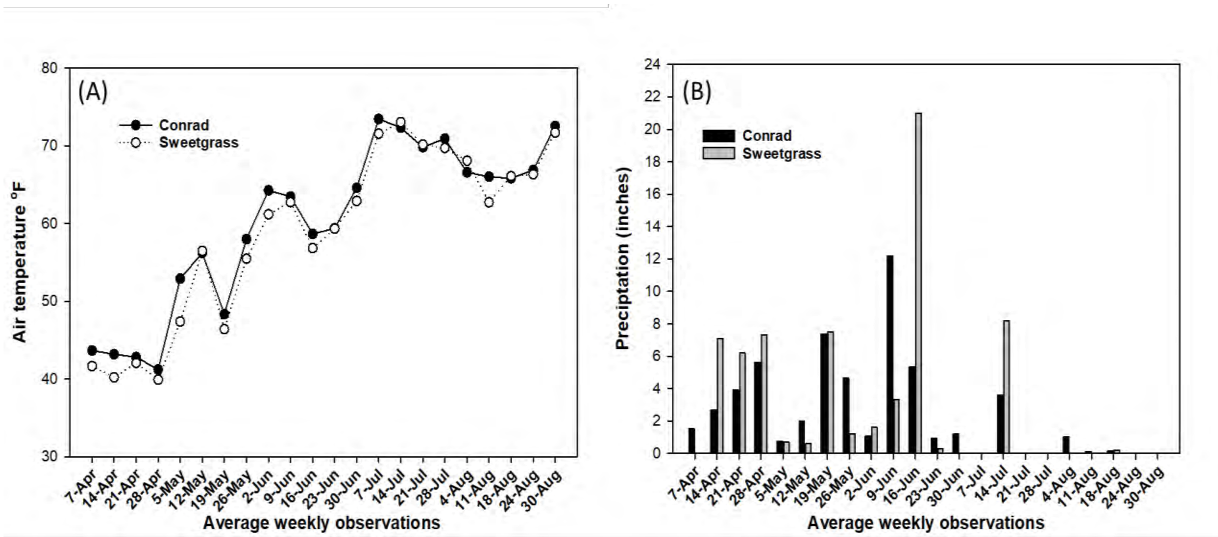

Figure 2: Weekly average air temperature (A) and precipitation (B) at Conrad and Sweetgrass study locations.

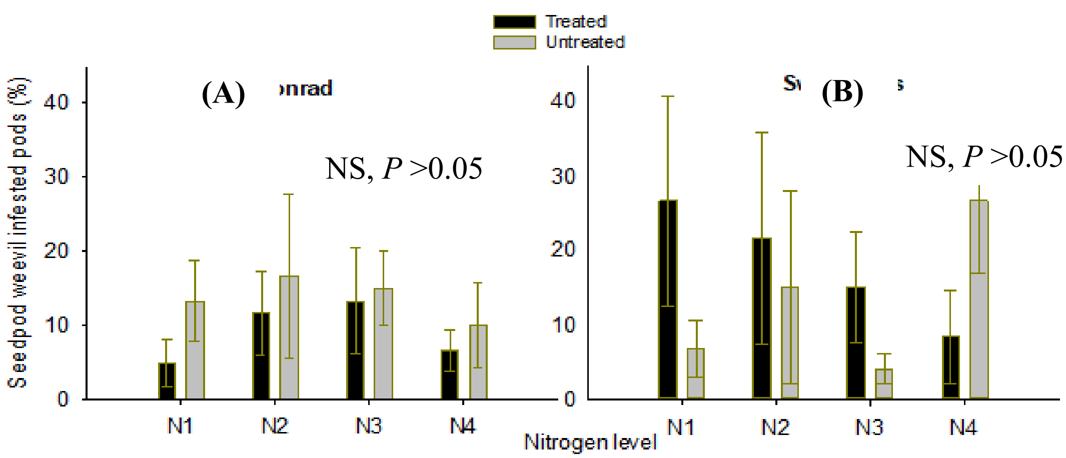

Figure 3: Seedpod weevil percent infested canola pods for four N levels at Conrad (A) and Sweetgrass (B) locations.

Toxicity of three bio-pesticides on first instar larvae of biological control agents *Chrysoperla carnea* (Neuroptera: Chrysopidae) and two-spotted ladybeetle *Adalia bipunctata* (Coleoptera: Coccinellidae)

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Aim of the Study
The aim of the study was to test the toxicity of three bio-pesticides: 1) Mycotrol ESO® (*Beauveria bassiana* GHA), 2) Xpectro OD® (*B. bassiana* GHA + Pyrethrin) and 3) Entrust WP® (spinosad 80%) on the two natural enemies (lacewing and ladybeetle). Consideration for these three bio-pesticides for study was primarily because they were found to be potential control agents for pea leaf weevil *Sitona lineatus* (L.) (Coleoptera: Curculionidae) management in field peas. Both beneficial insects are the most common species in Montana agricultural crops including field peas.

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

Bio-pesticide products and rates
Mycotrol ESO® (*Beauveria bassiana* GHA) and Xpectro OD® (*Beauveria bassiana* GHA + pyrethrins) were obtained from Lam International (Butte, MT). Entrust WP® (spinosad 80%) was received from Dow Agro Sciences (Indianapolis, IN). For this non-target experiment, the bio-pesticides were applied at concentrations of 1.44 ml/L (Mycotrol), 5 ml/L (Xpectro) and 0.182 g/L (Entrust), which correspond to the doses recommended by the manufacturers for agricultural practices. Furthermore, the selected concentrations were shown previously to be effective on killing pea leaf weevil adults.

These three products were chosen primarily for the non-target experiment because they were recently found as potential control agents for pea leaf weevil management in field peas. Lacewing and ladybeetles are the most naturally occurring beneficial insect species in Montana agricultural crops including field peas.

Laboratory bioassay
The bioassay experiment was performed to determine the toxicity of Mycotrol, Xpectro and Entrust 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 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 (November-December, 2017). The numbers 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).

Statistical analysis
One-way ANOVA was performed to determine the toxicity of three bio-pesticide products on the lacewing and ladybeetles larvae, as measured via total larval mortality. Tukey test was used as a post hoc test for multiple comparisons between the means at probability (α = 0.05). The data was analyzed using the software statistical package R 2.15.1 (R Development Core Team, 2017).

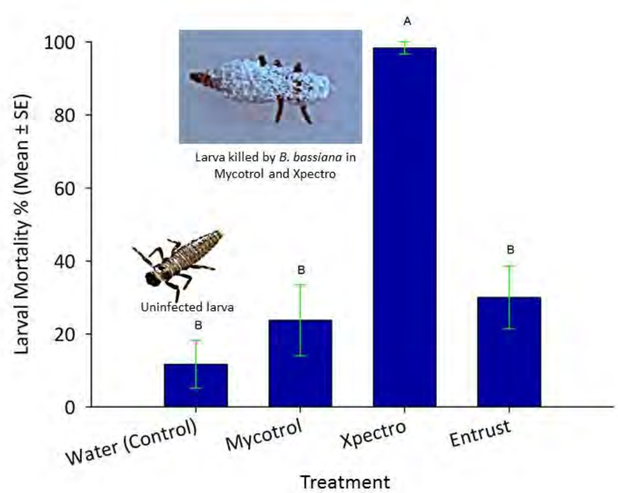

Figure 1. Toxicity of three bio-pesticide products against the first instar ladybeetle larvae. Bars bearing the same letters are not significantly different (Tukey test, P > 0.05). The total number of replicates per treatment was six.

Results

Ladybeetle larval mortality
This study reported that the treatments had significant impact on ladybeetle larval mortality (df = 3, 20; F = 28.4; P = 0.0001). Among the three bio-pesticide products, Xpectro was found to be

highly toxic to ladybeetle larvae, causing nearly 98 ± 1.66 % (Mean ± SE) mortality when compared to the control treatment (11.67± 6.54). However, Mycotrol and Entrust were inflicting minimal larval mortality and were not significantly different when compared to the control treatment (Fig 1).

Lacewing larval mortality

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 (df = 3, 32; F = 6.66; 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). There was no significant difference in treatments between water and Mycotrol, indicating that this product is less toxic to lacewing larvae (Fig 2).

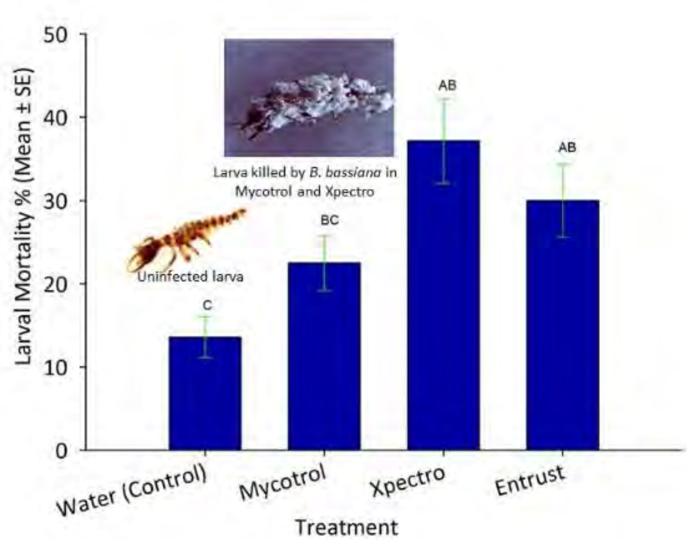

Figure 2. Toxicity of three bio-pesticide products against the first instar lacewing larvae. Bars bearing the same letters are not significantly different (Tukey test, P > 0.05). The total number of replicates per treatment was nine.

Acknowledgements

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New pest in Montana-Pea weevil: Determining weevil population distribution, abundance, and pea damage assessments

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Aim of the Study

The aim of this study was to survey for determining the pea weevil, *Bruchus pisorum* (Coleoptera: Chrysomelidae) population distribution, abundance and pea damage assessment for Montana. The pea weevil is one of the most problematic insect pests on field peas (Fig-1). The larvae feeding inside the developing pea seed cause damage. Weevil infestations ranges between 30–70% in untreated crops. Affected peas are unfit for human consumption and their seed germination rate decreases, which in turn diminishes the market value. In Montana, damage by this weevil was reported for the first time in the Hi-Line area in 2014, which alarmed pea growers and stakeholders because this pest could easily spread to neighboring pea-growing areas. Consequently, with the funding from USA Dry Pea and Lentil Council, the pea weevil surveys were carried out during 2016 and 2017 in 33 field sites, five elevators and 16 farm bins in the Golden Triangle Area including Hi-Line area. The primary objective was to determine the damage potential and distribution of the pea weevil.

Fig. 1. Brown colored, globular shape adult *Bruchus pisorum* with white patches. Elytra do not cover the end of the abdomen and leave the last terga exposed. Scale – 1mm.

Methods

Survey of pea weevil

Thirty three pea fields, five elevators and 16 farm bins in Pondera, Teton, Toole and Liberty counties were selected in Hi-Line and North Central areas of Montana for the survey of pea weevil (Figure-2). A sample of 2,000 seeds from the plots and elevators are collecting every two weeks from May 2017 to May 2018. Also, 150 sweep nets in each field are carried out before to the blooming stage during spring. The samples are transported to the laboratory at WTARC and analyzed for damage and different life stages of the pea weevil.

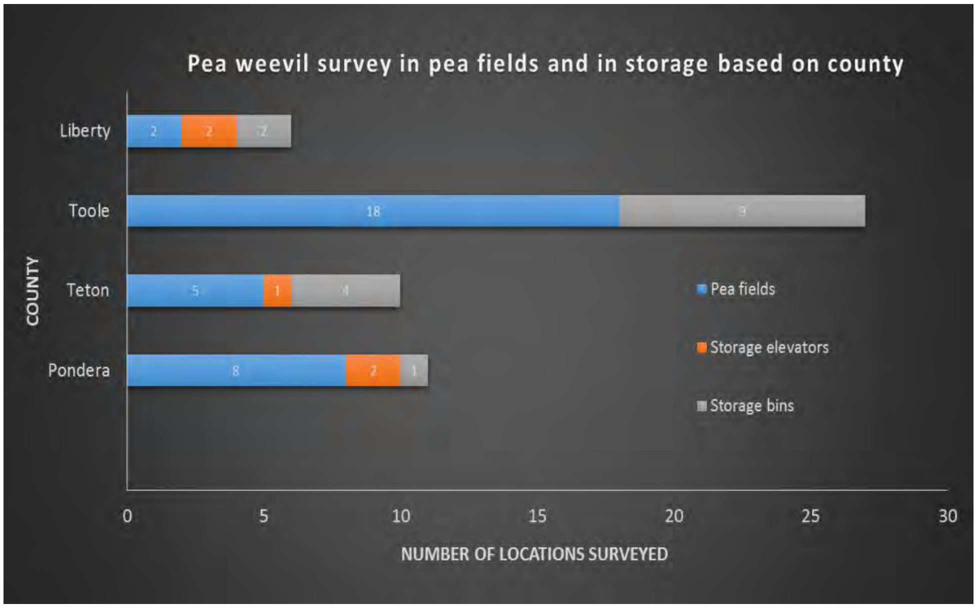

Figure 2. Surveyed areas for pea weevil (*Bruchus pisorum*) in Golden Triangle Area of Montana in 2016–2017.

Assessment of damage distribution and abundance
The number of peas with exit holes and immature stages (egg, larvae, pupae and adult) will be counted from the samples from different locations in the laboratory. Damage levels are assessed based on the scoring system. 0=no damage; 1= slight damage (less than 5%); 2= moderate damage (5-20%); 3= heavy damage (more than 20%).

Relationship between damage and weevil numbers
The intention was to identify a relationship (correlation) between damage levels and weevil numbers. Pearson’s correlation analysis - determine, whether or not, there is a significant correlation between damage levels and weevil number for both sampling periods, and in all damage categories. Data were include damage levels on different pea varieties, grown at different locations.

Mass rearing of pea weevil in the laboratory
The immature stages of the pea weevil will be collected from the field and grain bins. Mass reared in the laboratory to help in conducting further studies.

Results
No incidence of weevil presence was noticed in the surveys of 2016–2017. However, recently the damaged seeds with live pea weevils were confirmed from the Chester area (December, 2017) by the State Grain Lab. This incidence indicates the necessity of continuing the survey work.

Conclusions
Pea weevil damage was noticed in Montana during December 18, 2017. In an event of significant levels of crop damage and noticeable population levels, efforts will be undertaken to obtain a USDA-APHIS permit to introduce the pea weevil egg parasitoid *Uscana senex* (Hymenoptera:

Trichogrammatidae) into Montana. This parasitoid, is reported to show up to 82% of parasitism rate. Detailed information on the biology, ecology and management of pea weevil was reviewed and published by our team.

Acknowledgements
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Papers published

Reddy, G.V.P., A. Sharma, and R.L. Gadi. 2017. Biology, ecology and management of the pea weevil, *Bruchus pisorum* (Coleoptera: Chrysomelidae). *Annals of the Entomological Society of America* 110: 10.1093/aesa/sax078.

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Introduction and establishment assessment of two biocontrol agents *Euxestonotus error* and *Platygaster tuberosula* for wheat midge management

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Aim of the Study

The aim of the study were: 1) to release the parasitoids *Euxestonotus error* and *Platygaster tuberosula* for the control of wheat midges in western Montana and 2) to assess the establishment of *E. error* and *P. tuberosula* in 2016 release site (Valier) of Montana.

Material and Methods

A. Releasing the parasitoids *Euxestonotus error* and *Platygaster tuberosula* for the control of wheat midges in western Montana

The 2017 parasitoids releasing methods were similar to the 2016 study. The following four series of steps used for rearing and releasing of parasitoids: 1) collection and storage of parasitoids, 2) taking out parasitoids from refrigerators, 3) selection of wheat midge infested spring wheat fields, and 4) releasing the parasitoids (Fig 1).

Collection and storage of parasitoids
Prior to parasitoids collection, the federal import permits (Permit#P526-141217-033) for *E. error* and *P. tuberosula* were issued on July, 2016 by USDA-Animal and Plant Health Inspection Service. In August 2016, approximately 20,000 wheat heads were collected from spring wheat fields of Langenburg, Saskatchewan (Canada) where both parasitoids had been released in early 1990s and reported to be established. Immediately after the collection of heads, they were transported to Western Triangle Agriculture Research Center (WTARC), Montana State University, and the wheat heads were spread out in an even layer and left at room temperature (19–22°C) to dry for approximately two weeks in the laboratory. A small-sample de-awning machine was used to gently threshed dried heads. Midge larvae containing parasitoids were separated from the seeds and the chaff with an air cleaner. Approximately 1500 larvae were harvested in this manner from 20,000 infested wheat heads. Harvested larvae were then placed in a soil-less mixture of vermiculite and sphagnum and stored at 2–4°C.

Taking out parasitoids from the refrigerator
The soil mixtures containing the parasitoid larvae were taken out from the insect refrigerator on May 30, 2017. The parasitoids larvae were placed in plastic round deli container. However, the container was first filled with garden soil and afterwards the larvae were placed in top layer of the soil. These containers were sprayed (hand sprayer) with distilled water (3-4 ml) to moisten the soil. When the parasitoids were expected to emerge (3 weeks after the incubation), all these containers were taken out from the growth chamber and placed in insect cages where they were further sprayed with distilled water at 1-2 days intervals. In each insect cage, about 5-7 plastic

containers were placed and the parasitoids emergence were observed every day. The emerged parasitoids were observed under a microscope to determine the species.

Preparation Phase Extraction Phase Storage Phase Release Phase

Fig 1. Whole release process of parasitoids

Grower Name	Crop Type	GPS Coordinates	Approx. Distances from 2016 Parasitoid released sites
Cory Crawford, Crestview Road	Irrigated	Lat:48.30206, Lng: -112.1435	2 miles
Cory Crawford, Belgian Hill Road	Irrigated	Lat: 48.30647, Lng: -112.15275	10 miles
Cory Crawford, High land Road	Irrigated	Lat: 48.317322, Lng:-112.227895	Released site
Jodi Hobel, Belgian Hill Road	Irrigated	Lat: 48.2861, Lng: -112.0552	10 miles
Jodi Hobel, Crestview Road	Dryland	Lat: 48.30131, Lng: -112.1201	2.2 mils
Jolena Adams, North Valier	Irrigated	Lat: 48.35183, Lng: -112.21256	0.01 miles
Kyle Bean, North Valier	Irrigated	Lat: 48.4317, Lng: -112.1848	2 miles
Kyle Bean, North Valier	Dryland	Lat: 48.38166, Lng: -112.25097	1 mile

Table 1. Parasitoid sampled field sites, Valier, MT, 2017

Selection of wheat midge infested fields for release of parasitoids

Two wheat midge infested spring wheat fields were selected at around third week of June, 2017 in Ledger and Teton, Montana, based on midges trap count data. The consideration of these locations were mainly because the parasitoids were released in Valier 2016. Immediately after the fields selection, sweep netting activity (1-2 times before the parasitoids release) was performed in order to know either there was a presence of parasitoids or not before to releases.

B. Assessing the establishment of *Euxestonotus error* and *Platygaster tuberosula* in Valier, Montana
Eight spring wheat fields were sampled to check the presence of *P. tuberosula* and *E. error* in Valier MT (Table 1). Sweep net sampling was began from last week of June and continued until the end of growing season. About 120 sweeps were made per field and the collected samples were stored at -20^{O} C until processing. The parasitoids were identified under a microscope.

Results
Status of parasitoids before to release
The detailed information about the pre-release was mentioned below (Table 2). No *E. error* and *P. tuberosula* were found on the selected sites at parasitoids release.

Table 1. The information regarding to pre-releases of parasitoids

Pre-release sampling date	Growers name	Location	GIS	#Sweeps per field	Status of parasitoids
June 29, 2017	Terry Petes	Ledger, MT	48.24878; -111.6969	120	Not found
June 29 , 2017	Terry Petes	Teton, MT	48.2509; -111.59902	120	Not found
July 3, 2017	Terry Petes	Teton MT	48.2509; -111.59902	120	Not found

Release of *Euxestonotus error* and *Platygaster tuberosula*
This year, WTARC team could not able to release the parasitoids in what midge infested spring wheat fields though the same 2016 parasitoid rearing procedure was used. Parasitoids emergence percentage was nearly zero, and only about 10 parasitoids were found to emergence in insect cages but at the end of crop harvest season.

Establishment of parasitoids
This study for the first time indicated the presence of *P. tuberosula* in nearby released fields of 2016. Among the eight field sampled sites, the *P. tuberosula* was found in four fields that were very adjacent to 2016 released sites (Fig 2). Two morphological characters were used for identification of this parasitoid: 1) antennal segments (10-12) and 2) bump in the thorax. This parasitoid species recorded in 5-20 July, 2017. It remained unclear for what could be the cause for not seeing the *E. error* in nearby released site, it was likely due to difference in preference stage of wheat midge.

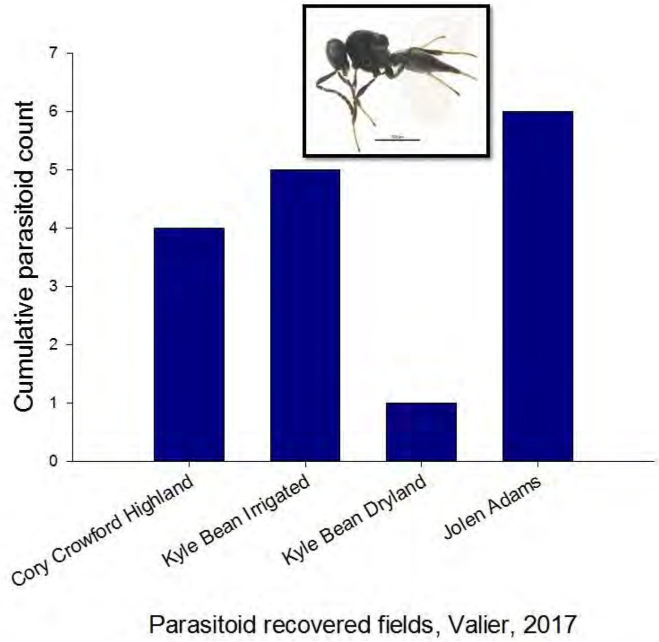

Figure 2. *Platygaster tuberosula* parasitoid recorded field sites, Valier, 2017

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

Monitoring of wheat midge and its parasitoid *Macroglenes penetrans* in irrigated and dryland spring wheat in Golden Triangle, Montana

Principal Investigator: Gadi V.P. Reddy

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Aim of the Study

The aims of this study were: 1) to determine the wheat midge population dynamics in irrigated and dryland spring wheat fields in the Golden Triangle area, Montana and 2) to monitor the wheat midge parasitoid *M. penetrans* population, in irrigated and dryland spring wheat fields in the Golden Triangle, Montana.

Materials and Methods

Wheat midge populations

Western Triangle Agricultural Research Center team installed 12 delta traps baited with wheat midge pheromone lures (2S, 7S)-nonadiyl dibutyrate in spring wheat fields (dryland and irrigated) at different locations (Pondera, Toole, Choteau and Teton Counties). Wheat midge pheromone delta traps were installed from during the first-second week of June, 2017. They were monitored nearly at 1-2 days interval from Monday to Friday in Pondera (Ledger, Valier and WTARC) and Toole (Ledger), while at 15 days interval in Choteau and Teton Counties. Trap monitoring work was completed from last week of July to first week of August, 2017.

Parasitoid *Macroglenes penetrans* population level

The *M. penetrans* adult population level was monitored in traps installed in dryland and irrigated spring wheat fields located at Valier, WTARC and Ledger locations. Sweep net method was used to sample the adult parasitoids from each field. About 120 sweeps were made per field and the collected samples were stored at -20 °C until processing. The parasitoids were identified under a microscope (Doane et al., 1989). Parasitoid adults were monitored at 3-4 days interval throughout wheat midge adult activity period. The sweep net sampling was began in June 20 and completed in July 20, 2017.

Results

Wheat midge population trend in the Golden Triangle areas of Montana

Total cumulative midge count observed in our trap established locations are shown in Table 1. In 2017, wheat midge populations were monitored in seven counties (Liberty, Toole, Teton, Choteau, Glacier, Cascade and Pondera). Portion of the wheat midge count data was extracted from Pestweb Montana. Total number of wheat midge pheromone traps installed in wheat fields were 46 in 2017. Among the seven counties, the highest wheat midge population level was recorded in Pondera County in comparison to no presence of wheat midge in Cascade County (Fig 1). The second highest wheat midge populations were noticed at Teton County followed by Toole, Glacier, and Chouteau Counties (Fig 1). Compared to the last year, wheat midge populations were generally at low irrespective of County, except in Teton County where population levels increased sharply this year.

County	Field name	Lat	Lng	Total cumulative count/trap	Parasitoid observed
Pondera	WTARC irrigated	48.31395	-111.9253	282	Yes
Pondera	WTARC dryland	48.31392	-111.92575	83	Yes
Pondera	Cory Crawford Irrigated	48.30644	-112.15416	211	Yes
Pondera	Cory Crawford dryland	48.30819	-112.0913	670	Yes
Pondera	Terry Peters dryland	48.24878	-111.69696	315	Yes
Toole	Terry Peters dryland	48.25049	-111.59902	34	Yes
Pondera	Jodi Hobel dryland	48.30131	-112.1201	34	Yes
Pondera	Jodi Hobel irrigated	48.2861	-112.0552	387	Yes
Teton	Scott Inbody dryland	47.9112	-112.03736	108	No
Choteau	Knees dryland	47.99638	-111.36411	2	No
Pondera	Kyle Dean dryland	48.38166	-112.25097	126	Yes
Pondera	Kyle Dean irrigated	48.4317	-112.1848	461	Yes

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

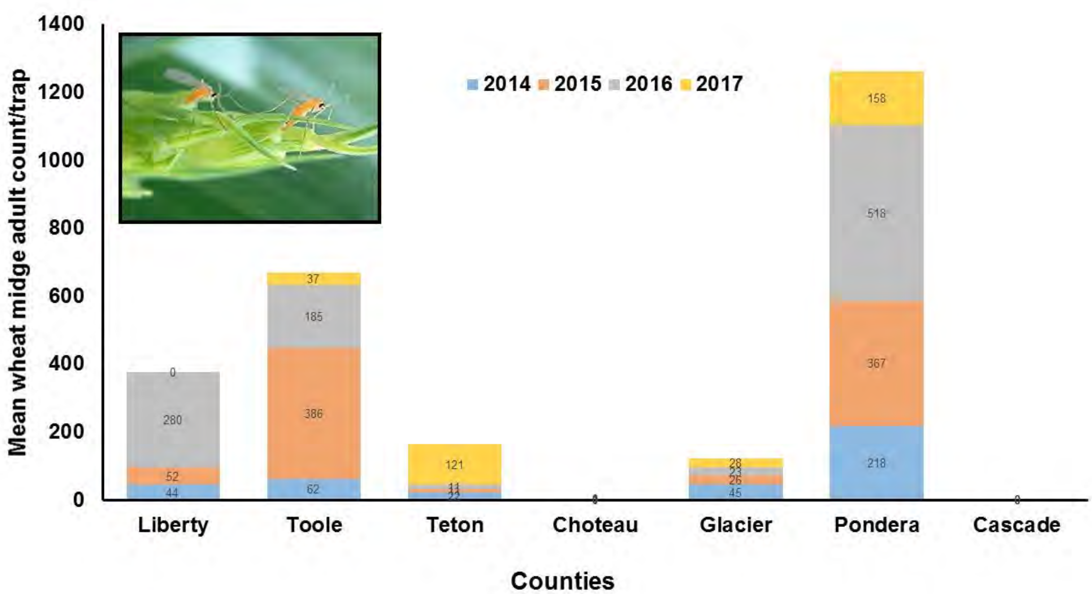

Figure1. Wheat midge population trends at the Golden Triangle area of Montana from 2014-2017

Wheat midge population level: Irrigated vs. dryland spring wheat fields
Generally, wheat midge populations were relatively at lower levels in dryland compared to irrigated spring wheat fields. At both cropping systems, the flight activity of wheat midge adults started at about the same date June 15-21, in 2017 (Fig 2). However, wheat midge peak population levels were recorded slightly earlier (June 25- 29) in dryland system while in the later period (June 29-July 1) in irrigated system. In addition, wheat midge emergence was observed until late period (July 10) in irrigated system while for a short period (July 5) in dryland system.

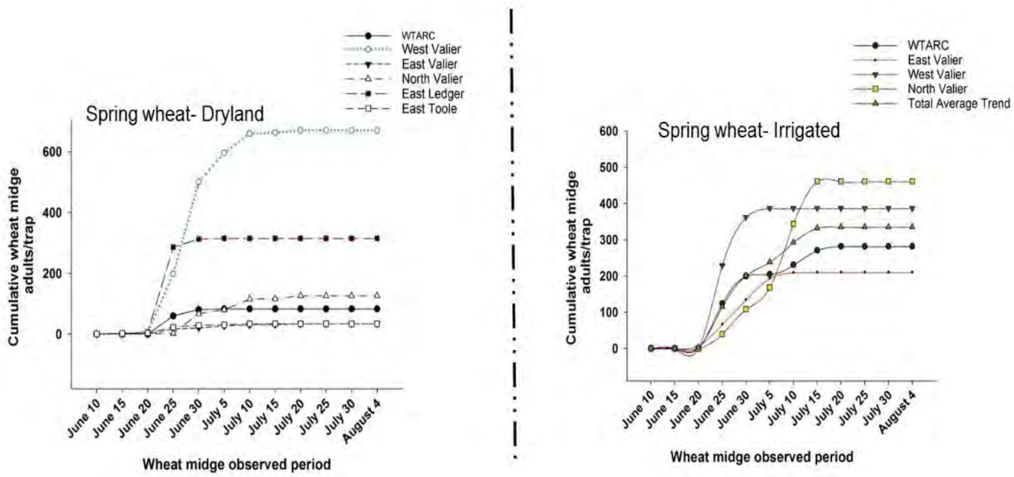

Figure 2. Wheat midge adult activity based on pheromone trap catch in dryland and irrigated spring wheat fields

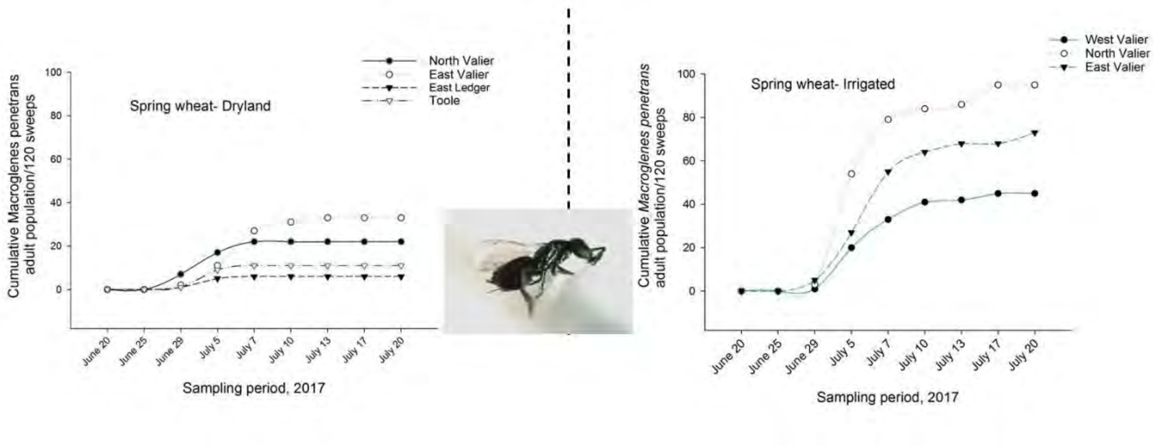

Figure 3. Wheat midge parasitoid, *Macroglenes penetrans* adult population level in dryland and irrigated spring wheat fields, 2017.

Parasitoid population level: Irrigated vs. dryland spring wheat fields
As expected, *M. penetrans* population was found at higher levels in irrigated compared to dryland spring wheat midge infested fields (Fig 3). At both cropping systems, the emergence of parasitoid has begun nearly at the same time (June 29 - July 5, 2017) (Fig 3). The total cumulative parasitoid number ranged and 11-22 and 45-73 in the dryland and irrigated cropping system, respectively.

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.

Reference

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Evaluation of the effectiveness of entomopathogenic fungi, reduced risk chemicals, and trap crops for the management of wireworms on spring wheat

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Project collaborators: Stefan T. Jaronski[2], Kevin Wanner[3] and Heikki M. Hokkanen[4]

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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. Wireworm damage to a spring wheat plant in Golden Triangle Area, Montana.

Material and Methods

Experimental sites

In earlier studies (Reddy et al. 2014; Adhikari and Reddy 2017), highly wireworm infested fields were selected in Ledger and Valier in the 'Golden Triangle' area of Montana. In 2017, experiments were conducted at two growers places Ledger (N48º 18'26.9244 W111º51'34.4376) and Valier (N48º 18'37.4148 W112º 25'19.0956). Experiment plots were seeded on 4 May 2017 in Valier and 10 May 2017 in Ledger. Before seeding, the herbicide glyphosate (RT3®, Monsanto Company, St. Louis, MO) was applied at the rate of 2.5 L/ha for weed control, following regional farming practice. Fertilizer (N, P, and K) was applied at a ratio of 224.2, 0, and 22.4 kg/ha by broadcast application during planting, and an additional fertilizer application (N, P, and K at a ratio of 12.3, 25.2, and 0 kg/ha) applied through the seed plot drill. The experimental plots received 5 cm of water via overhead irrigation whenever needed. The first irrigation was done 30 days after treatments. Harvesting was done at in July 2017.

Sampling for plant damage and wireworm density
To determine the level of crop damage from wireworms, the number of plants or seedlings in each plot was measured randomly using the 1 m line intercept method. From an individual plot two count are taken each from wheat and trap crops. The first count are taken two weeks after sowing. The subsequent counts are taken at the interval of a week in both sites. The same method was applied to the various trap crops intercropped with the wheat. The relative effectiveness of the various trap crops in attracting wireworms will be assessed through soil core samples taken within and between rows, as well as by assessments of damage to plants and yield.

To determine the density of wireworm larvae, traps were established in each plot and borders and were collected in 15 days and 30 days and were assessed separately. Traps were collected after 15 days, reestablished and again collected after 30 days. Whole set up was established once again and traps were again collected after 30 days. After collection traps were processed in berlese funnels and wireworms were separately collected from each plot. Later, they were identified using the keys of wireworm described by Etzler et. al (2013) and were used for lab study. Three wireworm species were identified from different fields which are, *Limonius californicus*, *Hypnoides bicolor, and Aeolus mellilus.*

Evaluating the effectiveness of trap crops (Exp 1)
Our previous results indicated that pea and lentil attracted significantly higher wireworms than wheat and other traps crops tested (canola, sweet corn, Montrail durum and Metealfa barley). Therefore, further experiments are conducted on the effect of seeding density on movement of wireworms on spring wheat. In 2017, experiment was established to study seeding density (Table 1). The experiment is designed in RCBD design for this study. All together there were 48 plots (4×3×4 = 48). An individual plot size was 3.6 m × 1.2 m. Buffer zone of 0.6 m was kept in between the plots. The cultivar of crop varieties used in 2017 are: Montech pea, Merrit lentil and Duclair wheat as control.

Evaluate the efficacy of entomopathogenic fungus (Exp 2a)
In the proposed study, different combinations of entomopathogenic fungi are tested for their efficacy against wireworms in spring wheat at two selected locations (Ledger and Valier) in Montana. The experiment is designed in RCBD design for this study. All together there were 48 plots (4×3×4 = 48). An individual plot size was 3.6 m × 1.2 m. Buffer zone of 0.6 m was kept in between the plots. Fungi are provided by USDA ARS (Sidney, MT) (Table 2). Duclair seeds were seeded at the rate of 22 seeds/sq feet. Below mentioned fungi were applied in plots in furrows at two different rate 5 gms/plot and 10 gms/plot. The name used for fungus name and rate is mentioned in Table 2. Same names are used in result section and figures.

Evaluating the efficacy of fungi and reduced risk chemicals in lab bioassay (Exp 2b)

In the proposed study, different combinations of entomopathogenic fungi are tested for their efficacy against wireworms. In 2017, only a small setup is established to check the effect of entomopathogenic fungus in lab conditions. Other reduced risk chemicals will be tested and etomopathogenic fugus will be tried in 2018 (Table 3).

Rearing of wireworms and bionomics of wireworms (Exp 3)
To fulfill our objective 1 (lab bioassay of entomopathogenic fungus and reduced risk chemicals), and objective 3 (lab bioassay of entomopathogenic nematodes), we will require the continuous supply of wireworms. To fulfill this requirement, we plan to build a rearing bed for wireworms and rear them in field conditions. Both field and lab rearing techniques of wireworm have been mentioned by Furlan (1996 and 1998), nevertheless the field conditions will be different in Montana to rear these insects. A study of rearing of wireworms in Montana climate will also provide the opportunity to evaluate the overwintering behavior of wireworms and also their movement in the soil with changing weather conditions of Montana. Ovipositional behavior, effect of temperature and moisture and life cycle variation of selected species of wireworms will be also be studied simultaneously.

Statistical analysis
Analysis of variance (ANOVA) was used to analyze data in Excel. For both field trials, we used date of sampling as a blocking factor and performed ANOVA. Paired T-test was also applied to compare within group and P-values < 0.05 were considered significant.

Results
Wireworm species composition
The identification of wireworm species composition was performed in 2017 at both research locations- Valier and Ledger. Overall, three wireworm species- *Limonius californicus, Hypnoidius bicolor* and *Aeolus mellilus* were observed regardless of study locations. However, in both locations, *A. mellilus* was the most predominant species followed by *H. bicolor* and *L. californicus* and *A. mellilus* at both sampling times.

Evaluating the effectiveness of trap crops
In 2017, at both locations plant counts, number of wireworms and yield is compared. In comparison to Valier site, Ledger site had greater wireworm pressure (Figure. 2). Hence variation in plant count is noticed and significant difference is found when t-test is applied (P<0.01; df=1, F=8, Figure 3). Nevertheless, no significance difference is found between the different seed rates of wheat, pea and lentil in terms of both plant count and plant height. Both pea and lentil performed significantly well at the rate of P8 and L12 respectively (Figure 3,4). Same rate is observed to attract more wireworm and therefore higher spring wheat yield is found to be associated at this rate. Difference in number of wireworms collected after 15 days and 30 days is also observed, although significant only associated with P4 and P8 at Valier. Significant variation in spring wheat yield is found when compared between two sites (P<0.01; df=2; F=4.9; Figure 5).

Evaluate the efficacy of entomopathogenic fungus
In 2017, at both locations plant counts, number of wireworms associated, and yield of spring wheat treated with entomopathogenic fungus at two rates is compared. In comparison to Valier site, Ledger site had greater wireworm pressure (Figure. 6). Greater association of wireworms is observed with MRM356, MR2009 (10gms) and MRM2009 (10 gms). At Ledger site number of wireworms collected after 15 days were significantly higher that

number of wireworms collected after 30 days (P<0.01; df=21, F=3.59). Nevertheless plant count and plant height is not found to be significantly different at both sites (Figure. 7, 8). Yield and test weight both are significantly different at both sites (P<0.01; df=11; F=5). Greater yield is associated with MR356 and MRM2009. Similarly greater test weight is associated with MR2009 (Figure 9).

Evaluating the efficacy of fungi and reduced risk chemicals in lab bioassay:
With limited number of wireworms small bioassay was setup to test the efficacy of entomopathogenic fungus against wireworms. This study was only conducted over 13 days and showed best results with MR356 and MRM2009 (Figure 10).

Rearing of wireworms and bionomics of wireworms
As per discussed design (Furlan 1996 and 1998) the wireworm rearing cage is under construction and the proposed size is 1 m x 1 m x 2 m deep. We consider that 2 m depth will provide the wireworms to move during peak winters in Montana. Iron boxes, closed at the bottom by a plastic net (0.5mm mesh), will be placed in the ground and filled with air dried soil. The cages will be closed at the top by a net (2mm mesh) that will allow the rain to penetrate but not alter the average soil temperature.

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

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Table 1: Seeding density of the trap crops.

Treatment	Crop	Seeds/Sq.ft.
T1	Wheat	0
T2		11
T3		**22**
T4		28
T5	Pea	0
T6		4
T7		**8**
T8		14
T9	Lentil	0
T10		6
T11		**12**
T12		18

Table 2: Material, rate, and method of application in each treatment in field.

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:	*Beauveria bassiana* GHA Granules (BB)	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T4:	*Metarhizium robertsii* DWR356 Granules (MR356)	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T5:	*Metarhizium robertsii* DWR356 on millet substrate (MRM356)	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T6:	*Metarhizium robertsii* DWR2009 Granules (MR2009)	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T7:	*Metarhizium robertsii*DWR2009 on millet substrate (MRM2009)	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T8:	*Beauveria bassiana* GHA Granules (BB-10)	(20lb/acre) 10 gms/plot	Stefan T. Jaronski USDA ARS
T9:	*Metarhizium robertsii* DWR356 Granules (MR356-10)	(20lb/acre) 10 gms/plot	Stefan T. Jaronski USDA ARS
T10:	*Metarhizium robertsii* DWR356 on millet substrate (MRM356-10)	(20lb/acre) 10 gms/plot	Stefan T. Jaronski USDA ARS
T11:	*Metarhizium robertsii* DWR2009 Granules (MR2009-10)	(20lb/acre) 10 gms/plot	Stefan T. Jaronski USDA ARS
T12:	*Metarhizium robertsii*DWR2009 on millet substrate (MRM2009-10)	(20lb/acre) 10 gms/plot	Stefan T. Jaronski USDA ARS

Table 3: Treatments for lab bioassay

Treatment	Material	Rate	Source
T1: Control	Water		
T2: Beauveria bassiana GHA Granules	*Beauveria bassiana* GHA Granules	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T3: Metarhizium robertsii DWR356 Granules	*Metarhizium robertsii* DWR356 Granules	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T4: Metarhizium robertsii DWR356 on millet substrate	*Metarhizium robertsii* DWR356 on millet substrate	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T5: Metarhizium robertsii DWR2009 Granules	*Metarhizium robertsii* DWR2009 Granules	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T6: Metarhizium robertsii DWR2009 on millet substrate	*Metarhizium robertsii* DWR2009 on millet substrate	(10lb/acre) 5 gms/plot	Stefan T. Jaronski USDA ARS
T7: Entrust®	spinosad	0.69g/1000ft^2 (1 oz/acre) (0.091 ml/L of water)	Dow Agro Science LLC, Indianapolis, IN
T8: Aza-Direct®	Neem	25 g/L	Gowan Company
T9: Pyganic®1.4 EC	pyrethrum	16 fl. Oz./acre	McLaughlin Gormley King Company (Minneapolis, MN)?Valent BioSciences
T10: Met52®	Met52 Microsclerotial granules (*M. brunneum*)	20 lb./acre.	Marrone Bio Innovations, Davis, CA
T11: Met52®	Met52 Corn grit granules (*M. brunneum*)	20 lb./acre.	Marrone Bio Innovations, Davis, CA
T12: Xpectro® OD	pyrethrin + *B. bassiana* GHA	2.5 ml/L of water	LAM International (Butte MT)

Table 4: Treatments for entomopathogenic nematodes.

Entomopathogenic nematode species	Strain	Source
Steinernemacarpocapsae	All strain	David Shapiro(USDA ARS)
	Cxrd strain	David Shapiro(USDA ARS)
Steinernemafeltiae	SN strain	David Shapiro(USDA ARS)
Heterorhabditis bacteriophora	HP88 strain	David Shapiro(USDA ARS)
	VS strain	David Shapiro(USDA ARS)
Steinernema riobrave	355 strain	David Shapiro(USDA ARS)
	7-12 strain	David Shapiro(USDA ARS)
Heterorhabditisfloridensis	K22 strain	David Shapiro(USDA ARS)
Heterorhabditis georgiana	Kesha strain	David Shapiro(USDA ARS)
Steinernemararum	17C&E	David Shapiro(USDA ARS)

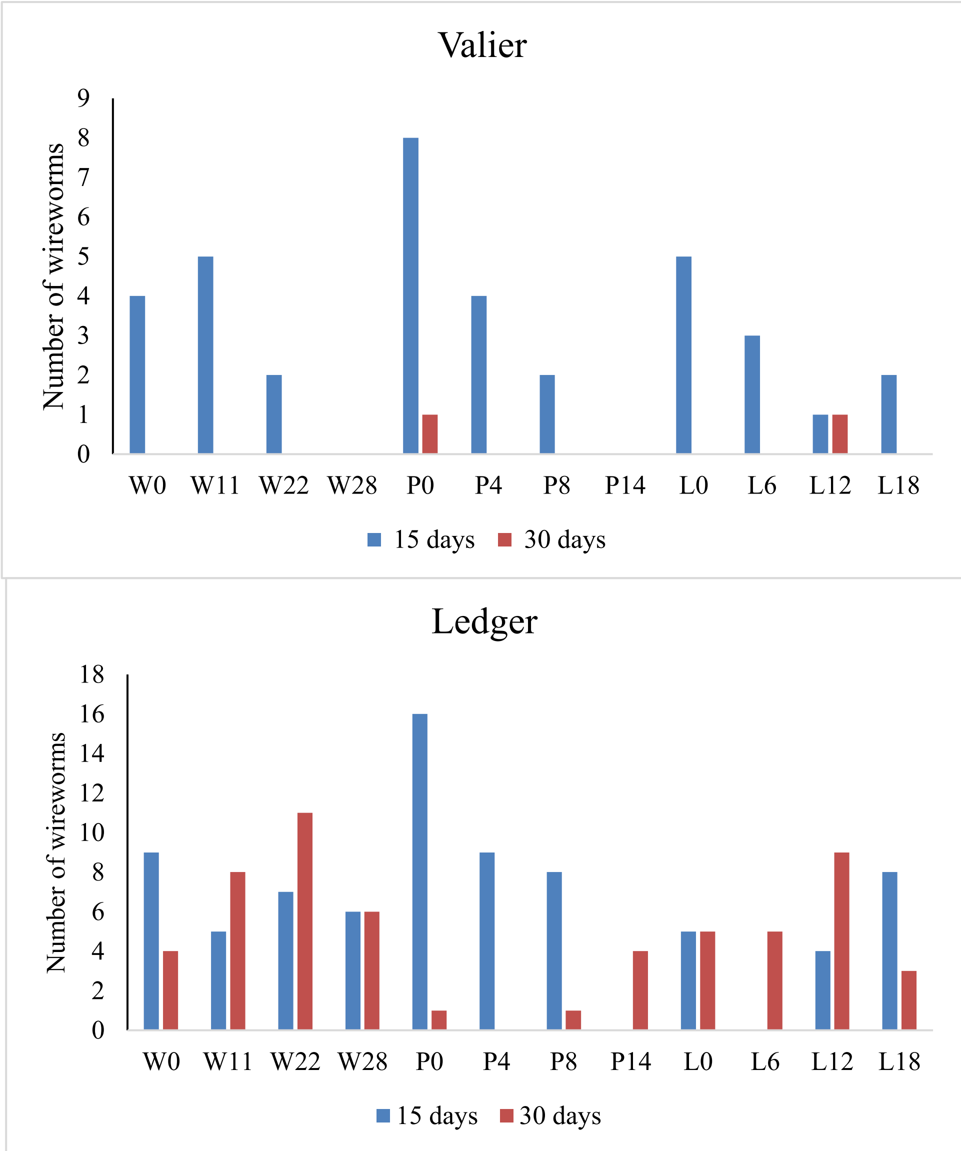


Figure. 2: Number of wireworms collected at Ledger and Valier in 2017.

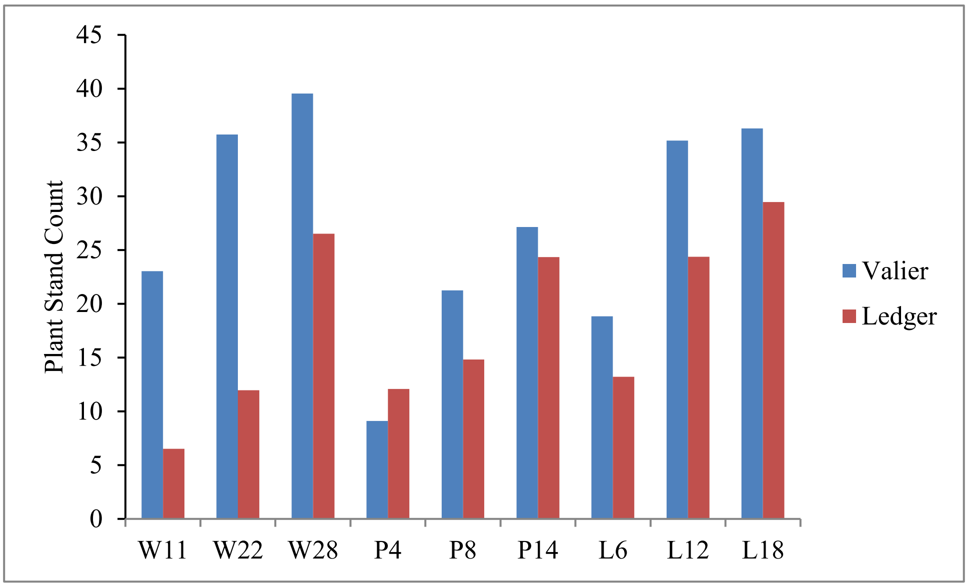


Figure 3. Mean number of plant stand count at both locations.

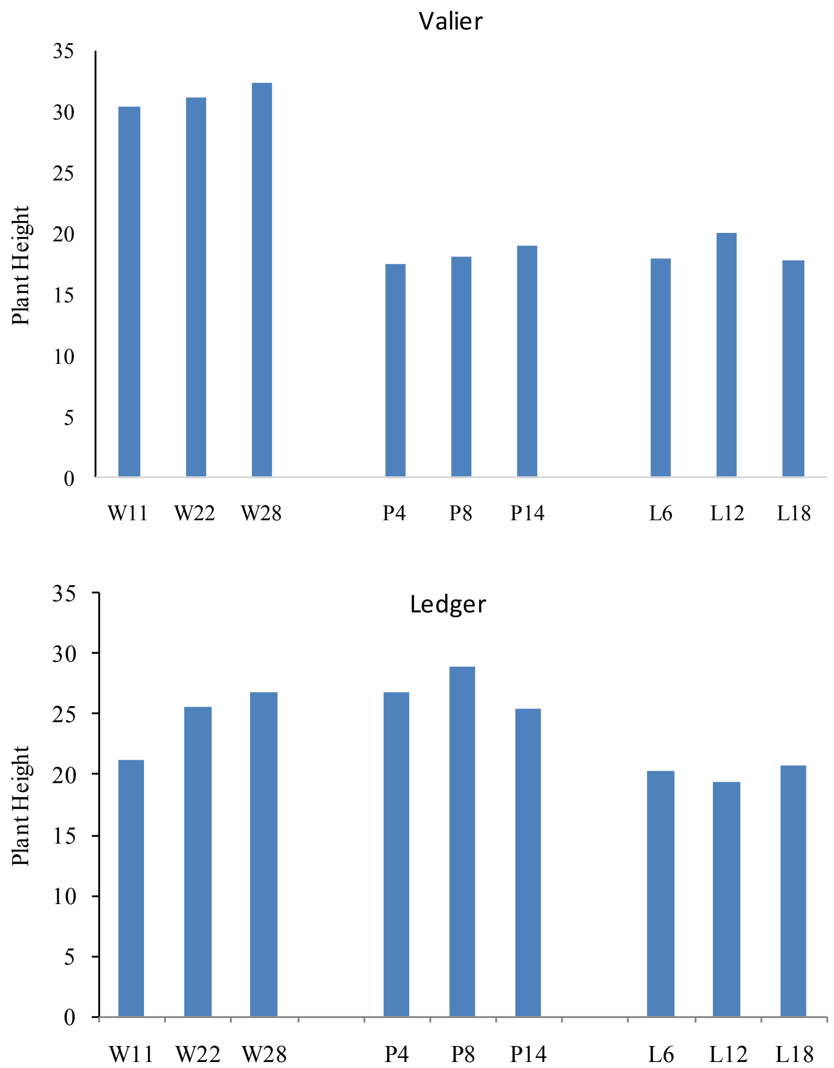
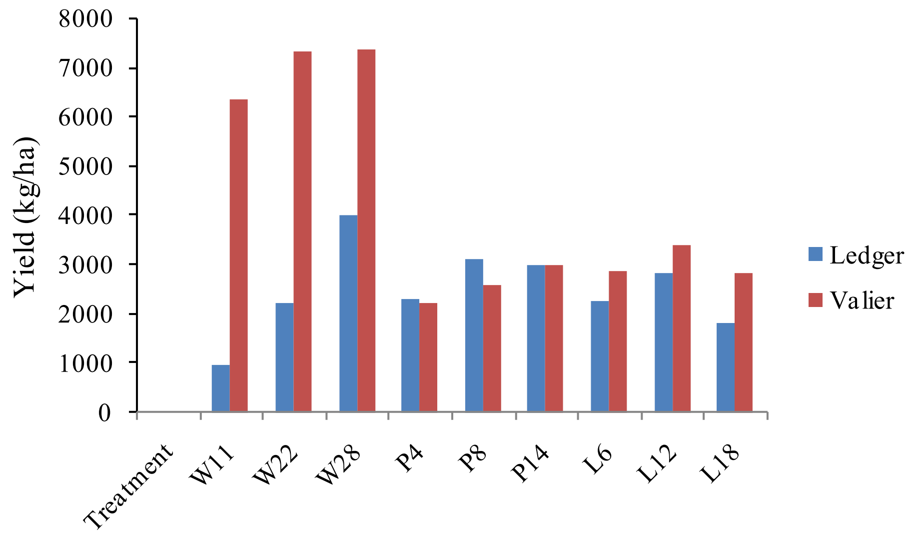


Figure 4. Plant height of spring wheat, pea and lentil at Ledger and Valier in 2017.



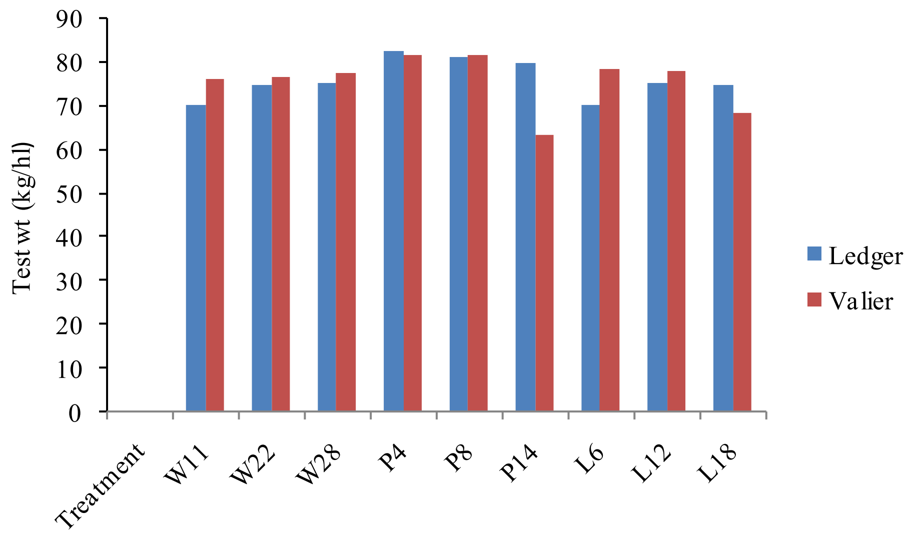
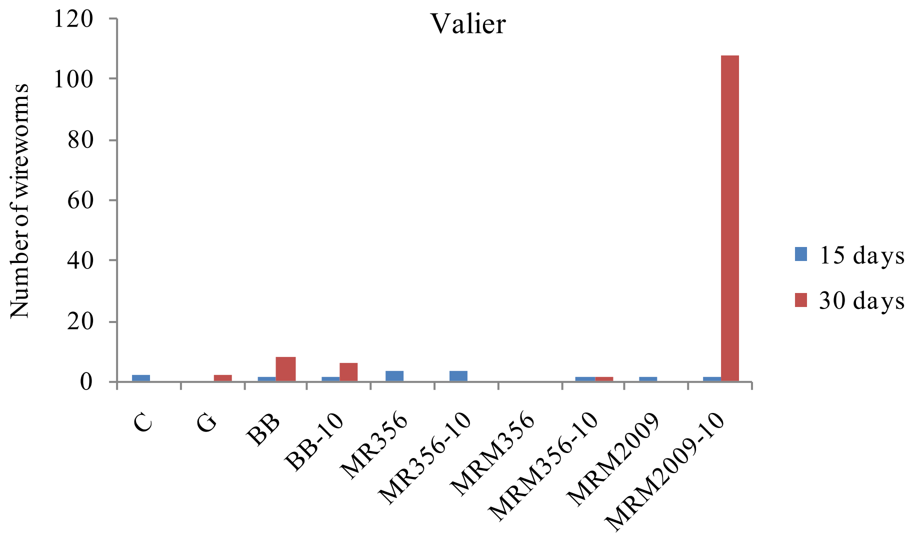


Figure 5. Yield (kg/ha) and test weight (kg./hl) of spring wheat, pea and lentil at Ledger and Valier in 2017.



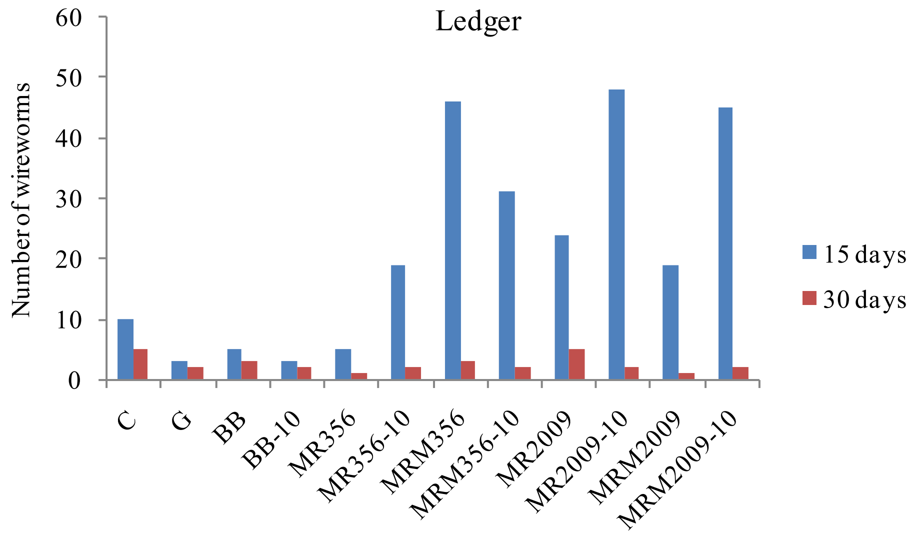


Figure 6. Number of wireworms after 15 days and 30 days at Valier and Ledger in various plots treated with entomopathogenic fungus.

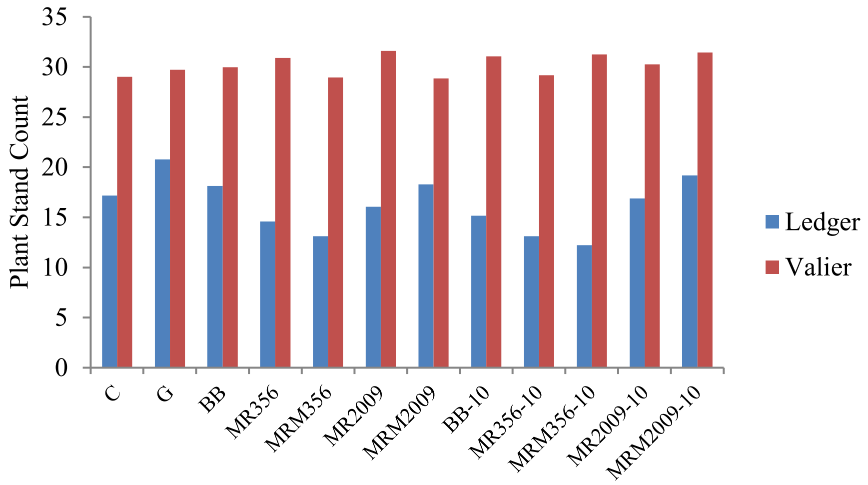


Figure 7. Plant stand count at Valier and Ledger in various plots treated with entomopathogenic fungus.

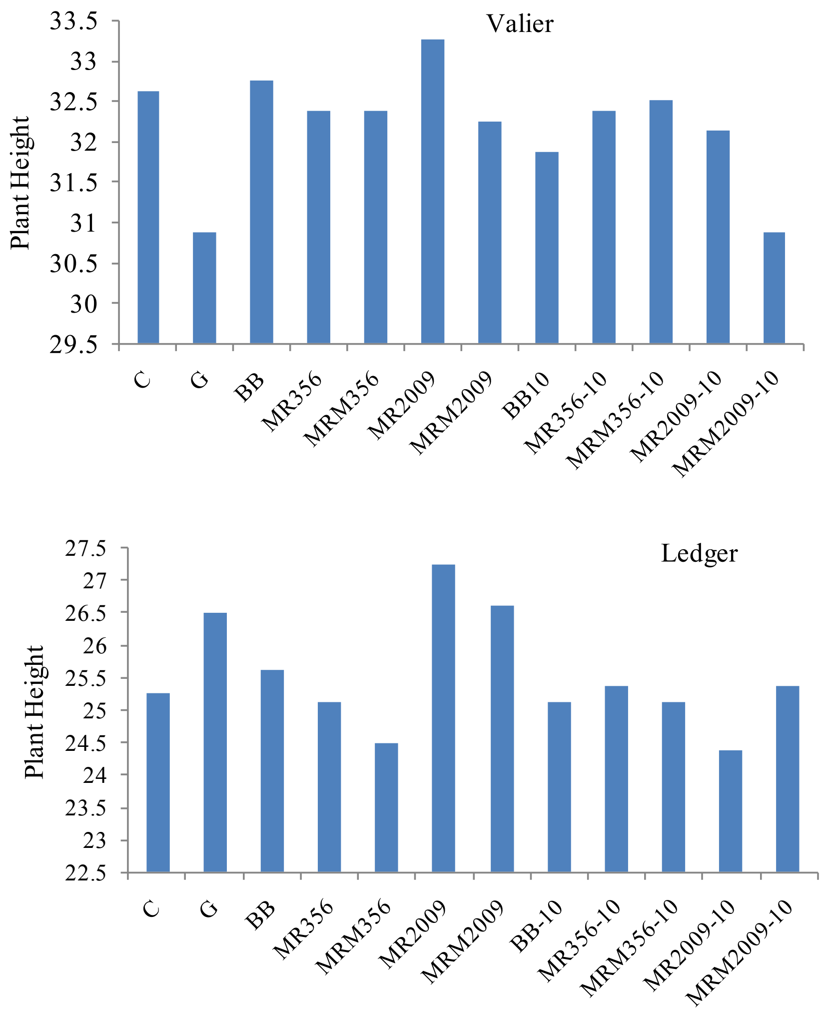


Figure 8. Plant height of spring wheat plants at Valier and Ledger treated with entomopathogenic fungus.

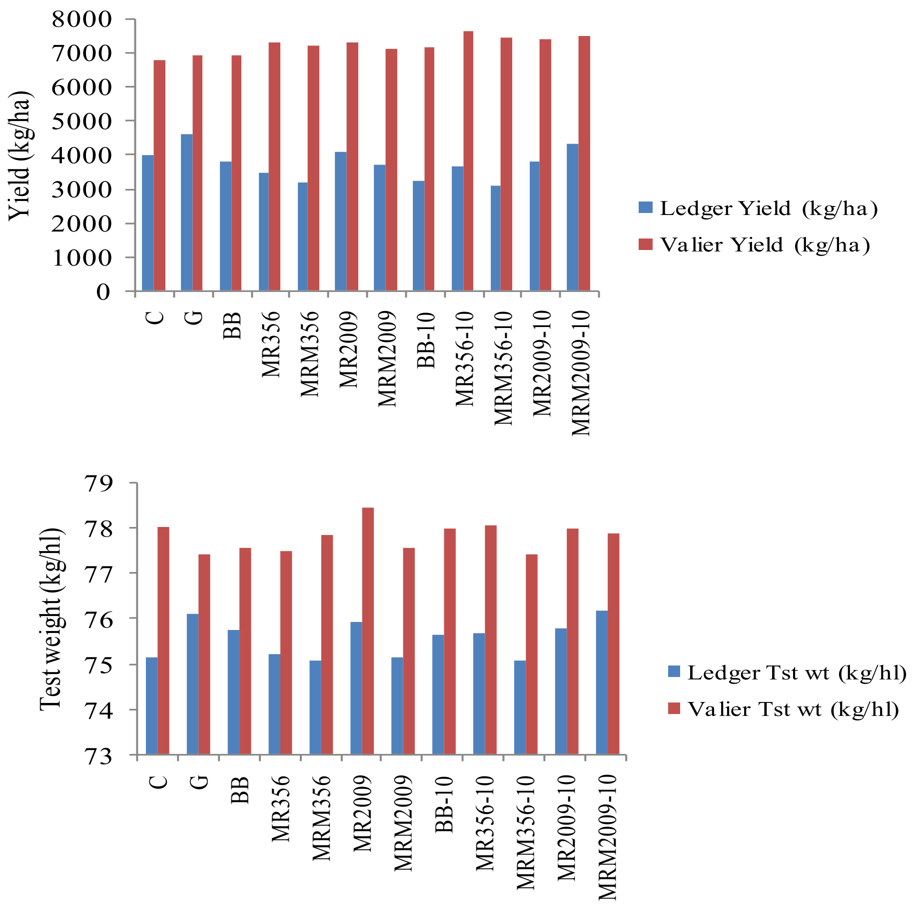


Figure 9. Yield (kg/ha) and test weight (kg/hl) of spring wheat at Ledger and Valier treated with entomopathogenic fungus.

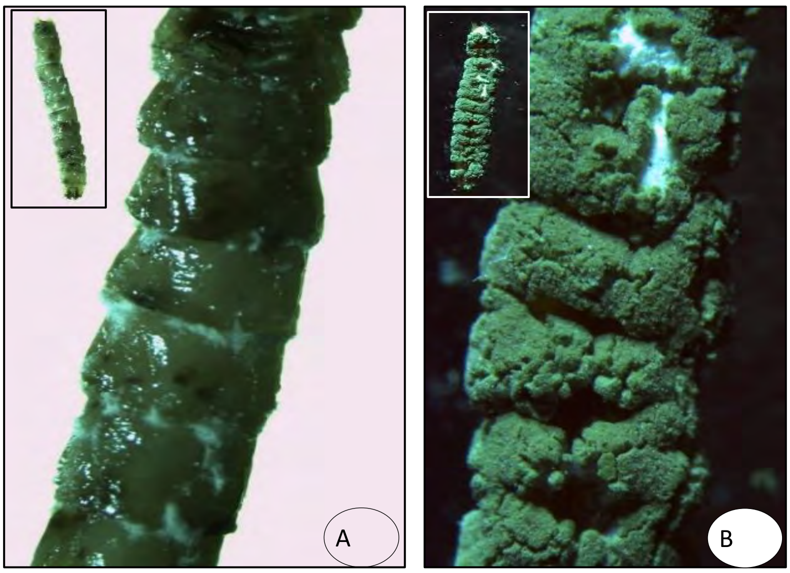


Fig. 10. Growth of *Metarhizium robertsii* DWR2009 (millet substrate) on *Hypnoidus bicolor* dead larvae after 9 days(A) and 13 days (B).

Efficacy of entomopathogenic nematodes (EPN's) against wireworms and non-target organisms (Green lacewings and Ladybugs)

Principal Investigator: Gadi V.P. Reddy

Project Personnel: Ramandeep Kaur Sandhi, Shabeg S. Briar, Anamika Sharma, Ramadevi Gadi and Deb Miller

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Aim of the Study

The aim of the study was to investigate whether Entomopathogenic (insect pathogenic) nematodes are able to kill wireworms and have any negative effect on non-target organisms such as green lacewings, *Chrysoperla carnea* (Neuroptera: Chrysopidae) and lady bugs, *Adalia bipunctata* (Coleoptera: Coccinellidae).

Materials and Methods

Wireworms

Wireworm collection

The larvae of different instars of wireworms were collected from two field locations (Conrad and Pendroy were collected by using stocking traps. The stocking traps with soaked wheat seeds were put at different spots beneath the soil in the wireworm infested fields and covered with the plastic sheets. After 15-20 days, the stocking traps were collected and brought back to the laboratoryand, replaced with new ones every time. The stocking traps with wireworms were put in the Berlese Funnels for 12 hours and wireworms were collected underneath in a glass jar. In addition wireworms were also manually handpicked from the soil samples collected from the infested fields (Figure 1). The collected wireworms were categorized into small, medium and large based on their body size. Mainly three types of wireworm species viz. *Limonius californicus, Hypnoides bicolor,* and *Aeolus mellillus* considered for collection of larvae in 2017.

Wireworms collected and separated from the plant roots or soil samples were stored in an incubator at 8° C in plastic cups with sterilized soil containing wheat seeds added as their food.

Figure 1. Wireworm collection from the soil and plant roots (Left) and separation from the soil samples using Berlese Funnels in the lab (Right).

EPN's species

Ten nematode strains were obtained from Dr. David Shapiro, USDA ARS, Byron, GA (Table-1).

S. No	Entomopathogenic nematode species	Strain
1	*Steinernema carpocapsae*	A11 strain
2		Cxrd strain
3	*Steinernema feltiae*	SN strain
4	*Heterorhabditis bacteriophora*	HP88 strain
5		VS strain
6	*Steinernema riobrave*	355 strain
7		7-12 strain
8	*Heterorhabditis floridensis*	K22 strain
9	*Heterorhabditis georgiana*	Kesha strain
10	*Steinernema rarum*	17 c+e strain

Table 1: Different entomopathogenic nematode species used in the present study

Entomopathogenic nematodes rearing

The EPNs obtained were further reared on waxworm, *Galleria mellonella* (Lepidoptera: Pyralidae) larvae. The five later-instar larvae were placed on the filter paper in the petri dishes. 500-1000 infective juveniles (IJs/ml) were inoculated in each petri dish with approximately 100-

200 IJs for single larva in the petri dish. Once inoculated, petri dishes were left at room temperature (20-25° C) for EPNs to enter the larvae and cause infection. After 3-5 days, EPNs infected larvae were placed on the white traps for rearing (Figure 2). In about 7 to 10 days later, EPNs were washed from the white traps with distilled water using pipette into the flasks.

Figure 2. Infected waxworm larvae on white trap

EPNs concentrations

For preparing different concentrations, EPNS were collected in distilled water (100-1000 ml). After making the solution, 1 ml of the suspension was taken onto the counting slide and number of EPNs were counted under the stereo-microscope. This was repeated 10 times to express an average number of EPNs per ml of solution. First, the higher concentration was made (2000 IJ/ml) and on the basis of this concentration, further dilutions of 1000, 500, 250, 100, 50 IJ/ml were made. EPN concentrations were stored in the incubator at 8° C temperature.

Laboratory bioassay

In the bioassay, three species of wireworms (medium size larvae) were used and due to low number of wireworm's availability, only selected EPN strains were tested in this study. Plastic cups of 30-ml volume were filled with 25 g of sandy loam sterilized soil and few soaked wheat seeds were provided as a food source for the larvae. Two wireworm larvae were placed in the cups. Different concentrations of EPNs (i.e. 50, 100, 250, 500, 1000 and 2000 IJ/ml) were inoculated onto the soil surface in 1 ml of water. Ambient moisture was maintained constantly for EPNs movement in the soil. In the control treatment, one ml of water was added. Cups were capped with 4-5 holes and then placed in the growth chamber at 25° C at 70-80 % RH in the dark (Figure 3). Larval mortality was observed at every 24 hrs intervals for up to 30 days. In case of *L. californicus* bioassay, all the EPN strains were used except *S. riobrave* 7-12 strain. In case of *H. bicolor*, seven EPN strains including *S. carpocapsae* (A11 and Cxrd strain), *S. feltiae* SN strain, *H. bacteriophora* HP88 strain, *S. riobrave* 355 strain, *H. floridensis* K22 strain and *S. rarum* 17C&E strain were used. On the other hand, five EPN strains; *S. carpocapsae* (A11 and Cxrd strain), *S. feltiae* SN strain, *H. floridensis* K22 strain, and *S. rarum* 17C&E strain were used on *A. mellilus.* The dead larvae were dissected to check for the presence of EPNs under the stereomicroscope and confirm that mortality was due to the EPNs infection.

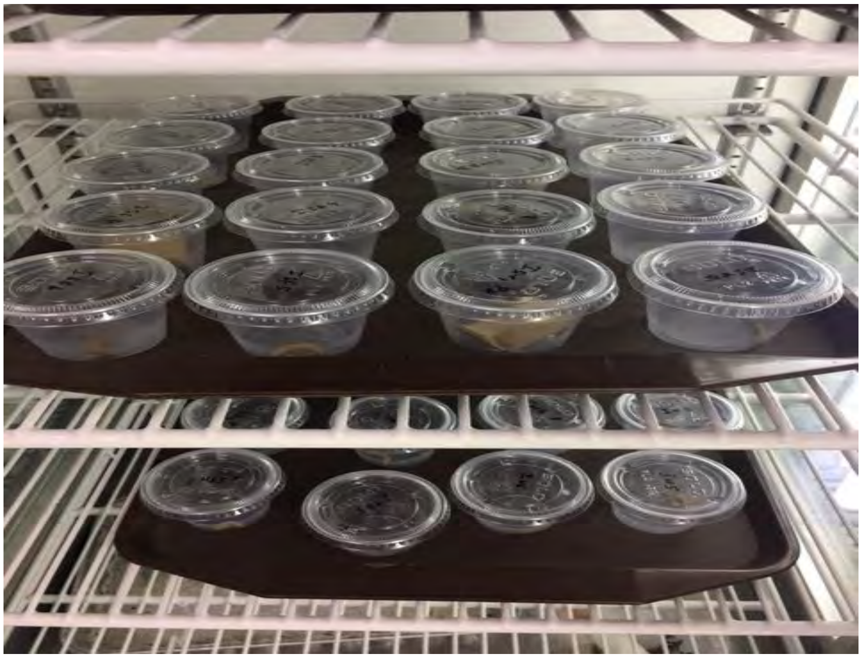


Figure 3: Inoculated cups in incubator

Beneficial insects
Two beneficial insects; Green lacewing, *Chrysoperla carnea* and two spotted lady beetle, *Adalia bipuncatata* were used in this laboratory bioassay. Second or third instar larvae of these insects were obtained from the Biobest Company.

EPNs concentrations: Only four EPN concentrations of 500, 250, 100, and 50 IJ/ml were used.

Laboratory bioassay
Five *C. carnea* larvae were placed in the 9 cm diameter petri plates with a piece of whatman filter paper and few eggs of *Ephestia kuehniella* (Lepidoptera: Pyralide) as a food source for the larvae. The EPN concentrations of 500, 250, 100 and 50 IJ/ml of water were inoculated individually to each petri plate (Figure 4). These petri dishes were kept in the growth chamber at 25° C at 70-80% RH and 16:8 photoperiod. The control received distilled water without EPNs. Each treatment was replicated five times. The larval mortality was observed at the 24 hr intervals for upto 7 days. The dead larvae were dissected under the stereomicroscope to confirm the EPNs infection. The same procedure was followed for the *A. bipunctata* larvae. In case of *C. carnea*, four EPN strains: *S. feltiae* SN strain*, S. carpocapsae* A11 strain, *H. bacteriophora* HP88 strain, and *S. rarum* 17C&E strain were used. On the other hand, for *A. bipunctata*, only three EPN strains, *S. feltiae* SN strain*, S. carpocapsae* A11 strain, and *S. rarum* 17 c+e strain were used.

Figure 4. Petri dishes with *A. bipunctata* larvae inoculated with nematodes

Results

Wireworms

The mean larval mortality were calculated on the basis of average of two replication. Since only two replications were possible in this study only mean values were calculated while this data set did not allow us to perform any parametric statistical analysis. However, more replications will be included in future studies in order to obtain enough data and perform the mean comparison tests among the treatments. The infected *L. californicus* and *A. mellilus* are shown in Figure 5.

Figure 5. Nematodes infected larvae; Left: *L. californicus*, Right: *A. mellilus*

The mean larval mortality in *L. californicus, H. bicolor*, and *A. mellilus* is presented in Figure 6. In *L. californicus*, EPN strain *H. floridensis* showed high mortality (30-65%) followed by *S. riobrave* 355 (30-60%). The other strains also showed mortality but not comparable to *H. floridensis* K22 strain and *S. riobrave* 355 strain.

In *H. bicolor*, out of 7 strains evaluated, high mortality (20-80 %) was observed in *S. carpocapsae* A11 strain followed by *S. feltiae* SN strain, *S. rarum* 17 c+e, and *S. carpocapsae* Cxrd strain with mortality ranging between 25-70 %. *S. riobrave* 355 strain also showed mortality in this case.

In *A. mellilus*, *S. rarum* 17 c+e and *S. carpocapsae* A11 strain showed more mortality ranging between 35-70 %. Other three strains; *S. feltiae* SN strain, *S. carpocapsae* cxrd strain, and *H. floridensis* K22 strain showed almost same results.

Conclusions
Overall, different EPN strains caused high mortality in different wireworm species. *H. floridensis* K22 strain, *S. carpocapsae* A11 strain, *S. rarum* 17 c+2 strain were found to be more infective than other strains. These results are based on the preliminary studies as number of larvae used in the bioassay were low. In the coming years, more research will be done with additional number of larvae and bioassays will be repeated with all the 10 EPN strains. Different size larvae (small, medium and large) will be used to check the efficacy of EPNs at different stages of the life cycle of wireworms. The time to cause mortality in different EPN strains will be observed carefully. Field/greenhouse experiments will also be conducted to check their effects in fields.

Beneficial insects
The mean larval mortality for seven days was calculated based on the five replications. In most of cases, higher the EPN concentration, higher the mortality. Mortality observed in the control was not due to nematodes but because of unfavorable environmental conditions.

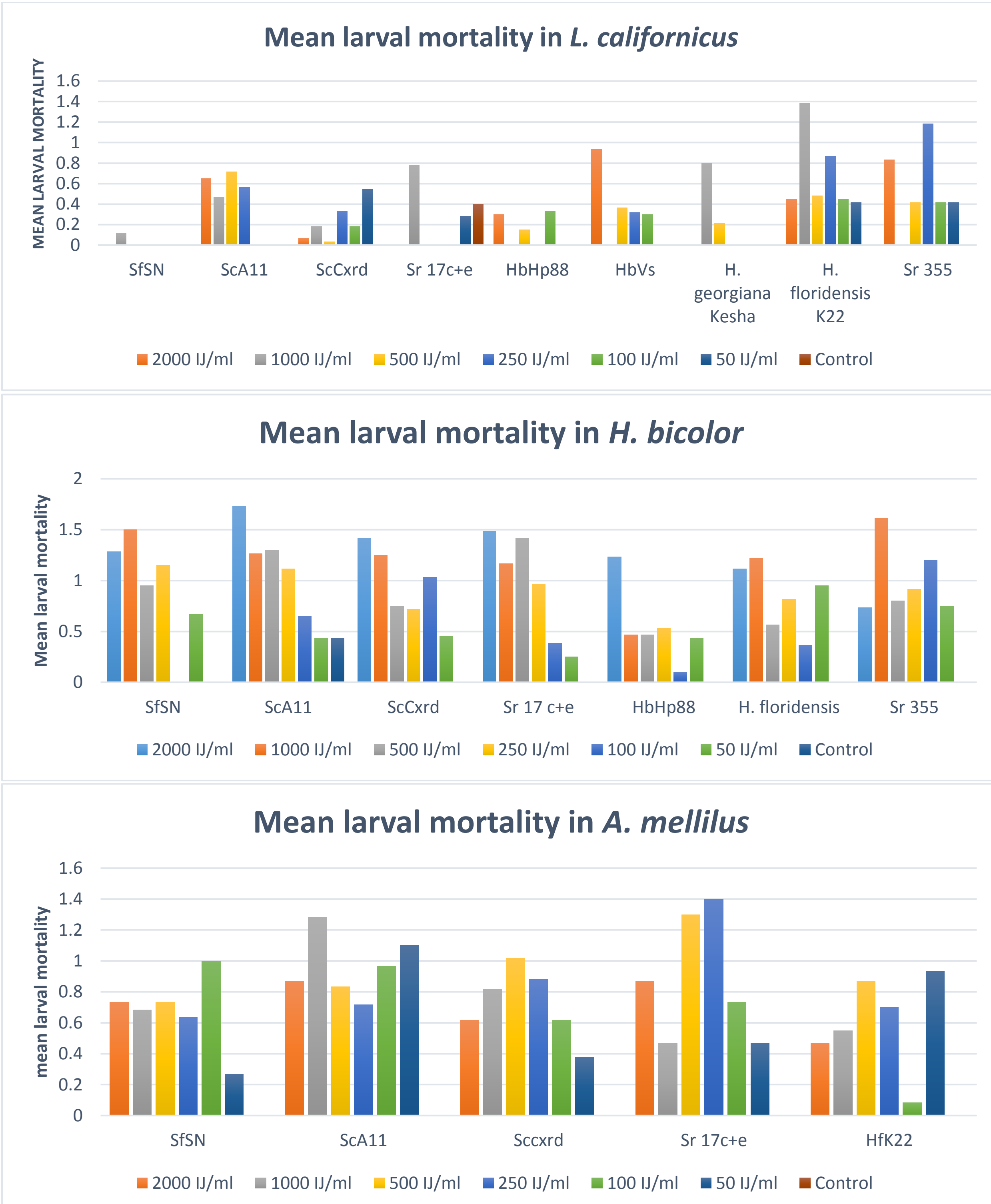
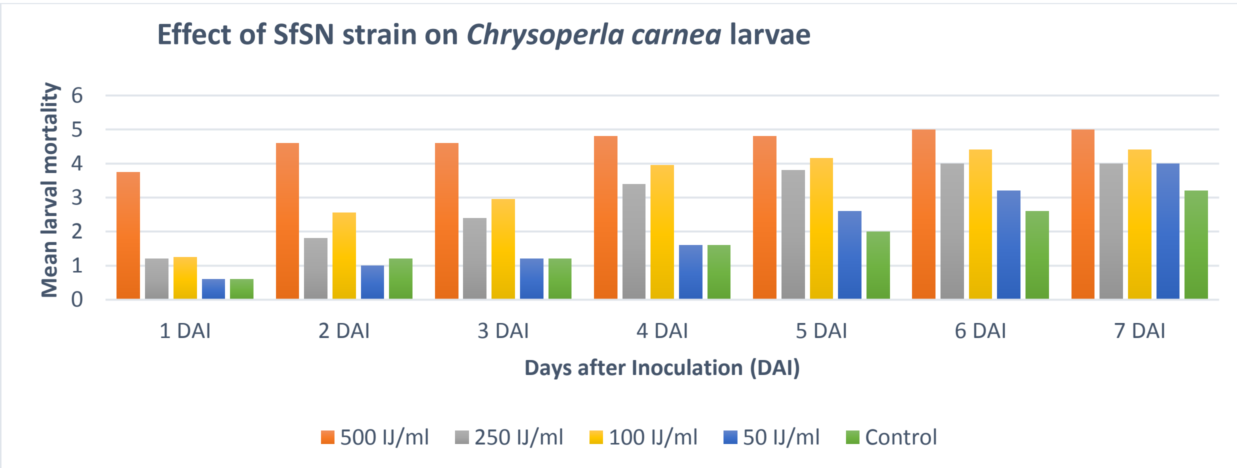
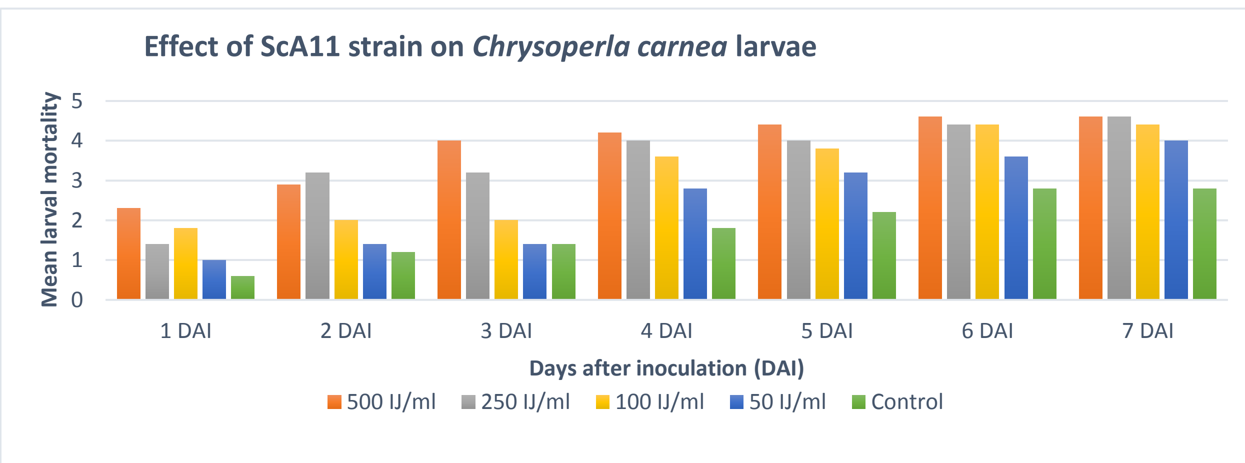


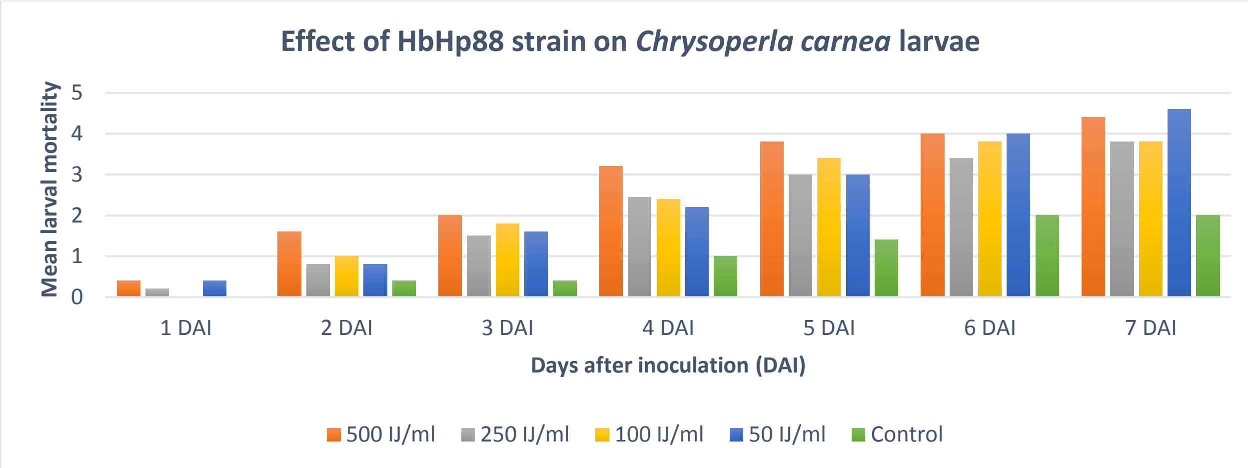
Figure 6. Mean number of larval mortality in *L. californicus*, *H. bicolor*, *A. mellilus*

Chrysoperla carnea

The mean larval mortality is shown in Figure 7. In *S. feltiae* SN strain, mortality at very first day at 500 IJ/ml was approximately 75 %. Likewise, in the other three concentrations, the mortality was about 50%. It went on increasing with the number of days. On sixth day, it showed 100% mortality at 500 IJ/ml EPN concentration. In the other concentrations also, mortality was around 70 to 80 %.







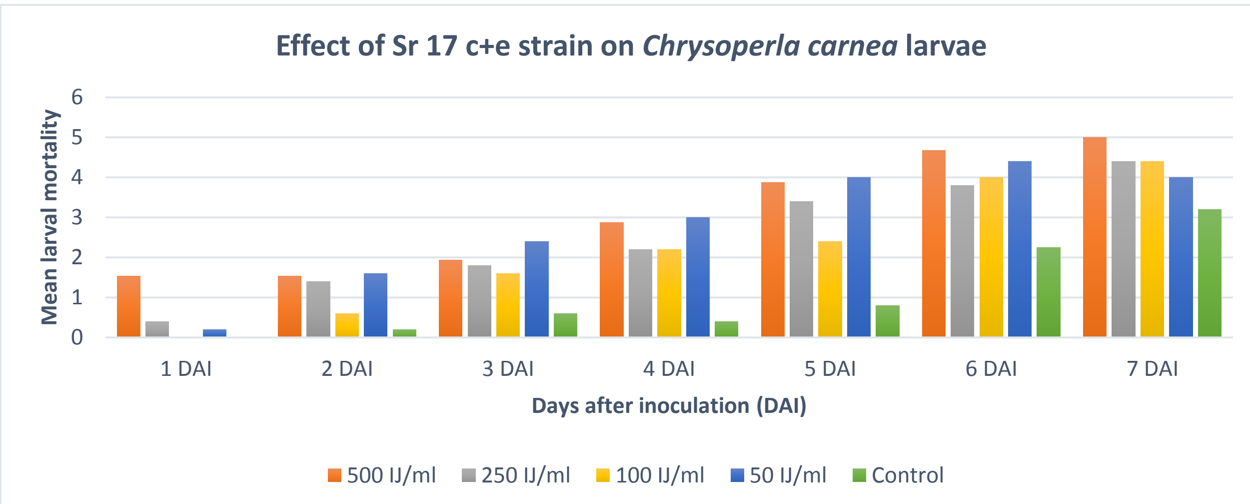


Figure 7. Mean number of larval mortality in *Chrysoperla carnea*

Similar trend was seen in *S. carpocapsae* A11 strain, as mortality was increasing with the passing days. It was 40-50 % on day second and reached 90% at the end of week.

Although, in *H. bacteriophora* Hp88 strain, mortality was higher with the passing days, unlike SfSN strain and ScA11 strain, the mortality during first 2 days was not high reached 30% on day third and mortality was 80-90 % on day six.

In *S. rarum* 17c+e strain, the trend in the mortality was similar to HbHp88 strain except the mortality reached 100% on day seven at 500 IJ /ml EPN concentration.

Adalia bipunctata

The mean larval mortality in *A. bipunctata* with *S. feltiae* SN strain, *S. carpocapsae* A11 strain, and *S. rarum* 17 c+e is presented in Figure 8. In *S. feltiae* SN strain, mortality was 85% on the very first day. It increased on day second and reached 100% at 500 IJ and 100 IJ/ml concentrations. The mortality was 100 % at day fourth in all the four concentrations.

In *S. carpocapsae* A11 strain, higher the EPN concentration, higher the larval mortality. On the second day, mortality was 100% in case of 500 IJ/ml and 250 IJ/ml concentrations. On day fourth, mortality reached 100% in case of 100 IJ/ml EPN concentration. At the end of one week, 100% mortality was there in all the four concentrations.

In *S. rarum* 17 c+e, mortality was very low on day first. It increased and reached 90-95 % on day fourth. However, 100 % mortality was observed only at 500 IJ/ml on day seventh. In the other three concentrations, mortality was around 90-95%.

Conclusions
Overall, in the tests with beneficial insects, the EPNs showed very high mortality in both the insects. Further research will be done with the other EPN strains. The bioassay will be repeated and other factors such as the surviving larvae are going through their developmental stages or not will be determined.

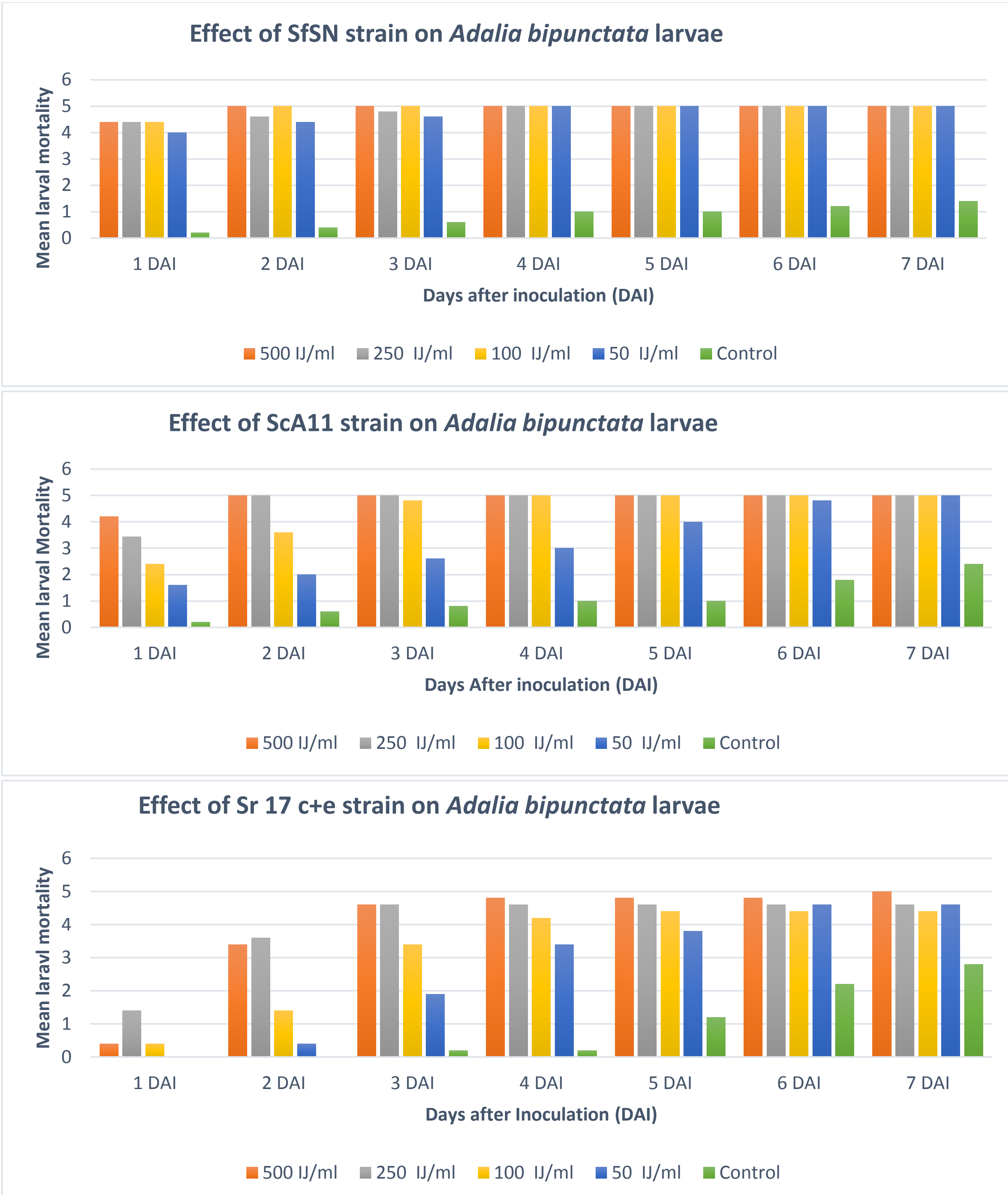


Figure 8. Mean larval mortality in *Adalia bipunctata*

Acknowledgements
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