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STATE UNIVERSITY

MONTANA AGRICULTURAL
EXPERIMENT STATION

2019 ANNUAL REPORT

Central Agricultural Research Center

ACKNOWLEDGEMENTS

Research at the MSU Central Agricultural Research Center (CARC) is only possible through the hard work of a dedicated staff at the center, and through the generosity and support of the farmers and ranchers throughout central Montana and the citizenry of the state, among others. We receive grant funding support from a growing number of public and private entities, as well as individuals, to supplement the state and federal funds which enable us to conduct research at the CARC. Much of this support is acknowledged in the summaries of research at CARC throughout this report. Those providing funding support that is not tied to a specific research project or study are listed below, but we extend a sincere thanks to all those providing funding support, whether it is project-directed or given for more general use in support of the research program at the CARC. We also are grateful for the interaction we have, and suggestions we receive, from CARC advisory board members, and from others who provide comments to us on the research that we are conducting. We welcome suggestions from others at any time.

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INTRODUCTION

The 2019 MSU Central Agricultural Research Center (CARC) summarizes much of the research that was completely recently or is ongoing at the CARC over the past 12-month period. Some research that was conducted is not included this year. This reflects the delays in harvest and grain/seed processing that resulted from the cool and wet conditions that occurred during much of the 2019 growing season. Results of studies at the CARC will be updated as additional data become available, with results accessible on the CARC web page (http://agresearch.montana.edu/carc/index.html).

There are several people who again deserve credit for this year's annual report. Simon Fordyce, a research associate in the cropping systems program at the CARC, was a major contributor, being the lead author and creator of several sections and tables that are contained within it. Dr. Jed Eberly, Assistant Professor of Agronomy and Microbiology at the CARC, provided the sections summarizing results of small-grain crop variety trials at the research center and at associated off-station locations, along with the soil microbiology research being conducted. Heather Fryer, a research associate at the CARC, helped organize and compile the report, and lined up the printing of this year's report. Lorrie Linhart, administrative assistant III, took on additional day-to-day office tasks so that others could work on compiling and printing this report.

Others at the CARC who deserve credit for its content include Eva Magnuson, a research associate in the agronomy/microbiology program at the CARC, along with Jenni Hammontree, research assistant III, also working in the agronomy/microbiology program. Additional credit for this report goes to Sally Dahlhausen, research assistant III, and to Sherry Bishop, research assistant III, both of whom work in the cropping systems program. Darryl Grove, the CARC farm manager, and Tim Bishop, the CARC farm mechanic, both assisted in the management of field experiments during the 2018-19 growing season. A college student intern was not employed at the CARC during the summer, so the research staff relied heavily on temporary summer student technicians to assist in field work and lab processing. These included Alyssa Thomas, an MSU student returning for her third summer at the CARC, her brother Zack (also back for another summer and a high-school senior at Hobson), Karlee Morris, a high school student at Hobson, and Cooper Bruchez, a Montana Tech student who worked at the CARC for several weeks during the summer.

A special thanks is extended to Drs. Darrin Boss, Head of the Department of Research Centers, Anton Bekkerman, Associate Director of MAES, and Sreekala Bajwa, Dean of the College of Agriculture and Director of MAES, for their capable leadership of MSU-directed research conducted at CARC and across the state.

I hope you find this report useful as a source of information for some of the research conducted at the CARC during the 2018-19 growing season. Feel free to call, send an email, or let me know face-to-face what you think about it. You are always welcome at the MSU Central Agricultural Research Center!

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USEFUL STATISTICAL TERMS AND DEFINITIONS

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Observation: The measured value of a particular variable, such as grain yield, test weight, soil nitrate, daily precipitation, etc.

Variable: An attribute describing some entity (person, place, thing, idea) with values that ‘vary’ from one entity to the next. For instance, if variable *x* represents crops on a farm, then *x* can take on the value ‘winter wheat’ in one case and ‘barley’ in another. In experimental design, two major variable types exist: dependent and independent. The independent variable is manipulated to determine its relationship (if any) to the dependent variable.

Factor: An independent variable such as seeding date or crop variety that can be manipulated by the experimenter. Factors always have two or more levels.

Factor Levels: Different values of a factor. For example, if our factor is ‘seeding date’, one factor level might take on the value September 15th and the other October 1st.

Treatments: Combinations of factor levels. The table below shows factors, factor levels, and treatments for a hypothetical experiment which tests the effects of seeding date and variety on winter wheat performance.

TABLE 1: HYPOTHETICAL EXPERIMENT TESTING EFFECTS OF SEEDING DATE AND VARIETY ON CROP PERFORMANCE.

Seeding Date	**Variety**		
	Keldin	Loma	Yellowstone
September 1st	Treatment 1	Treatment 2	Treatment 3
October 1st	Treatment 4	Treatment 5	Treatment 6

In this experiment there are two factors: seeding date and variety. The variety factor has three levels: Keldin, Loma, and Yellowstone. The seeding date factor has two levels: September 1st and October 1st. Thus, the experiment has six total treatments. Treatment 1 is *Keldin seeded on September 1st*, Treatment 2 is *Loma seeded on September 1st*, and so on.

NOTE: If we eliminate the seeding date factor from the above experiment, our treatment number drops from six to three—one treatment for each factor level. Because the experiment now contains a single factor with factor levels represented by individual varieties, we refer to the experiment as a variety trial. Variety trials are a type of single-factor experiment in which treatments are represented by the varieties themselves, i.e., the different levels of the variety factor.

Replicate: Experimental groups to which each treatment is randomly assigned. Experiments led by the Central Ag Research Center typically include three or four replicates. Replication is necessary to account for variation among treatments.

Treatment Mean: Treatment observations averaged across replicates. Cell values of summary tables in this report often represent treatment means. For example, Table 16 (Pg. 38) reports grain yield treatment means for several spring lentil varieties. The reported yield of the Avondale variety, for instance, is an average of yields from three different plots seeded to Avondale in three separate treatment groups or replicates.

Grand Mean, Mean, or Average: An average of treatment means. By definition, 50% of treatment means are greater than the overall mean, and vice versa. In Table 16 (Pg. 38), a summary of spring lentil variety trial results shows that average grain yield of the Avondale variety is much greater than the overall mean, (reported as 'Mean' in the lowermost section), while test weight for the same variety is much less than the (test weight) overall mean.

***P*-Value**: A measure of statistical significance. A *P*-Value of 0.05 indicates that 19 times out of 20, a difference would be detected among treatment means if the study was repeated. A *P*-Value of 0.001 probability indicates that 999 times out of 1000, a difference would be detected among treatment means if the study was repeated.

Coefficient of Variation (CV): A statistic used as an indicator of variation of large and small treatment observations among replicates. Larger CVs indicate more variation and vice versa. At the Central Ag Research Center, grain yield CVs of 15% and greater are considered to be problematic. In most cases, the grain yield LSD value will be replaced by 'NS' for 'non-significant', meaning grain yield treatment differences are not likely to be real.

Least Significant Difference (LSD): A statistic used to determine whether treatment means are significantly different from one another. In Table 16 (Pg. 38), note the LSD value for yield in 2019. Since the yield of the Avondale variety, for instance, exceeds that of the CDC Richlea variety by an amount *greater* than the LSD value, we may conclude that—all else constant—Avondale is expected to outyield CDC Richlea under conditions similar to those that occurred during the trial in 2019. Conversely, yield of the Avondale variety exceeds that of the CDC Maxim variety by an amount *smaller* than the LSD value, so we can have little confidence that Avondale will outperform CDC Maxim under similar environmental conditions.

WEATHER SUMMARY

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2019 Crop Year Summary:

1 September, 2018 – 31 August, 2019

Weather at the beginning of the crop year set the tone for the remainder of 2019. Above-average precipitation and cool temperatures occurring in fall 2018 delayed harvest of late-maturing crops like safflower and prevented timely planting of some 2019 winter crops. December of 2018 and January of 2019 were characterized by relatively warm and dry conditions, though this pattern ended abruptly in early February. A high of 53°F on 2 February was followed by a high of -5°F on 3 February, after which cold and wet conditions persisted through the month of May. An average air temperature of 3.3°F in the month of February made it the second coldest on record, behind February of 1936 (-2.9°F). From February through May, the Central Agricultural Research Center (CARC) received 7.42 inches of precipitation (2.39 inches above normal) and 972 growing degree days (264 below normal). This pattern largely explains why heading dates for winter crops of 2019 were nearly one week behind those of 2018 and two weeks behind those of 2017. Heavy frosts occurring in late April and early May also disproportionately set back winter crops, particularly early-seeded winter wheat. Reports of frost-damaged alfalfa were widespread. The CARC received 5.58 inches of precipitation in April and May alone, or 1.72 inches above normal. Above-normal snowpack and wetter-than-average spring conditions delayed planting of some 2019 spring crops. In June, air temperatures were consistent with long-term averages and rainfall was slightly below average. Light hail was observed at the CARC on 27 June, though damage to field crops was minimal. After a brief reprieve in June, cooler- and wetter-than-normal conditions persisted through the months of July and August, delaying maturity and seed fill of cereals, pulses, and oilseeds. Some of these crops were still in the field when snow arrived in late September. The 2019 average annual air temperature (41°F) was 1.8°F below the 108-yr average and 3.1°F below the 30-yr average. Annual precipitation (18.45 in) was 3.1 inches over the 110-yr average and 3.85 inches over the 30-yr average. Air temperatures maxed out at 92°F on 23 July and 3 August, two of only three days in the 2019 crop year when temperatures surpassed 90°F. The coldest day of the 2019 crop year was 2 March at -33°F. It has been colder than this only once in the last 30 years: -35°F on 20 December, 1990.

For historical weather records and summary tables (updated monthly) please visit: http://agresearch.montana.edu/carc/weather/index.html

SMALL GRAIN VARIETY TRIALS

WINTER WHEAT VARIETY TRIAL

Jed Eberly[1,2], Eva Magnuson[1,2], and Jenni Hammontree[1,2] (CARC Project Personnel) Phil Bruckner[1,3], and Jim Berg[1,3] (MSU Winter Wheat Breeding Program)

Montana State University[1]; Dep. Research Centers, Central Agricultural Research Center, Moccasin, MT[2]; Dep. Plant Sciences and Plant Pathology[3]

Summary

Agronomic performance was evaluated for 25 winter wheat varieties and experimental lines. Average yield for the winter wheat trial at Moccasin in 2019 was 71.2 bu/ac and average protein was 10.1%. Top yielding varieties at Moccasin included LCS Jet (86.0 bu/ac) and SY Clearstone (80.9 bu/ac). The top varieties for protein were Brawl CLP (10.9%), Decade (10.4%), and Warhorse (10.3%).

Introduction

Montana is one of the leading producers of winter wheat and the development of new and improved varieties is important for enhancing the economics of wheat production in the state. The objective of this study was to identify new varieties with enhanced yield, quality, and resistance to disease and pests compared to the most commonly grown varieties in central Montana.

Methods

On-farm winter wheat performance trials were established at Moccasin, Denton, Belt, Highwood, and Geraldine. Varieties were compared for height, propensity to lodge, heading date, yield, test weight, and protein. Each variety was planted in three 5 x 15 ft plots in a randomized experimental design to determine differences between varieties. Seeding dates were 27 September 2018 at Moccasin, 9 October at Highwood and Belt, and 25 October at Denton and Geraldine. Planting depth was 1 inch at a rate of 20 seeds/ft2. Starter fertilizer, 20-30-20-10 NPKS, was applied at seeding at a rate of 50 lb/ac. An additional 120 lb/ac of ESN (44:0:0) was broadcast applied at the CARC location on 23 May. Broadleaf and grass weeds were controlled with a burndown of glyphosate at 1.25 pt/ac prior to planting. Trials were also sprayed 23 May with Vendetta at 24 oz/ac for broadleaf control. Plots were harvested with a small-plot harvester on 14 August at Moccasin, 16 August at Belt and Highwood, 28 August at Geraldine, and 4 September at Denton.

Results and Discussion

Table 2 shows average heading date, yield, test weight, and protein for all named varieties tested. Winter wheat yields are reported at a moisture content of 13.5%. Average yield for all winter wheat trials (including experimental lines) at Moccasin in 2019 was 71.2 bu/ac. Top yielding varieties at Moccasin included LCS Jet (86.0 bu/ac), SY Clearstone (80.9 bu/ac), and Northern (79.4 bu/ac). Average protein was 10.1%. The top varieties for protein were Brawl CLP (10.9%), Decade (10.4%), and Warhorse (10.3%). Average heading date was 19 June which was 5 days later than last year, and Brawl had the earliest heading date on 14 June. No lodging was observed with any of the varieties. Gross returns per acre were also calculated for each variety and location based on prices and protein premiums and discounts obtained from United Grain Corporation on 19 November 2019. Average gross return at Moccasin was $312.34 per acre. Numerically, the highest gross return was obtained with LCS Jet ($380.90/ac). Note that this calculated return does not account for any expenses but does account for dockage and premiums associated with the test weight and protein.

Average yield at the Belt, MT location was 70.8 bu/ac. Top yielding varieties were Byrd CL Plus, a new entry for 2019, (89.6 bu/ac), SY Monument (76.2 bu/ac), and Loma (74.3 bu/ac). Average test weight was 63.0 lb/bu and average protein was 9.5%. No statistically significant difference in protein was observed between any of the varieties. Substantial sawfly damage was observed with many of the varieties at Belt this year (Table 3). Average gross return was $321.20/ac and differences in gross return were not statistically significant between varieties. At Geraldine, average yield was 77.2 bu/ac. Top performers for yield included Bryd CL Plus (85.7 bu/ac) and Northern (85.0 bu/ac). Differences in yield was not significant among the top 10 performers (Table 4). Average protein at Geraldine was 11.5% and the variety with the highest protein was Brawl CLP (13.0%). Average gross return at Geraldine was $339.80 per acre. Numerically, the highest gross return was obtained with Brawl CLP ($391.90/ac). Average yield at Denton, MT was 62.3 bu/ac (Table 5) and differences in yield were not significant among the top 6 varieties. Protein averaged 11.8% at Denton and differences in protein were not significant among the top 11 varieties. Average gross return at Denton was $282.00 per acre. Numerically, the highest gross return was obtained with Keldin ($332.90/ac). At Highwood, the average yield was 51.5 bu/ac (Table 6). Top performing varieties included a new entry for 2019, AAC Wildfire, (61.9 bu/ac) and SY Monument (60.6 bu/ac). Differences in yield was not significant among the top 7 performers. Average protein was 11.5% and differences in protein were not significant between the top 14 varieties. Average gross return at Highwood was $228.00/ac and differences in gross return were not statistically significant between varieties.

Acknowledgments

MSU winter wheat breeder Phil Bruckner and associate breeder Jim Berg coordinated the selection of entries and the preparation of seed for the on-farm variety trials. This work was supported by the Montana Wheat & Barley Committee and the Montana Agricultural Experiment Station for providing funding for this research through the USDA National Institute of Food and Agriculture, Hatch project 1015780. Additional information on variety trials can be found at

TABLE 2: 2019 WINTER WHEAT VARIETY TRIAL, MOCCASIN, MONTANA.

Variety/Pedigree	Year of Release	Source	Heading Date		Height	Test	Protein	Gross	Grain Yield (bu/ac)			
			cal	jul	(in)	(lb/bu)	(%)	($/ac)	2017	2018	2019	Avg
+ AAC Wildfire	2015	Alberta: SECAN	26-Jun	177	34.7	61.3	9.7	**349.40**			77.9	
Brawl CL Plus	2011	Colorado Research Foundation	14-Jun	165	28.9	**65.0**	**10.9**	266.39	61.4	59.1	63.1	61.2
+ Byrd CL Plus	2018	Plainsgold/Col. Wheat Res Fdn	17-Jun	169	32.2	61.0	9.0	**367.47**			76.2	
Decade	2010	Montana/North Dakota	18-Jun	169	33.0	**63.8**	**10.4**	296.12	58.2	59.3	72.0	63.2
FourOsix	2018	Montana (MT1465)	20-Jun	171	30.5	63.1	9.5	**337.09**		70.0	76.3	
Judee	2011	Montana	19-Jun	170	31.3	**64.5**	10.1	300.98	59.7	57.9	69.6	62.4
Keldin	2011	Westbred	23-Jun	174	31.6	**63.5**	9.6	**331.74**	**71.5**	66.3	73.0	70.3
LCS Jet	2015	Limagrain Cereal Seeds	19-Jun	170	29.0	59.9	8.8	**380.90**	-	**70.7**	**86.0**	
Loma	2016	Montana	20-Jun	171	30.5	63.0	9.6	**340.04**	55.7	**68.0**	71.6	65.1
MT1564 (Flathead)	2019	Montana	16-Jun	167	30.6	**64.0**	10.1	280.49			64.4	
MTS1588 (Bobcat)	2019	Montana	20-Jun	171	29.9	**63.7**	9.8	**348.82**			71.4	
Northern	2015	Montana	22-Jun	174	31.9	63.1	9.8	329.61	60.5	66.5	**79.4**	68.8
Ray	2018	Montana (MTF1432)	24-Jun	175	36.4	61.4	9.0	259.69	-	**78.9**	56.7	
SY Clearstone	2012	Montana/Syngenta	20-Jun	171	34.7	62.6	9.3	**347.32**	**68.5**	**67.8**	**80.6**	72.3
SY Monument	2015	Syngenta	18-Jun	169	29.6	63.4	9.6	**354.49**	**61.6**	**71.5**	77.6	70.2
Warhorse	1013	Montana	19-Jun	170	30.4	**63.6**	**10.3**	278.09	57.8	60.6	66.0	61.5
Yellowstone	2005	Montana	20-Jun	171	33.9	62.9	9.6	321.07	**63.1**	**68.7**	71.9	67.9
Average			19-Jun	170	30.5	63.2	10.1	312.34	60.3	65.5	71.2	
LSD (0.05)			2.5	2.5	2.3	1.7	0.6	50.5	10.0	10.4	9.4	
CV (%)			0.9	0.9	4.4	1.6	3.8	10.0	9.9	11.1	7.6	
P-value			<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.1119	0.0006	<0.0001	

+ = New for 2019

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 3: 2019 WINTER WHEAT VARIETY TRIAL, BELT, MONTANA

Variety/Pedigree	Year of Release	Source	Height (in)	Sawfly cutting (%)	Test Weight (lb/bu)	Protein (%)	Gross Return ($/ac)	Grain Yield (bu/ac)			
								2017	2018	2019	Avg
+ AAC Wildfire	2011	Montana	29.7	3.3	63.2	9.5	331.3			72.9	
Brawl CLP	2012	Montana/Syngenta	26.1	10.0	62.5	9.4	288.8	60.0	57.4	62.2	59.9
+ Byrd CL Plus	2015	Alberta: SECAN	29.6	13.3	62.7	9.6	421.2			**89.6**	
Decade	2019	Montana	29.9	3.3	63.2	9.6	308.2	49.5	**73.5**	68.2	63.7
FourOsix	2015	Montana	26.5	20.0	62.8	9.3	310.5		**71.4**	64.0	
Judee	2011	Westbred	28.4	3.3	**64.0**	9.5	313.9	47.0	70.2	70.9	62.7
Keldin	2005	Montana	27.2	20.0	62.6	9.5	269.5	50.6	**72.7**	57.7	60.3
LCS Jet	2016	Montana	23.6	16.7	59.6	9.5	322.9		**69.6**	68.7	
Loma	2010	Montana/North Dakota	26.6	3.3	63.8	9.6	329.9	45.4	**80.3**	**74.3**	66.7
MT1564 (Flathead)	2015	Syngenta	28.5	20.0	63.0	9.7	273.0			62.2	
MTS1588 (Bobcat)	2018	Plainsgold/Col. Wheat Res Fdn	27.4	0.0	63.6	9.5	339.5			**75.3**	
Northern	2018	Montana (MT1465)	27.9	20.0	63.8	9.5	327.0	51.6	70.3	73.1	65.0
Ray	2018	Montana (MTF1432)	32.8	33.3	62.4	9.2	281.8		65.6	62.6	
SY Clearstone 2CL	2019	Montana	29.9	30.0	62.2	9.5	301.7	56.4	**73.5**	64.5	64.8
SY Monument	2011	CO Research	25.7	10.0	62.1	9.4	352.7	50.5	**79.1**	**76.2**	68.6
Warhorse	1013	Montana	26.8	0.0	**63.9**	9.4	282.6	45.0	**73.4**	61.8	60.1
Yellowstone	2015	Limagrain Cereal Seeds	29.6	26.7	62.6	9.7	308.8	53.7	68.7	68.8	63.7
Average			28.1	13.3	63.0	9.5	321.2	51.1	70.9	70.8	
LSD (0.05)			2.7	9.0	1.0	0.6	87.4	N.S.	6.9	15.3	
CV (%)			5.4	41.2	0.9	3.5	16.6	55.0	9.0	12.3	
P-value			<0.0001	<0.0001	<0.0001	0.7050	0.1980	0.0840	0.0015	0.0239	

+ = New for 2019

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 4: 2019 WINTER WHEAT VARIETY TRIAL, GERALDINE, MONTANA

	Variety/Pedigree	Year of Release	Source	Height	Test Weight	Protein	Gross Return	Grain Yield (bu/ac)			
				(in)	(lb/bu)	(%)	($/ac)	2017	2018	2019	Avg
+	AAC Wildfire	2015	Alberta: SECAN	31.4	61.4	11.4	346.6			**79.5**	
	Brawl CLP	2011	Colorado Research Foundation	27.6	62.3	**13.0**	**391.9**	**83.8**	75.5	**80.9**	80.1
+	Byrd CL Plus	2018	Plainsgold/Col. Wheat Res Fdn	29.2	61.1	11.0	**367.6**			**85.4**	
	Decade	2010	Montana/North Dakota	33.1	61.4	11.6	347.3	**82.9**	**79.7**	**78.1**	80.2
	FourOsix	2018	Montana (MT1465)	29.2	61.2	11.5	311.6		70.0	69.9	70.0
	Judee	2011	Montana	28.5	**62.4**	11.6	321.9	71.1	78.9	72.4	74.1
	Keldin	2011	Westbred	29.9	61.6	11.3	**357.0**	**90.4**	**85.7**	**82.8**	86.3
	LCS Jet	2015	Limagrain Cereal Seeds	26.7	58.3	11.0	313.2		**82.9**	73.4	78.2
	Loma	2016	Montana	28.2	61.4	11.3	335.0	75.0	**80.0**	**77.6**	77.5
	MT1564 (Flathead)	2019	Montana	29.2	61.9	11.4	312.2			71.5	
	MTS1588 (Bobcat)	2019	Montana	27.3	61.2	11.7	316.2			70.5	
	Northern	2015	Montana	31.6	61.6	11.5	**379.1**	**84.0**	78.7	**85.0**	82.6
	Ray	2018	Montana (MTF1432)	36.1	60.1	11.6	277.7		76.2	61.7	
	SY Clearstone 2CL	2012	Montana/Syngenta	34.0	60.3	11.5	**366.5**	82.2	**81.1**	**84.1**	82.5
	SY Monument	2015	Syngenta	29.3	60.3	10.8	**356.3**	**88.1**	78.4	**84.8**	83.8
	Warhorse	1013	Montana	29.4	61.1	11.9	329.2	72.0	74.3	73.1	73.1
	Yellowstone	2005	Montana	31.2	60.9	11.1	331.0	**85.1**	74.3	**77.7**	79.0
	Average			29.8	61.3	11.5	339.8	82.1	76.9	77.2	
	LSD (0.05)			2.1	0.7	0.6	40.1	7.6	5.2	8.5	
	CV (%)			4.1	0.6	3.4	7.2	5.6	6.6	6.7	
	P-value			<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0004	

+ = New for 2019

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 5: 2019 WINTER WHEAT VARIETY TRIAL, DENTON, MONTANA

Variety/Pedigree	Year of Release	Source	Height	Test Weight	Protein	Gross Return	Grain Yield (bu/ac)			
			(in)	(lb/bu)	(%)	($/ac)	2017	2018	2019	Avg
+ AAC Wildfire	2015	Alberta: SECAN	32.2	58.5	**13.0**	**279.0**			59.4	
Brawl CLP	2011	Colorado Research Foundation	25.2	**61.8**	**13.0**	**276.1**	**49.0**	54.7	56.1	53.3
+ Byrd CL Plus	2018	Plainsgold/Col. Wheat Res Fdn	30.5	59.6	**11.7**	**307.8**			**65.9**	
Decade	2010	Montana/North Dakota	31.1	59.7	**12.9**	**320.9**	**41.9**	58.2	**67.4**	55.8
FourOsix	2018	Montana (MT1465)	27.7	59.0	**12.4**	**326.1**		50.6	**69.1**	
Judee	2011	Montana	29.4	60.1	**13.1**	**286.7**	37.3	51.6	56.5	48.5
Keldin	2011	Westbred	30.2	60.4	**12.8**	**332.9**	**46.0**	30.4	**70.1**	48.8
LCS Jet	2015	Limagrain Cereal Seeds	26.7	57.1	11.2	**284.9**		58.9	**66.5**	
Loma	2016	Montana	26.9	60.0	10.6	242.0	22.1	56.2	61.6	46.6
MT1564 (Flathead)	2019	Montana	27.9	60.6	**11.7**	249.4			54.2	
MTS1588 (Bobcat)	2019	Montana	26.4	60.9	11.1	256.5			60.8	
Northern	2015	Montana	28.7	61.0	11.1	269.3	37.3	53.0	**67.2**	52.5
Ray	2018	Montana (MTF1432)	35.6	58.8	**11.6**	261.4		48.6	58.2	
SY Clearstone 2CL	2012	Montana/Syngenta	32.9	59.2	**11.9**	**280.8**	40.3	61.2	59.7	53.7
SY Monument	2015	Syngenta	27.6	59.6	11.1	265.2	36.1	53.3	60.1	49.8
Warhorse	1013	Montana	27.9	60.5	**11.7**	**276.0**	34.3	54.8	61.8	50.3
Yellowstone	2005	Montana	31.4	60.2	10.5	227.3	40.3	51.8	59.4	50.5
Average			29.2	60.1	11.8	282.0	39.2	53.7	62.3	
LSD (0.05)			1.6	1.3	1.6	57.8	8.2	22.5	7.5	
CV (%)			2.9	1.2	8.3	12.5	12.8	19.8	6.6	
P-value			<0.0001	<0.0001	0.0300	0.0270	<0.0001	0.5000	0.0062	

+ = New for 2019

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 6: 2019 WINTER WHEAT VARIETY TRIAL, HIGHWOOD, MONTANA

Variety/Pedigree	Year of Release	Source	Height	Test Weight	Protein	Gross Return	Grain Yield (bu/ac)			
			(in)	(lb/bu)	(%)	($/bu)	2017	2018	2019	Avg
+ AAC Wildfire	2015	Alberta: SECAN	29.8	**62.4**	**11.3**	268.5			**61.9**	**-**
Brawl CLP	2011	Colorado Research Foundation	23.0	**62.4**	**12.1**	178.7	35.6	21.5	38.5	31.9
+ Byrd CL Plus	2018	Plainsgold/Col. Wheat Res Fdn	27.3	61.9	10.6	249.7			**58.8**	
Decade	2010	Montana/North Dakota	29.1	61.4	**11.5**	247.8	64.2	**45.2**	**57.5**	55.6
FourOsix	2018	Montana (MT1465)	26.7	61.6	**11.1**	240.6		38.9	53.3	
Judee	2011	Montana	25.1	**63.0**	**11.7**	221.3	56.5	**50.8**	49.7	52.3
Keldin	2011	Westbred	26.8	60.9	**11.7**	215.8	55.4	32.6	44.4	44.1
LCS Jet	2015	Limagrain Cereal Seeds	22.4	59.4	**11.0**	189.5		39.4	49.0	
Loma	2016	Montana	24.9	61.5	**11.8**	272.1	60.9	36.6	**55.2**	50.9
MT1564 (Flathead)	2019	Montana	26.9	62.0	**12.1**	199.6			42.1	
MTS1588 (Bobcat)	2019	Montana	25.0	59.4	**11.9**	209.9			44.7	
Northern	2015	Montana	26.8	61.7	**11.1**	245.6	60.5	33.8	**58.3**	50.9
Ray	2018	Montana (MTF1432)	32.3	60.5	**12.0**	210.4		31.1	42.1	
SY Clearstone 2CL	2012	Montana/Syngenta	29.9	61.1	10.8	233.5	67.6	**45.9**	**55.7**	56.4
SY Monument	2015	Syngenta	26.9	60.9	**10.9**	239.3	65.0	46.4	**60.6**	57.3
Warhorse	1013	Montana	26.5	61.4	**12.1**	234.7	51.2	43.3	47.9	47.5
Yellowstone	2005	Montana	29.3	61.4	10.6	249.4	53.2	35.2	**54.2**	47.5
Average			26.7	61.5	11.5	228.0	57.2	36.4	51.5	
LSD (0.05)			2.1	1.2	1.3	55.1	8.9	8.79	8.6	
CV (%)			4.4	1.2	6.8	14.7	8.4	13.3	9.1	
P-value			<0.0001	<0.0001	0.0280	0.0730	<0.0001	<0.0001	<0.0001	

+ = New for 2019

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

SPRING WHEAT VARIETY TRIAL

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Summary

Agronomic performance was evaluated for 23 spring wheat varieties and experimental lines. Average yield for all spring wheat trials at Moccasin in 2019 was 51.4 bu/ac. Varietal differences in yield were not detected ($P > 0.05$). Average heading date was 5 July. Off station location spring wheat trials yielded an average of 38.3 bu/ac at Denton, 47.9 bu/ac at Geraldine, and 43.4 bu/ac at Highwood.

Introduction

Spring wheat is an important crop throughout Montana. Ongoing breeding programs are focused on improving the performance of spring wheat varieties. Performance targets include yield, protein, lodging, and heading date that improved relative to the most commonly grown varieties, as well as increased resistance to pathogens and insects.

Methods

Off-station spring wheat variety trials were established at Moccasin, Denton, Geraldine and Highwood. The Moccasin trials were established at a site that was planted in a pea/lentil cover crop the previous year. Twenty-three varieties were compared for height, propensity to lodge, heading date, yield, test weight, and protein. Each variety was planted in three 5 x 15 ft plots in a randomized experimental design to determine differences between varieties. Seeding dates were 25 April at Moccasin, 9 May at Geraldine, 10 May at Denton, and 13 May at Highwood. Planting depth was 1 inch at a rate of 20 seeds/ft2. Starter fertilizer, 20-30-20-10 NPKS, was applied at seeding at a rate of 50 lb/ac. An additional 80 lb/ac of urea was broadcast applied on 21 May. Broadleaf and grass weeds were controlled with a burndown of glyphosate at 1.25 pt/acre prior to planting. Trials were also sprayed 30 May with Curtail M at 28 oz/ac for Canada thistle and broadleaf control. Plots were harvested with a small-plot harvester on 28 August at Geraldine, 5 September at Highwood, 16 September at Denton, and 18 September at Moccasin.

Results and Discussion

Table 7 shows the average height, yield, and test weight for the named varieties tested at the Moccasin location. The average yield for the spring wheat trial at Moccasin in 2019 was 51.4 bu/ac. Differences in grain yield were not significant across the varieties ($p>0.05$). The average heading date was 5 July with the earliest varieties heading on 3 July. Average yield for all varieties at Denton was 38.2 bu/ac (Table 8). The top yielding varieties were Vida (44.8 bu/ac), Lanning (43.7 bu/ac), NS Presser CLP (41.9 bu/ac), Duclair (41.7 bu/ac), MS Barracuda (41.3), Reeder (40.5 bu/ac). Average yield for varieties at Geraldine was 47.9 bu/ac, a dramatic drop from last year's average of 71.2 bu/ac (Table 9). This could be due to the sawfly damage observed at this location. The top yielding variety at Geraldine was Vida at 55.0 bu/ac. Average protein at Geraldine was 13.3%. Top varieties for protein were Egan (14.7%), and SY Soren (14.0%). Average yield for all varieties at Highwood was 43.4 bu/ac (Table 10). No statistically significant difference was observed between varieties (p= 0.3150). Only the Geraldine location had protein values available at the time this report was prepared.

Acknowledgements

MSU spring wheat breeder Luther Talbert coordinated the selection of entries and the preparation of seed for the on-farm cultivar trials. This work was supported by the Montana Wheat & Barley Committee and the Montana Agricultural Experiment Station for providing funding for this research through the USDA National Institute of Food and Agriculture, Hatch project 1015780. Additional information on variety trials can be found at http://agresearch.montana.edu/carc/.

TABLE 7: 2019 SPRING WHEAT VARIETY TRIAL, MOCCASIN, MONTANA

Variety/Pedigree	Year of Release	Source	Heading date		Height	Test	Grain Yield (bu/ac)			
			cal	jul	(in)	(lb/bu)	2017	2018	2019	3 yr
ALUM	2014	WSU	7-Jul	188	31.0	55.5	29.6	48.3	45.4	41.1
MS Barracuda		Meridian Seeds	3-Jul	184	29.3	**57.3**		43.7	56.9	
BRENNAN	2009	Syngenta/AgriPro	4-Jul	185	29.3	**58.9**	35.2	39.2	52.2	42.2
MS Camaro		Meridian Seeds	4-Jul	185	29.0	**58.5**	33.4	35.8	50.1	39.8
MS Cheville		Meridian Seeds	5-Jul	186	30.0	53.6	33.8	49.1	47.1	43.3
CHOTEAU	2003	MAES	6-Jul	187	30.3	55.2	28.3	43.1	47.0	39.5
CORBIN	2006	Westbred, LLC	5-Jul	186	32.3	55.7	31.1	46.0	48.0	41.7
DUCLAIR	2011	MAES	4-Jul	185	31.7	54.0	32.1	50.8	48.4	43.8
EGAN	2013	Westbred, LLC	7-Jul	188	31.7	55.9	32.5	43.5	57.9	44.6
FORTUNA	1966	MAES/NDSU	8-Jul	189	39.3	55.2	39.5	40.5	43.5	41.2
LANNING	2016	MAES	3-Jul	184	30.0	56.4	33.8	43.0	56.4	44.4
LCS PRO	2015	LIMAGRAIN	5-Jul	186	35.3	55.2	30.1	42.7	55.2	42.7
NS PRESSER CLP	2016	MAES	8-Jul	189	31.3	53.7	32.1	50.7	52.9	45.2
REEDER	1999	NDSU	7-Jul	188	33.0	**56.7**	33.0	48.2	49.3	43.5
SY INGMAR	2015	Syngenta/AgriPro	7-Jul	188	31.3	56.4	33.7	40.7	58.5	44.3
SY SOREN	2011	Syngenta/AgriPro	5-Jul	186	27.7	55.9	31.2	45.4	52.3	43.0
VIDA	2005	MAES	7-Jul	188	31.7	54.3	31.1	50.0	55.1	45.4
WB GUNNISON	2011	Westbred, LLC	5-Jul	186	29.0	56.2	32.7	48.0	48.4	43.0
Average			5-Jul	186	31.3	55.6	32.0	44.5	51.4	
LSD (0.05)			1.5	1.5	2.3	2.5	N.S.	N.S.	15.0	
CV (%)			0.5	0.5	4.5	2.7	8.4	11.4	4.5	
P-value			<0.0001	<0.0001	<0.0001	<0.0001	0.3672	0.0570	0.5620	

+ = New for 2019
Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD)
Note: Study averages include experimental lines not listed here.
N.S. = Not Significant

TABLE 8: 2019 SPRING WHEAT VARIETY TRIAL, DENTON, MONTANA

Variety/Pedigree	Year of Release	Source	Height	Test Weight	Grain Yield (bu/ac)			
			(in)	(lb/bu)	2017	2018	2019	3 yr avg
ALUM	2014	WSU	26.0	**59.2**	18.2	34.1	37.1	29.8
MS Barracuda		Meridian Seeds	26.7	58.3		29.6	**41.3**	
BRENNAN	2009	Syngenta/AgriPr	28.0	**59.1**	20.5	26.8	32.4	26.6
MS Camaro		Meridian Seeds	27.3	**59.1**	26.0	26.3	35.4	29.2
MS Cheville		Meridian Seeds	26.7	57.7	35.8	34.9	37.8	36.2
CHOTEAU	2003	MAES	26.3	57.6	20.1	28.3	**38.3**	28.9
CORBIN	2006	Westbred, LLC	26.7	56.4	18.2	29.7	34.0	27.3
DUCLAIR	2011	MAES	26.7	58.3	21.8	29.5	**41.7**	31.0
EGAN	2013	Westbred, LLC	28.7	58.2	18.6	25.4	35.4	26.5
FORTUNA	1966	MAES/NDSU	31.7	56.8	16.9	29.7	31.3	26.0
LANNING	2016	MAES	29.0	**58.7**	21.5	29.6	**43.7**	31.6
LCS PRO	2015	LIMAGRAIN	29.3	**58.7**	19.0	30.6	35.5	28.4
NS PRESSER CLP	2016	MAES	27.7	57.8	16.6	29.7	**41.9**	29.4
REEDER	1999	NDSU	28.7	**59.3**	17.2	27.8	**40.5**	28.5
SY INGMAR	2015	Syngenta/AgriPr	26.3	**59.0**	16.1	18.1	35.0	23.1
SY SOREN	2011	Syngenta/AgriPr	29.0	**58.5**	17.5	27.9	**38.6**	28.0
VIDA	2005	MAES	27.3	57.5	19.8	31.5	**44.8**	32.0
WB GUNNISON	2011	Westbred, LLC	28.0	**60.1**	19.3	30.5	**39.9**	29.9
Average			27.8	58.2	20.0	29.1	38.2	
LSD (0.05)			2.7	1.8	N.S.	N.S.	7.0	
CV (%)			5.9	1.9	15.2	14.6	11.2	
P-value			0.0380	0.0090	<0.0001	0.0500	0.0390	

+ = New for 2019

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 9: 2019 SPRING WHEAT VARIETY TRIAL, GERALDINE, MONTANA

Variety/Pedigree	Year of Release	Source	Height	Test Weight	Protein	Grain Yield (bu/ac)		
			(in)	(lb/bu)	(%)	2018	2019	2 yr avg
ALUM	2014	WSU	30.0	**61.9**	12.7	67.2	47.1	57.2
MS Barracuda		Meridian Seeds	27.0	**60.3**	13.1	70.0	47.6	58.8
BRENNAN	2009	Syngenta/AgriPro	29.0	**61.9**	**14.0**	67.0	48.0	57.5
MS Camaro		Meridian Seeds	28.0	**62.3**	13.7	62.8	46.2	54.5
MS Cheville		Meridian Seeds	28.0	**60.3**	12.3	79.5	50.7	65.1
CHOTEAU	2003	MAES	29.0	60.1	13.4	**79.1**	46.6	62.9
CORBIN	2006	Westbred, LLC	28.7	59.8	13.5	**76.8**	45.4	61.1
DUCLAIR	2011	MAES	29.0	59.9	12.9	**70.6**	47.0	58.8
EGAN	2013	Westbred, LLC	31.3	59.3	**14.7**	68.1	48.8	58.5
FORTUNA	1966	MAES/NDSU	35.0	60.9	13.5	59.1	41.7	50.4
LANNING	2016	MAES	29.0	59.9	13.1	70.6	49.8	60.2
LCS PRO	2015	LIMAGRAIN	31.0	59.8	13.2	**73.2**	47.2	60.2
NS PRESSER	2016	MAES	31.0	58.7	12.3	**72.7**	46.9	59.8
REEDER	1999	NDSU	31.3	60.8	13.5	71.3	48.7	60.0
SY INGMAR	2015	Syngenta/AgriPro	28.7	**61.8**	13.6	67.2	48.7	58.0
SY SOREN	2011	Syngenta/AgriPro	28.3	60.2	**14.0**	**73.9**	48.4	61.2
VIDA	2005	MAES	29.3	60.3	12.2	**82.0**	**55.0**	68.5
WB GUNNISON	2011	Westbred, LLC	28.0	**61.3**	12.8		43.3	43.3
Average			29.8	60.3	13.3	71.2	47.9	
LSD (0.05)			1.2	1.0	0.9	10.5	4.5	
CV (%)			2.6	1.0	4.1	9.0	5.7	
P-value			<0.0001	<0.0001	<0.0001	0.0050	0.0005	

+ = New for 2019
Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test
Note: Study averages include experimental lines not listed here.
N.S. = Not Significant

TABLE 10: 2019 SPRING WHEAT VARIETY TRIAL, HIGHWOOD, MONTANA

Variety/Pedigree	Year of Release	Source	Height	Test Weight	Grain Yield (bu/ac)			
			(in)	(lb/bu)	2017	2018	2019	3 yr avg
ALUM	2014	WSU	23.7	61.5	**37.7**	39.7	42.5	40.0
BRENNAN	2009	Syngenta/AgriPr	23.3	62.6	27.6	32.9	40.0	33.5
CHOTEAU	2003	MAES	24.3	63.1	**37.7**	39.8	40.1	39.2
CORBIN	2006	Westbred, LLC	23.3	61.8	28.6	37.2	46.4	37.4
DUCLAIR	2011	MAES	22.0	62.5	32.0	35.1	41.6	36.2
EGAN	2013	Westbred, LLC	22.7	61.6	**37.5**	39.9	51.9	43.1
FORTUNA	1966	MAES/NDSU	23.7	61.9	30.1	35.0	43.6	36.2
LANNING	2016	MAES	24.7	62.5	**40.3**	37.0	45.0	40.8
LCS PRO	2015	LIMAGRAIN	23.0	62.5	31.2	42.1	42.5	38.6
NS PRESSER	2016	MAES	22.3	62.6	**34.7**	40.8	43.9	39.8
REEDER	1999	NDSU	26.3	62.0	**37.0**	44.7	36.9	39.5
SY INGMAR	2015	Syngenta/AgriPr	23.7	62.6	**37.8**	44.8	44.4	42.3
SY SOREN	2011	Syngenta/AgriPr	24.7	62.8	**34.2**	24.3	43.7	34.1
VIDA	2005	MAES	24.0	62.5	**34.9**	36.7	44.5	38.7
WB GUNNISON	2011	Westbred, LLC	22.7	63.0	29.7	25.7	42.7	32.7
Average			23.7	62.3	32.5	34.9	43.4	
LSD (0.05)			2.8	1.7	7.0	N.S.	9.3	
CV (%)			7.2	1.6	13.1	24.0	12.9	
P-value			0.4710	0.5310	<0.0001	0.0580	0.3150	

+ = New for 2019
Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test
Note: Study averages include experimental lines not listed here.
N.S. = Not Significant

SPRING BARLEY VARIETY TRIAL

Jed Eberly[1,2], Eva Magnuson[1,2], and Jenni Hammontree[1,2] (CARC Project Personnel)

Jamie Sherman[1,3] (MSU Barley Breeding Program)

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Summary

Agronomic performance was evaluated for 25 barley varieties and experimental lines. Barley yields are reported on a moisture content of 14.5%. The top average yielding location for all barley varieties was Moccasin at was 67.5 bu/ac.

Introduction

Barley is an important agriculture commodity in Montana for feed, food, and malt. The MSU barley breeding program is focused on developing improved varieties of both hulled and hull-less barley varieties for food, malting, and feed.

Methods

The barley variety trial tested the agronomic performance and potential of 25 varieties and experimental lines. Both malt and feed varieties were evaluated. Off-Station variety trials were established at Denton, and Geraldine. The Moccasin trials were established at a site that was planted in a pea/lentil cover crop the previous year. Varieties were compared for height, propensity to lodge, heading date, yield, test weight, and protein. Each variety was planted in three 5 x 15 ft plots in a randomized experimental design to determine differences between varieties. Seeding dates were 19 April at Moccasin, 9 May at Geraldine, and 10 May at Denton. Planting depth was 1 inch at a rate of 20 seeds/ft2. Starter fertilizer, 20-30-20-10 NPKS, was applied at seeding at a rate of 50 lb/ac. Broadleaf and grass weeds were controlled with a burndown of glyphosate at 1.25 pt/acre prior to planting. Trials were also sprayed 23 May with Curtail M at 28 oz/ac for Canada thistle and broadleaf control. Plots were harvested with a small-plot harvester on 28 August at Geraldine, 29 August at Moccasin, and 16 September at Denton.

Results and Discussion

The average yield for all barley varieties at Moccasin was 67.5 bu/ac (Table 11). Odyssey was the top yielding variety and differences in yield were not significant among the 8 top yielders which included AAC Connect, Balster, Champion, Craft, Expedition, Fraser, Haxby, and Hockett. Plump kernel average was 87.2% with Synergy (96.7%), Craft (96.0%), and Fraser (94.6%) having the highest percentage of plump kernels. Genie (61.7 bu/ac), was numerically the top yield variety at Denton but yield differences were not significant among the top 10 varieties. The average yield at Denton was 52.0 bu/ac (Table 12). Average plump kernel percentage was 62.5% with no statistical difference in varieties. Geraldine average yield was 63.6 bu/ac (Table 13) and yield differences were not statistically significant among any of the varieties. Plump kernels averaged 74.7% and differences in plump kernel percentages were not significant among the top 13 varieties.

Acknowledgements

MSU barley breeder Jamie Sherman coordinated the selection of entries and the preparation of seed for the on-farm cultivar trials. This work was supported by the Montana Wheat & Barley Committee and the Montana Agricultural Experiment Station for providing funding for this research through the USDA National Institute of Food and Agriculture, Hatch project 1015780. Additional information on variety trials can be found at http://agresearch.montana.edu/carc/

TABLE 11: 2019 BARLEY VARIETY TRIAL, MOCCASIN, MONTANA

Variety/Pedigree	Year of Release	Source	Height	Test	Plumps	Grain Yield (bu/ac)			
			(in)	(lb/bu)		2017	2018	2019	Avg
AAC Connect	2016	Meridian	22.7	52.9	82.5		47.7	**72.5**	60.1
Balster			24.3	52.9	**90.0**	32.0		**73.7**	52.9
Champion	2007		24.7	**56.3**	**91.9**	38.3	50.5	**74.9**	54.6
Conrad	2007		24.7	52.9	**90.3**	37.4		68.5	53.0
Copeland			27.3	54.2	**89.7**	38.7		66.2	52.5
+ Craft			27.3	**56.0**	**96.0**			**71.8**	71.8
+ Expedition			21.3	54.9	88.5			**73.7**	73.7
Fraser	2015	CDC	24.3	52.6	**94.6**			**76.8**	76.8
Genie			22.0	53.9	87.2	37.9		68.3	53.1
Growler			23.7	53.3	83.6	28.0		62.6	45.3
Haxby	2003	MAES	23.0	**56.0**	87.4	34.3	49.9	**72.8**	52.3
Haybet	1989	MAES/USDA	29.7	53.5	59.7	33.7		47.0	40.4
Hays	2003	MAES	23.7	52.4	76.9	33.8		67.8	50.8
Hockett	2008	MAES	25.3	55.7	**92.1**	34.8	52.6	**69.7**	52.4
Lavina	1989	MAES/USDA	25.3	52.7	69.8	36.3		62.7	49.5
Merit 57			25.0	52.8	83.2	28.8	53.9	66.7	49.8
Metcalfe		Canada	26.0	54.7	84.0	36.9	45.7	65.4	49.3
Odyssey			21.3	53.5	81.5	34.3		**79.0**	56.6
+ Opera			21.0	52.4	73.1		62.3	75.4	68.8
Synergy			24.7	53.7	**96.7**	34.6		69.6	52.1
+ Voyager			24.0	53.6	**93.0**			66.8	66.8
Average			24.3	54.2	87.2	34.3	52.5	67.5	
LSD (0.05)			1.9	1.4	7.8	N.S.	9.7	10.4	
CV (%)			4.7	1.6	5.4	15.8	11.5	9.4	
P-value			<0.0001	<0.0001	<0.0001	0.5901	<0.0001	<0.0001	

+ = New for 2019

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 12: 2019 BARLEY VARIETY TRIAL, DENTON, MONTANA

Variety/Pedigree	Year of Release	Source	Height (in)	Test Weight (lb/bu)	Plumps	Grain Yield (bu/ac)			
						2017	2018	2019	Avg
AAC Connect	2016	Meridian	26.0	50.0	54.6		48.9	**58.9**	53.9
Balster			26.0	49.3	47.1	**27.5**	55.3	49.0	43.9
Champion	2007		27.3	**53.7**	61.7	**32.6**	46.7	**60.6**	46.6
Conrad	2007		26.7	51.1	61.4	**30.1**	48.6	48.8	42.5
Copeland			28.3	50.4	69.2	10.4	43.1	51.7	35.1
+ Craft			27.7	**55.1**	82.0			**51.8**	51.8
+ Expedition			23.0	50.5	44.5			51.0	51.0
Fraser	2015	CDC	26.7	48.5	48.5		49.1	52.5	50.8
Genie			25.0	51.9	59.6		50.6	**61.7**	56.2
Growler			26.7	49.5	49.6		50.7	51.1	50.9
Haxby	2003	MAES	26.0	**53.6**	70.0	**31.9**	55.5	**59.8**	49.1
Haybet	1989	MAES/USDA	31.0	52.9	35.3	**29.1**	45.1	41.1	38.4
Hays	2003	MAES	28.0	50.2	39.7	26.0	49.0	50.9	42.0
Hockett	2008	MAES	26.3	**54.5**	78.7	**30.6**	51.3	**52.2**	44.7
Lavina	1989	MAES/USDA	29.0	51.0	39.0	**27.5**	54.5	**54.7**	45.6
Merit 57			26.7	50.4	38.0	22.9	50.0	45.2	39.4
Metcalfe		Canada	28.0	**54.1**	74.7	**31.6**	45.2	**53.4**	43.4
Odyssey			22.0	52.2	51.4	**30.1**	50.4	**54.4**	45.0
+ Opera			22.7	48.6	36.2		-	49.7	49.7
Synergy			28.0	51.5	76.1	**30.1**	-	**54.1**	42.1
+ Voyager			26.7	50.7	72.5			50.5	50.5
Average			26.3	51.8	62.5	27.8	48.6	52.0	
LSD (0.05)			2.0	2.2	18.8	6.1	N.S.	10.0	
CV (%)			4.7	2.6	18.3	13.3	15.7	11.8	
P-value			<0.0001	<0.0001	<0.0001	<0.0001	0.3670	0.0456	

+ = New for 2019

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines.

N.S. = Not Significant

Table 13: **2019 Barley Variety Trial, Geraldine, Montana**

Variety/Pedigree	Year of Release	Source	Height (in)	Test Weight (lb/bu)	Plumps	Grain Yield (bu/ac)		
						2018	2019	2 yr avg
AAC Connect	2016	Meridian	24.0	**54.0**	**71.3**	**97.9**	68.4	83.2
Balster			24.0	**54.2**	**84.1**	93.6	65.6	79.6
Champion	2007		24.7	**56.6**	**78.5**	**94.6**	68.9	81.8
Conrad	2007		25.0	53.6	**77.5**	**95.9**	67.8	81.9
Copeland			26.7	53.5	**79.6**	85.6	63.0	74.3
+ Craft			25.0	**56.1**	**86.8**		60.9	60.9
+ Expedition			21.3	**54.9**	**83.8**		73.7	73.7
Fraser	2015	CDC	24.7	53.6	**74.7**	**99.8**	68.4	84.1
Genie			22.7	**54.8**	**73.5**	**95.7**	71.5	83.6
Growler			24.3	52.1	**81.9**	**94.0**	67.7	80.9
Haxby	2003	MAES	22.0	**56.0**	**75.6**	**101.5**	66.3	83.9
Haybet	1989	MAES/USDA	25.3	**54.0**	35.4	62.9	47.6	55.3
Hays	2003	MAES	24.7	51.8	47.0	89.4	60.8	75.1
Hockett	2008	MAES	23.0	53.5	70.1	88.9	64.2	76.6
Lavina	1989	MAES/USDA	25.7	**54.1**	55.6	81.5	63.4	72.5
Merit 57			25.7	52.7	50.0	**111.0**	62.8	86.9
Metcalfe		Canada	26.7	52.9	61.9	92.4	55.4	73.9
Odyssey			21.7	53.8	67.4	86.7	61.8	74.3
+ Opera			21.0	53.6	67.8	-	63.4	63.4
Synergy			26.0	53.4	**83.5**	-	65.8	65.8
+ Voyager			26.3	**54.5**	**88.3**		70.4	70.4
Average			24.1	54.4	74.7	93.0	63.6	
LSD (0.05)			2.5	2.2	17.3	17.1	14.1	
CV (%)			6.3	2.4	14.1	11.2	13.5	
P-value			0.0001	0.0002	<0.0001	0.0030	0.1000	

+ = New for 2019

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

DURUM VARIETY TRIAL

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Summary

Agronomic performance was evaluated for 24 durum varieties and experimental lines. Average yield for the durum trial at Moccasin in 2019 was 45.6 bu/ac and average protein was 13.3%.

Introduction

Durum wheat is an important crop in Montana. The objective of this study was to identify new varieties with enhanced yield, quality, and resistance to disease and pests compared to the most commonly grown varieties in central Montana.

Methods

A durum variety trial was established at Moccasin, MT. Varieties were compared for height, propensity to lodge, heading date, yield, test weight, and protein. Each variety was planted in three 5 x 15 ft plots in a randomized experimental design to determine differences between varieties. The trial was planted 23 April. Planting depth was 1 inch at a rate of 20 seeds/ft^2. Starter fertilizer, 20-30-20-10 NPKS, was applied at seeding at a rate of 50 lb/ac. An additional 120 lb/ac of ESN (44:0:0) was broadcast applied on 23 May. Broadleaf and grass weeds were controlled with a burndown of glyphosate at 1.25 pt/ac prior to planting. Trials were also sprayed 23 May with Vendetta at 24 oz/ac for broadleaf control. Plots were harvested with a small-plot harvester on 13 September.

Results and Discussion

Average yield for all the durum varieties was 45.6 bu/ac and average protein was 13.3%. There were no significant differences in yield or protein among the varieties tested.

Acknowledgements

Durum breeder Mike Giroux and research associate Andy Hogg coordinated the selection of entries and the preparation of seed for the variety trial. This work was supported by the Montana Wheat & Barley Committee and the Montana Agricultural Experiment Station for providing funding for this research through the USDA National Institute of Food and Agriculture, Hatch project 1015780. Additional information on variety trials can be found at http://agresearch.montana.edu/carc/.

TABLE 14: 2019 DURUM VARIETY TRIAL, MOCCASIN, MT

Variety/Pedigree	Year of Release	Source	Height	Test	Protein	Grain Yield (bu/ac)	
			(in)	(lb/bu)	(%)	2018	2019
Alkabo	2005	NDSU	35.3	**59.2**	13.3	51.7	43.3
Alzada	2004	Westbred	29.3	58.3	12.8	51.3	46.8
Carpio	2012	NDSU	36.3	57.9	13.1	49.1	42.4
Divide	2005	NDSU	37.3	57.8	13.1	46.8	52.8
Dynamic	2016	CDC	35.7	58.2	13.5	49.2	45.0
Fortitude	2015	CDC	35.3	**58.4**	13.7	56.2	44.8
Grano			36.0	**58.4**	13.3		44.1
Grenora	2005	NDSU	33.3	57.4	13.2	53.9	45.5
Joppa	2013	NDSU	39.3	58.3	13.5	47.5	47.7
Mountrail	1998	NDSU	36.7	58.3	13.4	50.9	46.1
Precision	2016	CDC	36.3	**58.7**	13.4	52.1	45.3
Riveland			38.7	57.9	13.8		48.4
Tioga	2010	NDSU	39.0	57.8	13.3	46.0	44.1
Vivid	2013	CDC	35.7	**58.7**	13.7	51.7	45.1
Average			36.5	57.8	13.3	50.5	45.6
LSD (0.05)			1.7	0.9	0.9	7	8.6
CV (%)			2.9	0.9	4.1	8.4	11.5
P-value			<0.0001	<0.0001	0.3710	0.0050	0.6660

+ = New for 2019

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

ALTERNATIVE CROP VARIETY TRIALS

SPRING FIELD PEA VARIETY TRIAL

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Summary

Montana's dry pea acreage increased 46% from 2018 to 2019. The pea acreage bump comes after a 14% decline from 2016 to 2017 and a 36% decline from 2017 to 2018, perhaps reflecting a renewed interest in pea as a rotation crop. This increased interest in field pea warrants an evaluation of varietal performance in Montana's unique growing environments. Here, we evaluated agronomic performance of 27 varieties and experimental lines in a small plot trial at the Central Agricultural Research Center. On average cultivars yielded 2,255.3 lb/ac, down from 2,813.2 lb/ac in 2018.

Introduction

Pea green fallow-wheat rotations can reduce uncertainty of economic returns when compared to wheat-only systems. Field pea also improves soil fertility and breaks pest cycles when incorporated into wheat-fallow or wheat-only systems. The objective of this study is to identify spring pea varieties that might outperform those currently being grown commercially in central Montana.

Methods

Twenty-seven varieties and experimental lines were compared for height, propensity to lodge, vine length, date of 50% flowering, grain yield, test weight, and seed weight. Each cultivar was planted in four, 5x15 ft plots in an experimental design to determine varietal differences. The study was located in a field where an alfalfa/grass mix had been established for several years prior to cultivation in fall of 2018. Peas were planted on 23 April at a depth of 1 inch and at a rate of 8 PLS/ft2 using a low-disturbance, double-disc plot drill. Soil temperature at time of planting was 48°F. Broadleaf and grass weeds were controlled with a pre-plant burn down of RT3 (i.e., glyphosate) at 36 fl oz/ac on 18 April and a single application of Raptor (i.e., imazamox) at 4 fl oz/ac tank mixed with Basagran (i.e., generic bentazon) at 13 fl oz/ac was made on 11 June. Grizzly Too at 1.9 fl oz/ac was applied on 23 May for the control of pea leaf weevil. Plots were harvested on 14 August.

Results and discussion

Respective averages of green and yellow type cultivars were 2,061.4 and 2,315.9 lb/ac in this year's trial, compared to 2,693.2 and 2,830.2 lb/ac in 2018. Based on 2-yr averages, Hampton (2,622.4 lb/ac) was the highest yielding cultivar among green types and AAC Carver (2,836 lb/ac) was the highest yielding cultivar among yellow types.

In 2019, two cultivars yielded statistically equivalent to the top performer, AAC Carver (2,704.2 lb/ac). These were DS Admiral (2,556.6 lb/ac) and AC Earlystar (2,551.5 lb/ac). Lodging was a factor in this year's trial, averaging 19% across all cultivars. Specifically, four cultivars were shown to lodge at statistically higher percentages than AC Earlystar and CDC Greenwater, which exhibited minimal lodging (4%) this year. The lodged cultivars were Navarro (25%), Aragorn (36%), Delta (49%), and Hampton (70%). Two of these cultivars, Hampton and Aragorn, have lodged at statistically higher percentages for two years in a row. AAC Carver was among the tallest cultivars at flowering (i.e. vine length), while CDC Amarillo was among the tallest at maturity (i.e., canopy height). Regarding hundred seed weight, Salamanca (24.2 g), Navarro (24.5 g), and AAC Comfort (24.6 g) were the top performing cultivars in this year's trial. Navarro and AAC Comfort were the top performers for seed weight in 2018 as well. Spider was among the top performers for test weight at 65.8 lb/bu. Aragorn and Navarro were the first to flower (2 July) and AAC comfort was the last (8 July), 70 and 76 days after planting, respectively.

Cool, wet conditions from flowering to maturity led to the development of Ascochyta blight on several cultivars in 2019. Disease severity for each plot was ranked 1 to 5 from low to high severity. Five cultivars were shown to have statistically higher disease scores than AAC Profit, AC Earlystar, CDC Amarillo, CDC Greenwater, CDC Inca, Hampton, Hyline, and Salamanca, which showed no sign of the disease. The susceptible cultivars were AAC Comfort (1.8), Aragorn (1.8), DS Admiral (2), Bridger (2.2), and Delta (3.8).

Acknowledgments

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TABLE 15. 2019 MONTANA STATE UNIVERSITY SPRING PEA VARIETY TRIAL SUMMARIZED RESULTS FROM THE CENTRAL AGRICULTURAL RESEARCH CENTER, MOCCASIN, MT.

CULTIVAR	COTYL TYPE	FLWR DATE (julian)	CNPY HT (in)	VINE LTH (in)	ASCOCH BLIGHT (1 5)	LDGE (%)	TEST WT (lb/bu)	100 SEED (g)	YIELD		
									2018	2019 (lb/ac)	AVG
AAC Carver	Yellow	185.8	**24**	**32.5**	**1.5**	**6**	64	21.8	**2967.7**	**2704.2**	2836.0
AAC Comfort	Green	189.8	20.2	26.8	1.8	**20**	**65.5**	**24.6**	**2844**	1949.5	2396.8
AAC Profit	Yellow	189	**24.5**	**31.2**	**1**	**8**	65	20.9	2582.9	2198.3	2390.6
AC Agassiz	Yellow	187.8	**22.8**	28	**1.5**	**16**	62.7	21.2	2736.1	2389.7	2562.9
AC Earlystar	Yellow	186.2	**23.5**	30	**1**	**4**	63.5	20.6	**2848.8**	**2551.5**	2700.2
Aragorn	Green	**183**	18.8	25.5	1.8	36	63.1	20.9	2743.6	2269.2	2506.4
Bridger	Yellow	185.2	21.5	25.8	2.2	**23**	64.2	20.8	**2898.1**	2339.5	2618.8
CDC Amarillo	Yellow	189.5	**25**	29	**1**	**15**	**65.2**	20	2513.6	2090	2301.8
CDC	Green	187.2	**24.2**	27.8	**1**	**4**	65	20.6	2353.8	1982.4	2168.1
CDC Inca	Yellow	187.8	**22.8**	**30.5**	**1**	**8**	64.7	21.1	2663.7	2295.9	2479.8
CDC Saffron	Yellow	188.2	21.2	27.2	**1.2**	**20**	64.9	21.9	**2910.6**	2231.5	2571.1
CDC Spectrum	Yellow	188.8	22.2	27	**1.2**	**8**	64.5	21.3	2510.4	1970	2240.2
Delta	Yellow	184.2	18	24.5	3.8	49	65	22.4	**3065.8**	2304.6	2685.2
DS-Admiral	Yellow	186.8	**22.8**	29.2	2	**13**	64.1	23.4	2783.6	**2556.6**	2670.1
Hampton	Green	187.5	15	22	**1**	70	64.3	20	**3164.2**	2080.5	2622.4
Hyline	Yellow	186.8	21	30.2	**1**	**23**	64	22.3	2706.9	2359.9	2533.4
Jetset	Yellow	187.5	21.5	29.2	**1.5**	**9**	63.6	22.5	**3159.6**	2410.6	2785.1
Majoret	Green	186.8	21.2	25.5	**1.5**	**14**	**65.2**	22.4	2358.1	2025.4	2191.8
Navarro	Yellow	**183.2**	22.2	28.5	**1.2**	25	63.8	**24.5**	**3048.2**	2268.4	2658.3
Salamanca	Yellow	188	**23.5**	29.8	**1**	**21**	64.3	**24.2**	2744.7	2282.7	2513.7
Spider	Yellow	188	**24.8**	**31.2**	**1.2**	**19**	**65.8**	23.5	2731.1	2100.3	2415.7
Mean		187	21.9	28.2	1.5	19	64.4	21.9	2813.2	2255.3	2534.3
CV%		0.3	7.6	5.1	29.2	70.9	0.7	3	8.2	9.2	-
LSD		0.9	2.4	2	0.6	19.5	0.7	0.9	325.2	293.3	-
P-Value		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-

Bold = top-performing cultivar; **Bold** = statistically equivalent to top-performer; Yield adjusted to 13% moisture

SPRING LENTIL VARIETY TRIAL

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Summary

Lentil acreage in Montana has fallen by greater than 30% for two consecutive years. Still, Montana accounted for greater than 60% of lentil acreage nationwide in 2019. We assessed agronomic performance of 10 spring lentil varieties and experimental lines at the MSU Central Agricultural Research Center (CARC) in a small plot trial, with the objective of identifying varieties best suited to this environment. Yields averaged 1,466.6 lb/ac in 2019, down from a record-breaking 1,876.9 lb/ac in 2018.

Introduction

Montana typically leads the nation in total lentil acreage, but the state's production on a per acre basis is consistently below national averages. Selection of top-performing varieties in Montana is one way to close this yield gap. At the CARC in 2018 and 2019, two-year average yields ranged from 1,706.2 lb/ac (CDC Richlea) to 2,030.5 lb/ac (Avondale), or a difference of 324.3 lb/ac (5.4 bu/ac) between these two varieties, highlighting the importance of cultivar selection for successful lentil production in this environment. In this study, we assessed performance of 10 spring lentil varieties and experimental lines at the CARC.

Methods

Seven named varieties and three experimental lines were compared for height, propensity to lodge, date of 50% flowering, grain yield, test weight, and seed weight. Each entry was planted in four, 5x15 ft plots in an experimental design to determine varietal differences. The trial was located in a field where an alfalfa/grass mix had been established for several years prior to cultivation in fall of 2018. Lentils were planted on 19 April at a depth of 1 inch and at a rate of 12 PLS/ft2 using a low-disturbance, double-disc plot drill. Soil temperature at time of planting was 48°F. Broadleaf and grass weeds were controlled with a pre-plant burn down of RT3 (i.e., glyphosate) at 36 fl oz/ac on 18 April. A single application of Assure II (i.e., quizalofop) at 12 fl oz/ac was made on 30 May for additional control of grass weeds. Plots were hand-weeded thereafter. Lentils were harvested 15 August.

Results and Discussion

In 2019, the yield of all varieties in the trial averaged 1,466.6 lb/acre. Compare this to 702 lb/ac in 2017 and 1,876.9 lb/ac in 2018. Avondale has out yielded Richlea for two consecutive years at the CARC. In 2019, Richlea (1309 lb/ac) and Sage (1011.5 lb/ac) were the only two named varieties that did not yield statistically equivalent to Avondale (1730.7 lb/ac). NDL09017L had the highest seed wt (6.3 g/100 seed) and Viceroy outperformed all other varieties for test weight (66.8 lb/bu). Lodging was a factor in this year's trial, averaging 33% across cultivars. CDC Maxim (1%), CDC Imvincible (13%), and Avondale (19%) all lodged at percentages statistically equivalent to NDL09024R (0%), the cultivar most resistant to lodging in this year's trial. CDC Avondale (17.2

inches) was among the the tallest lentil varieties at maturity. The earliest flowerer, Sage, reached 50% bloom on 2 July, 74 days after planting, nearly 2 weeks later than in 2018.

Acknowledgements

We are grateful to the Montana Agricultural Experiment Station for providing funding for this research through the USDA National Institute of Food and Agriculture, Hatch project 1012796 and to the Montana Pulse Advisory Committee.

TABLE 16: 2019 MONTANA STATE UNIVERSITY SPRING LENTIL VARIETY TRIAL SUMMARIZED RESULTS FROM THE CENTRAL AGRICULTURAL RESEARCH CENTER, MOCCASIN, MT.

CULTIVAR	FLWR DATE (julian)	CNPY HT (in)	LODGE (%)	TEST WT (lb/bu)	100 SEED WT (g)	YIELD 2018	YIELD 2019 (lb/ac)	YIELD AVG
Avondale	184.2	**17.2**	**19**	62.6	4.7	**2330.2**	**1730.7**	2030.5
CDC Impress	184.2	**16.8**	61	62.1	5	**-**	**1501.5**	-
CDC	186.8	15.6	**16**	65	2.8	1933.8	**1707.7**	1820.8
CDC Maxim	184	15.1	**1**	64.6	3.8	**2176.8**	**1512.6**	1844.7
CDC Richlea	185.2	**16.5**	65	61.5	5.2	2103.4	1309	1706.2
NDL09017L	**183.8**	**16.5**	86	60.5	**6.3**	**-**	**1531.6**	-
NDL090185R	185	**17.1**	25	62.7	4.5	-	1394	-
NDL09024R	186	14.1	**0**	63.7	5.1	-	1375.7	-
Sage	**183.2**	14.9	36	64	3.2	-	1011.5	-
Viceroy	186.5	16.1	23	**65.5**	2.8	**-**	**1592**	**-**
Mean	184.9	16	33	63.2	4.3	1876.9	1466.6	1850.5
CV%	0.3	3.9	41.6	0.3	3.3	8.2	13.1	-
LSD	0.7	0.9	20	0.3	0.2	220.8	279.8	-
P-Value	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	-

Bold = top-performing cultivar; **Bold** = statistically equivalent to top performer; Yield adjusted to 13% moisture

SPRING CANOLA VARIETY TRIAL

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Summary

Though unchanged from 2018 to 2019, canola acreage in Montana has increased nearly 2000% since 2009. The growing interest in canola among Montana farmers creates a need for hybrid performance assessments in areas of the state previously dominated by wheat-based systems. Performance of 18 canola hybrids was evaluated at six locations in Montana (Conrad, Corvallis, Havre, Kalispell, Moccasin, and Sidney) in both dryland and irrigated systems.

Introduction

Technological advances in hybridization systems have led to the release of canola hybrids that are superior to conventional cultivars by virtually all metrics. However, similar to conventional cultivars, hybrids tend to perform well in certain environments and poorly in others. In this study, agronomic performance of 18 canola hybrids was assessed at multiple locations in Montana.

Methods

Up to 17 cultivars with five different herbicide resistance systems (including two cultivars with no herbicide resistance) from seven different sources were planted in randomized complete block designs at two irrigated sites (Corvallis, Sidney) and four dryland sites (Conrad, Havre, Kalispell, Moccasin) in Montana (Table 17). All cultivars were planted at a rate of 14 PLS/ft^2. All seed was treated for control of flea beetle prior to planting. A comprehensive account of management and climatic information will be provided in a subsequent report.

Results and discussion

Pests, residual herbicide damage, and severe weather were factors in this year's trials, leading to unfavorably high yield CV% values and, in one case, total trial abandonment. Mid-season hail damage forced abandonment of the trial established at Huntley, while deer, bird, and flea beetle damage likely contributed to highly variable yields observed at Kalispell, Corvallis, and Sidney, respectively. Certain cultivars at Havre exhibited damage from Sharpen applications made in fall 2018, though performance impacts were minimal.

Just 11 of the 18 cultivars included in the trials were tested at all six locations (Table 17). Only these 11 cultivars are used in the following descriptions of multi-location comparisons:

Average yield of the irrigated site at Corvallis (2319 lb/ac) far surpassed that of the other irrigated site, Sidney (1071 lb/ac). This difference can be explained, in part, by severe flea beetle damage early in the growing season at the latter site. Of the four dryland sites, Havre (3,948 lb/ac) achieved the highest average yield, followed by Kalispell (1,898 lb/ac), Conrad (1,310lb/ac), and Moccasin (1,095 lb/ac). The average yield across dryland and irrigated sites was 1,940 lb/ac, average test weight was 49.6 lb/bu, and average height was 37 inches. Averaged across six locations, 1) CP930RR (2,131 lb/ac) was the highest yielder and 16MH6004 (1,811 lb/ac) was the lowest; 2) 16MH6001 (50.2 lb/bu) had the highest test weight and 16CH4181 (48.9 lb/bu) along with NCC101S (48.9 lb/bu) had the lowest; and 3) CP955RR (39 in) was the tallest hybrid while NCC101S (35 in) was the shortest, though statistical differences were not assessed in these three comparisons. Oil analyses are pending for two of the 6 locations. No shattering or lodging was observed in any of the 2019 trials, with the exception of minimal trial-wide shatter losses at Kalispell. Cultivar performance by location is summarized in Tables 18-23.

Acknowledgments

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TABLE 17: 2019 MONTANA STATE UNIVERSITY SPRING CANOLA VARIETY TRIAL CULTIVAR LIST GROUPED BY SOURCE, WITH HERBICIDE SYSTEM, GENETIC MODIFICATION STATUS, SHATTER/DISEASE RESISTANCE STATUS, AND TESTING LOCATIONS.

CULTIVAR	HERB RESIST	GM STATUS	SHATTER	BLACKLEG	CLUBROOT	2019 TESTING LOCATIONS
BASF Corporation						
InVigor L233P	LL	GM	R	R	-	Conrad, Kalispell, Sidney
InVigor L234P	LL	GM	R	R	R	Conrad, Kalispell, Sidney
InVigor L255P	LL	GM	R	R	R	Conrad, Kalispell, Sidney
BrettYoung						
4187 RR	RR	GM	-	R	R	All
5545 CL	CL	Non-GM	R	R	-	All
6090 RR	RR	GM	R	R	R	All
Cargill Inc.						
16CH4181	Conventional	Non-GM	-	R	-	All
16MH6001	CL	Non-GM	-	R	-	All
16MH6004	CL	Non-GM	-	R	-	All
CROPLAN by Winfield United						
CP930RR	RR	GM	R	R	-	All
CP955RR	RR	GM	R	R	R	All
CP9978TF	TruFlex RR	GM	R	R	-	Moccasin
Dekalb/Bayer						
DKTF91SC	TruFlex RR	GM	R	R	-	All
DKTF92SC	TruFlex RR	GM	R	R	-	All
Meridian Seeds, LLC						
CS2100	RR	GM	R	R	-	Conrad, Havre, Kalispell, Moccasin
CS2300	RR	GM	-	R	-	Conrad, Havre, Kalispell, Moccasin
CS2500 CL	CL	Non-GM	-	R	-	Conrad, Havre, Kalispell, Moccasin
PHOTOSYNTECH, LLC						
NCC101S	Conventional	Non-GM	R	MR	-	All

LL = Liberty Link; RR = Roundup Ready; CL = Clearfield

R = Resistance; MR = Moderate Resistance

TABLE 18: 2019 MONTANA STATE UNIVERSITY SPRING CANOLA VARIETY TRIAL SUMMARIZED RESULTS FROM THE CENTRAL AGRICULTURAL RESEARCH CENTER, MOCCASIN, MT (DRYLAND).

CULTIVAR	SOURCE	HERB RESIST	COUNT (sqft)	FLWR DATE (julian)	CNPY HT (in)	LDGE (1 9)	SHTTR (1 9)	YIELD (lb/ac)	TEST WT (lb/bu)	OIL (%)
5545CL	BrettYoung	CL	9.5	177	**46**	1	1	**1136.8**	**48.9**	PENDING
16MH6001	Cargill Inc	CL	8.9	176	41.5	1	1	**1156.5**	45.9	PENDING
16MH6004	Cargill Inc	CL	9.4	176.2	40.8	1	1	1025.8	44	PENDING
CS2500 CL	Meridian Seeds, LLC.	CL	9.2	177.5	**47**	1	1	866	45.2	PENDING
16CH4181	Cargill Inc	Conventional	10.6	174	42.8	1	1	**1175.2**	44.1	PENDING
NCC101S	PHOTOSYNTECH, LLC.	Conventional	9.9	**171.8**	39.8	1	1	**1154.2**	41.4	PENDING
4187RR	BrettYoung	RR	9.5	179	**45.2**	1	1	**1184.5**	**49.2**	PENDING
6090RR	BrettYoung	RR	7.7	177.2	**47.5**	1	1	**1120.2**	46.7	PENDING
CS2100	Meridian Seeds, LLC.	RR	10	174.7	43.7	1	1	**1229**	**48.9**	PENDING
CS2300	Meridian Seeds, LLC.	RR	8.7	177.2	**45**	1	1	**1253.5**	**47.5**	PENDING
CP930RR	Winfield United	RR	9.7	174	42	1	1	**1098.5**	45.9	PENDING
CP955RR	Winfield United	RR	10.6	174.5	41.2	1	1	**1071.5**	**47.1**	PENDING
DKTF91SC	Dekalb/Bayer	TruFlex RR	10.1	173.8	42.5	1	1	**1165**	**47**	PENDING
DKTF92SC	Dekalb/Bayer	TruFlex RR	10.4	173	41.8	1	1	915.8	43.3	PENDING
CP9978TF	Winfield United	TruFlex RR	11.5	175	43.2	1	1	851.8	43.5	PENDING
Mean			9.7	175.4	43.3	1	1	1091.3	45.9	PENDING
CV%			13.4	0.4	4.3			13.5	3.5	
LSD			NS	1	2.7			226.3	2.4	
P-Value			0.0514	<0.001	<0.001			0.0038	<0.001	

Bold = top-performing cultivar

Bold = statistically equivalent to top-performer

Fisher's protected LSD not significant when CV% > 15 (YIELD only) and/or P-Value > 0.05

Yield adjusted to 8.5% moisture

Table 19: 2019 Montana State University Spring Canola Variety Trial summarized results from the Eastern Agricultural Research Center, Sidney, MT (irrigated).

CULTIVAR	SOURCE	HERB RESIST	COUNT (sqft)	FLWR DATE (julian)	CNPY HT (in)	LDGE (1 9)	SHTTR (1 9)	YIELD[1] (lb/ac)	TEST WT (lb/bu)	OIL (%)
5545CL	BrettYoung	CL	14.5	196	19	1	1	1028.8	54	**46**
16MH6001	Cargill Inc	CL	12	194	17	1	1	1165.5	54.1	**45**
16MH6004	Cargill Inc	CL	9.8	193	18.8	1	1	1434.8	53.3	44.5
16CH4181	Cargill Inc	Conventional	12	193	**24.8**	1	1	1293.5	52.2	44
NCC101S	PHOTOSYNTECH, LLC.	Conventional	16	193	17.2	1	1	360.2	48.5	35.4
InVigor L233P	BASF Corporation	LL	12.2	194	17.5	1	1	998	52.4	42.4
InVigor L234P	BASF Corporation	LL	15	196	15.2	1	1	908.5	52.4	42
InVigor L255P	BASF Corporation	LL	14	195	15.5	1	1	873.2	54.5	44.6
4187RR	BrettYoung	RR	14.5	193	19.8	1	1	1550.8	53.7	**46.6**
6090RR	BrettYoung	RR	11.6	195.7	16	1	1	698	53	43.5
CP930RR	Winfield United	RR	12.5	193.2	**24.2**	1	1	1414.2	53.9	**46.7**
CP955RR	Winfield United	RR	13.2	193	**26.8**	1	1	1392.2	54.1	**46.2**
DKTF91SC	Dekalb/Bayer	TruFlex RR	12.5	194	18.8	1	1	911.2	52.7	42.4
DKTF92SC	Dekalb/Bayer	TruFlex RR	10.2	193	16	1	1	598	50.7	41
Mean			12.8	194	19.1	1	1	1051.1	53	43.6
CV%			21.9	0.7	13.8			25.6	1.7	2.9
LSD[2]			NS	-	4.1			NS	-	1.9
P-Value			0.1490	-	<0.001			<0.001	-	<0.001

Bold = top-performing cultivar

Bold = statistically equivalent to top-performer

Fisher's protected LSD not significant when CV% > 15 (YIELD only) and/or P-Value > 0.05

Yield adjusted to 8.5% moisture

Table 20: 2019 Montana State University Spring Canola Variety Trial summarized results from the Northern Agricultural Research Center, Havre, MT (dryland).

CULTIVAR	SOURCE	HERB RESIST	COUNT (sqft)	FLWR DATE (julian)	CNPY HT (in)	LDGE (1 9)	SHTTR (1 9)	YIELD (lb/ac)	TEST WT (lb/bu)	OIL (%)
5545CL	BrettYoung	CL	**6.4**	168	41.8	1	1	3868.5	51.7	43.8
16MH6001	Cargill Inc	CL	5.5	168	40	1	1	3660.2	51.3	43.2
16MH6004	Cargill Inc	CL	4.3	167	38.3	1	1	3468	51.6	42.1
CS2500 CL	Meridian Seeds, LLC.	CL	6	168	44.2	1	1	3451.2	52	43.8
16CH4181	Cargill Inc	Conventional	5	166.8	41.3	1	1	3790.8	50.8	44
NCC101S	PHOTOSYNTECH, LLC.	Conventional	**6.7**	**162**	34.9	1	1	3915.2	**52.8**	39
4187RR	BrettYoung	RR	**6.3**	169	44.8	1	1	3774.8	51.4	44.1
6090RR	BrettYoung	RR	5.8	168	44.7	1	1	3932.5	51.2	43.8
CS2100	Meridian Seeds, LLC.	RR	**6.7**	166.2	42.4	1	1	3663.2	**52.5**	42.2
CS2300	Meridian Seeds, LLC.	RR	**6.2**	168.2	**49.5**	1	1	4060.8	51.7	43.7
CP930RR	Winfield United	RR	**6.3**	164.8	41	1	1	4037	50.7	**46.8**
CP955RR	Winfield United	RR	**6.6**	166.2	42.5	1	1	**4334.2**	51.6	44.4
DKTF91SC	Dekalb/Bayer	TruFlex RR	6	164.5	39.6	1	1	3975	51.5	42.7
DKTF92SC	Dekalb/Bayer	TruFlex RR	**7**	164	39.2	1	1	**4404**	52.2	41.9
Mean			6.1	166.5	41.7	1	1	3881.1	51.6	43.2
CV%			10.9	0.3	6.5			5.3	0.7	2
LSD			0.9	0.7	3.9			296.1	0.5	1.2
P-Value			<0.001	<0.001	<0.001			<0.001	<0.001	<0.001

Bold = top-performing cultivar

Bold = statistically equivalent to top-performer

Fisher's protected LSD not significant when CV% > 15 (YIELD only) and/or P-Value > 0.05

Yield adjusted to 8.5% moisture

Table 21:2019 Montana State University Spring Canola Variety Trial summarized results, Northwestern Agricultural Research Center, Kalispell, MT (dryland).

CULTIVAR	SOURCE	HERB RESIST	COUNT (sqft)	FLWR DATE (julian)	CNPY HT (in)	LDGE (1 9)	SHTTR (1 9)	YIELD (lb/ac)	TEST WT (lb/bu)	OIL (%)
5545CL	BrettYoung	CL	13.5	177	53.8	1	2	1914	**49.7**	48.1
16MH6001	Cargill Inc	CL	14	177	47.2	1	2	2070.8	**49.8**	47.5
16MH6004	Cargill Inc	CL	12	176.5	47.5	1	2	1615.8	**49.7**	47.9
CS2500 CL	Meridian Seeds, LLC.	CL	13.2	175.5	52.8	1	2	1646.5	49	48.4
16CH4181	Cargill Inc	Conventional	13.8	175.5	51.2	1	2	1737.2	47.3	49.1
NCC101S	PHOTOSYNTECH, LLC.	Conventional	13.8	**169**	48	1	2	1964.8	49.3	47
InVigor L233P	BASF Corporation	LL	14.2	177	52.8	1	2	2318.2	48	48.4
InVigor L234P	BASF Corporation	LL	14.8	179.2	54	1	2	2493.2	47.4	47.8
InVigor L255P	BASF Corporation	LL	14.5	180.8	54	1	2	2424.2	49.1	**50.6**
4187RR	BrettYoung	RR	14.2	177.2	55.8	1	2	2520.2	48.1	49.4
6090RR	BrettYoung	RR	13.8	177	**59.5**	1	2	2111.5	48.1	48.6
CS2100	Meridian Seeds, LLC.	RR	13	175.5	52.8	1	2	1947.2	49.1	48.8
CS2300	Meridian Seeds, LLC.	RR	11	178.2	**60.8**	1	2	2231.5	48.3	49.3
CP930RR	Winfield United	RR	14	173	50.5	1	2	1981	48.2	**51.1**
CP955RR	Winfield United	RR	13.5	176	50.8	1	2	1847.8	48.6	**50.3**
DKTF91SC	Dekalb/Bayer	TruFlex RR	13.8	**171.5**	47.5	1	2	2000	49	49.6
DKTF92SC	Dekalb/Bayer	TruFlex RR	16	172	49.5	1	2	1965.3	**49.4**	48.5
Mean			13.7	175.8	52.2	1	2	2047.6	48.7	48.8
CV%			21.8	1	6.1			18.1	0.5	1.7
LSD			NS	2.6	4.5			NS	0.4	1.3
P-Value			0.9560	<0.001	<0.001			0.0194	<0.001	<0.001

Bold = top-performing cultivar

Bold = statistically equivalent to top-performer

Fisher's protected LSD not significant when CV% > 15 (YIELD only) and/or P-Value > 0.05

Yield adjusted to 8.5% moisture

TABLE 22: 2019 MONTANA STATE UNIVERSITY SPRING CANOLA VARIETY TRIAL SUMMARIZED RESULTS FROM THE WESTERN AGRICULTURAL RESEARCH CENTER, CORVALLIS, MT (IRRIGATED).

CULTIVAR	SOURCE	HERB RESIST	COUNT (sqft)	FLWR DATE (julian)	CNPY HT (in)	LDGE (1 9)	SHTTR (1 9)	YIELD (lb/ac)	TEST WT (lb/bu)	OIL (%)
5545CL	BrettYoung	CL	21.5	**177.2**	**41**	1	1	2499.2	49.9	44.1
16MH6001	Cargill Inc	CL	19.1	180.5	36.6	1	1	2150.8	49.8	42.3
16MH6004	Cargill Inc	CL	17.7	180.8	35.5	1	1	2080.2	49.2	43.9
16CH4181	Cargill Inc	Conventional	22.5	**178.2**	37.2	1	1	2157.8	49	45.1
NCC101S	PHOTOSYNTECH, LLC.	Conventional	21.6	**175.5**	34.7	1	1	2878.8	50.3	39.7
4187RR	BrettYoung	RR	21.3	183	**39.5**	1	1	2558	50.1	45.5
6090RR	BrettYoung	RR	21.5	182	**40.9**	1	1	2205.5	50.3	46.2
CP930RR	Winfield United	RR	22	**178.2**	35.6	1	1	2631.8	49.9	46
CP955RR	Winfield United	RR	18	180.8	35.9	1	1	2316	49.1	45.6
DKTF91SC	Dekalb/Bayer	TruFlex RR	23.7	**175.2**	35.1	1	1	1931	49.4	45.2
DKTF92SC	Dekalb/Bayer	TruFlex RR	21.2	**175.2**	36.7	1	1	2402.8	49.1	43.2
Mean			20.9	178.8	37.2	1	1	2346.5	49.6	44.2
CV%			17.4	1.4	5.9			16.1	2.2	6.4
LSD			NS	3.6	3.2			NS	NS	-
P-Value			0.429	<0.001	0.001			0.0498	0.6454	-

Bold = top-performing cultivar

Bold = statistically equivalent to top-performer

Fisher's protected LSD not significant when CV% > 15 (YIELD only) and/or P-Value > 0.05

Yield adjusted to 8.5% moisture

TABLE 23: 2019 MONTANA STATE UNIVERSITY SPRING CANOLA VARIETY TRIAL SUMMARIZED RESULTS FROM THE WESTERN TRIANGLE AGRICULTURAL RESEARCH CENTER, CONRAD, MT (DRYLAND).

CULTIVAR	SOURCE	HERB RESIST	CNPY HT (in)	LDGE (1 9)	SHTTR (1 9)	YIELD (lb/ac)	TEST WT (lb/bu)	OIL (%)
5545CL	BrettYoung	CL	41.9	1	1	1384.5	51.2	PENDING
16MH6001	Cargill Inc	CL	36.8	1	1	1185.5	50.4	PENDING
16MH6004	Cargill Inc	CL	33.4	1	1	1242.2	50.5	PENDING
CS2500 CL	Meridian Seeds, LLC.	CL	42	1	1	1175.8	50.8	PENDING
16CH4181	Cargill Inc	Conventional	36.5	1	1	1174	50	PENDING
NCC101S	PHOTOSYNTECH, LLC.	Conventional	34.1	1	1	1034	51.1	PENDING
InVigor L233P	BASF Corporation	LL	36.1	1	1	1177	51.2	PENDING
InVigor L234P	BASF Corporation	LL	38.8	1	1	908	**51.3**	PENDING
InVigor L255P	BASF Corporation	LL	38.8	1	1	1684.8	**51.9**	PENDING
4187RR	BrettYoung	RR	38.6	1	1	1569	50.3	PENDING
6090RR	BrettYoung	RR	40.9	1	1	956	50.4	PENDING
CS2100	Meridian Seeds, LLC.	RR	34.6	1	1	1124	**51.4**	PENDING
CS2300	Meridian Seeds, LLC.	RR	38	1	1	1165.8	49.4	PENDING
CP930RR	Winfield United	RR	34.8	1	1	1624.5	49.9	PENDING
CP955RR	Winfield United	RR	39.5	1	1	1576.5	50.3	PENDING
DKTF91SC	Dekalb/Bayer	TruFlex RR	35.4	1	1	1356.5	50.7	PENDING
DKTF92SC	Dekalb/Bayer	TruFlex RR	35.4	1	1	1286.2	50.4	PENDING
Mean			37.4	1	1	1272	50.7	PENDING
CV%			12			27.7	0.8	
LSD			NS			NS	0.6	
P-Value			0.1635			0.0748	<0.001	

Bold = top-performing cultivar

Bold = statistically equivalent to top-performer

Fisher's protected LSD not significant when CV% > 15 (YIELD only) and/or P-Value > 0.05

Yield adjusted to 8.5% moisture

SPRING SAFFLOWER VARIETY TRIAL

Patrick Carr[1,2], Sherry Bishop[1,2], and Heather Fryer[1,2] (Co-Principal Investigators)

Montana State University[1], Dep. Research Centers; Central Agricultural Research Center, Moccasin, MT[2]

Summary

Statewide safflower yield averaged 990 lb/ac during 2018. This was the highest state-wide average yield for safflower since 2013. Safflower acres also were up in 2018 (42,000 acres) from the previous two years (37,000 acres in 2016 and 39,000 acres in 2017). Safflower can be used to diversify wheat-based cropping systems in central Montana. Safflower cultivars/varieties are compared annually at the MSU Central Agricultural Research Center (CARC) for seed yield and quality, as part of a multi-state testing program coordinated by North Dakota State University. Safflower was not favored by the cool conditions that persisted during 2019. Seed yield averaged only 564 lb/ac across the 12 entries grown under no-till management. High variability in the study (CV% > 15%) prevented safflower cultivars from being ranked for yield.

Introduction

Montana ranked second in safflower acreage nationally during 2018 (Sommer, 2019). Safflower was planted on 42,000 acres that year, and with harvested acreage totaling 36,000. Safflower can be grown successfully in Montana, with average statewide yields > 1000 lb/ac in some years (Sommer, 2018). However, timely planting (mid- to late-April) and average to warmer-than-average temperatures are important to ensure that safflower is exposed to sufficient heat units so that seed production is optimized. It also is important to select safflower cultivars/varieties best adapted to growing conditions under dryland management in this region of the state.

Methods

Twelve commercial safflower cultivars/varieties/hybrids were direct planted in a field on 26 April where foxtail millet was grown for grain in 2018. Seed was planted in four, 5 by 15 ft plots in an experimental design that allowed data to be analyzed statistically. Cool conditions delayed harvest; both processing of seed samples and data analyses have been delayed and are not yet completed.

Results and Discussion

Seed yield averaged only 564 lb/ac in 2019 (Table 24). The low seed yield reflects the cool temperatures that persisted during the 2019 growing season, particularly in late summer. Safflower is a full-season crop and requires greater exposure to warmer temperatures than wheat to reach physiological maturity. In addition, there was considerable variability in seed yield across plots of several varieties/hybrids in the trial, as reflected in a coefficient of variation (CV) percentage > 15%. These results indicate that safflower can be a risky crop to grow during cool summers in central Montana.

Literature Cited

Sommer, E. 2019. Montana agricultural statistics. USDA National Agric. Statistics Serv. Available online at https://www.nass.usda.gov/Statistics_by_State/Montana/ Publications /Annual_Statistical_ Bulletin /2019/Montana_Annual_Bulletin_2019.pdf (accessed 26 November, 2019)

Acknowledgments

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TABLE 24: 2019 SPRING SAFFLOWER VARIETY TRIAL, CENTRAL AG RESEARCH CENTER, MOCCASIN, MT.

			PLANT	TEST		GRAIN YIELD	
CULTIVAR	FLWR DATE		HT	WT	2018	2019	AVG
	(August)	(Julian)	(in)	(lb/bu)		(lb/ac)	
Cardinal	--	--	29	40.2	**778**	724	751
Chickadee	--	--	24	43.7	--	625	--
Hybrid 1601	--	--	28	35.1	**813**	637	725
Hybrid 200	--	--	28	42.7	**726**	680	703
Hybrid 446	--	--	28	43.9	**824**	806	815
MonDak	--	--	25	40.8	564	508	536
Montola 2003	--	--	25	39.9	495	488	492
Morlin	--	--	24	37.5	576	496	536
NutraSaff	--	--	27	34.8	447	452	450
Rubis Red	--	--	27	46.6	**748**	631	690
STI 1201	--	--	24	35.8	629	344	487
STI 1401	--	--	25	33.3		374	
Mean			26.1	39.5	671	563.7	
CV%			7.2	2.4	13.5	15.6	
LSD (.050)			2.7	1.3	130	NS	
P-value			<0.01	<0.01	<0.01	<0.01	

Bold = top performer(s)

Bold = statistically equivalent to top performer(s)

^{1}Fisher's protected LSD not significant when CV% > 15 (YIELD only) and/or P-Value > 0.05

PROSO MILLET VARIETY TRIAL

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Summary

Wheat and other cool-season cereals are well adapted to dryland management in central Montana. Incorporating warm-season cereals into cropping systems may allow farmers access to new markets. Thirty proso millet cultivars/varieties and experimental lines were compared for grain yield and test weight at the MSU Central Agricultural Research Center (CARC) during 2019. Grain yield was relatively low, averaging only 729 lb/ac. However, average grain yield was even lower in the past. The grain yield data indicate that current proso millet cultivars/varieties and experimental lines are marginally adapted to growing conditions in central Montana, making it a risky crop to grow in the Moccasin area.

Introduction

Wheat and barley are well adapted to dryland management in central Montana. Warm-season cereals (e.g., corn) are grown under dryland management, though to a lesser extent than cool-season cereals. Proso millet is a warm-season cereal crop that can be grown using the same planting and harvesting equipment used with wheat and barley. We have been screening proso millet cultivars/varieties and experimental lines for their adaptation to growing conditions in central Montana. The proso millet seed has been provided by Dipak Santra, a plant breeder working with proso millet at the University of Nebraska.

Methods

Proso millet cultivars/varieties and experimental lines were direct planted in a field on 29 May 2019, where a cover crop cocktail was planted and terminated with glyphosate in 2018. Seed was planted in four, 5 by 15 ft plots in an experimental design that allowed data to be analyzed statistically. Entries were compared for plant height, grain yield and test weight.

Results and Discussion

Differences in plant height were not detected across cultivars/varieties and experimental lines (P = 0.32). Plant height averaged just under 24 inches (Table 25). Grain yield averaged 729 lb/ac in 2019, with considerable variability across plots for several cultivars/varieties and experimental lines (CV = 17.6%). The high CV (< 15%) prevented ranking cultivars/varieties and experimental lines for grain yield. In contrast, cultivars/varieties and experimental lines were ranked for grain test weight. Several cultivars/varieties and experimental lines produced grain with a heavy test weight, including Horizon (59.4 lb/bu), Sunrise (59.3 lb/bu) and Huntsman (58.6 lb/ac). Those producing grain with a light test weight included Plateau (56.7 lb/bu). Overall, proso millet cultivars/varieties and experimental lines underperformed in 2019 at the CARC, just as happened in 2018. Results of these field experiments suggest that proso millet remains a risky crop to grow for grain in central Montana.

Acknowledgments

We are grateful to the Montana Agricultural Experiment Station for providing funding for this research through the USDA National Institute of Food and Agriculture, Hatch project 1012796.

TABLE 25: 2019 MILLET VARIETY TRIAL, CENTRAL AG RESEARCH CENTER, MOCCASIN, MT.

CULTIVAR	HEAD DATE (julian)	CANOPY HT (in)	TEST WT[1] (lb/bu)	GRAIN YIELD[2] (lb/ac)
Earlybird		25.9	57.7	553.9
HXM-10-29		23.6	56.9	794.6
HXR-1-23		23.3	58.2	764
HXR-2-75		22.3	56.7	740.9
Horizon		23.1	**59.4**	914.1
Huntsman		23.9	**58.6**	775.2
PMx11.35-52		24.7	57.1	770.3
PMx11.10-82		22.5	56.9	584.1
PMx11.14-10		21	56.1	682.2
PMx11.23-52		24.5	55.8	608
PMx11.26-48		24.1	58	816.3
PMx11.26-63		23.9	58.1	697.9
PMx11.27-79		23.1	58.1	738.5
PMx11.28-13		23.9	56.7	574.3
PMx11.28-52		21.9	**59**	750.1
PMx11.3-21		22.5	**59.6**	683.6
PMx11.31-101		24.2	**58.8**	819.5
PMx11.32-72		24.7	57.7	754.6
PMx11.32-93		23.9	**58.6**	652.9
PMx11.35-32		23.6	56.6	731.1
PMx11.4-16		24.6	**58.5**	820.8
PMx12.1		25.2	55.8	755.8
PMx12.10		23.5	56.4	673.8
PMx12.13		24.5	57.9	838.6
PMx12.15.2		24.1	57.9	688.6
PMx12.4.2		24.6	**58.6**	680.4
PMx12.5		23.8	56.5	691.2
PMx12.7		22.2	**59**	831.7
Plateau		26.1	56.7	666.9
Sunrise		24.1	**59.3**	803.2
Mean		23.8	57.7	728.6
CV%		9	1.3	17.6
LSD		NS	3.5	NS
P-Value		0.32	<0.01	0.02

Bold = top performer(s)

Bold = statistically equivalent to top performer(s)

[1] Not enough seed to measure test weight for all plots

[2] No moisture adjustment

[3] Fisher's protected LSD not significant when CV% > 15 (YIELD only) and/or P-Value > 0.05

FORAGES

WINTER CEREAL FORAGE TRIAL

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Summary

There is interest among Montana farmers and ranchers in growing annual crops for high-quality forage to supplement traditional sources (e.g., alfalfa). Winter triticale and wheat cultivars/lines have been compared to determine which produce greatest amounts of dry matter (DM) under dryland management at the MSU Central Agricultural Research Center (CARC) for several years, as well as other research centers in the state (e.g., the Northern Ag Research Center near Havre). Forage and grain yield of four winter wheat and nine winter triticale cultivars/lines were determined at the CARC during 2018-19. Winter triticale FX 1001 (WCF 1060) produced equal or greater amounts of forage DM (5.6 tons/ac) compared to other entries in the trial. Forage quality likely was superior for the winter wheat compared with winter triticale cultivars/lines included in the trial in 2018-19, but those data are not yet available. Forage quality data will be included in updated results posted on the CARC web page (http://agresearch.montana.edu/carc/index.html) when they become available.

Introduction

Annual forages can produce greater amounts of DM than traditional forage sources in central Montana during some years, as well as high-quality hay when managed properly (Meccage et al., 2019). Over 40% of Montana farms have both crop and livestock enterprises represented, and it is on these farms that cereal forage crops may have the best fit. Winter wheat and triticale lines were evaluated for forage and grain yield at Bozeman, Creston, Conrad, Corvallis, Havre, and Moccasin, MT during 2018-19. Forage quality analyses are underway but have not yet been completed. Preliminary results of the trial at the Moccasin (CARC) location are provided.

Methods

Four winter wheat and nine winter triticale cultivars (i.e., varieties)/lines were direct planted on 30 September, 2018, in a field that was green-fallowed with a lentil/pea cover that was sprayed with glyphosate in mid-summer. Each entry was planted in four, 5 by 15 ft plots in an experimental design to determine cultivar differences. Entries were compared for plant height, moisture content at forage harvest, forage and grain yield. Forage plots were harvested targeting the milk growth stage of kernel development, though untimely rains delayed harvest until the early kernel soft dough stage of development.

Results and Discussion

Forage moisture content averaged 50% when samples were harvested during 2019, with a range of 46 to 53% (Table 26). This was lower than desired; the targeted moisture content should be ~ 65%. Forage DM yield for winter triticale and wheat varieties and experimental lines averaged 4.2 t/ac, compared with 2.7 t/ac in 2018. Greatest amount of DM was produced by the winter triticale cultivar FX 1001 (5.6 t DM/ac). Conversely, a non-commercial winter wheat entry (PI 197732) produced the lowest amount of DM (3.5 t DM/ac). The winter wheat cultivars/varieties MT 1435, Ray, and Willow Creek all produced around 4 t DM/ac. Winter wheat forage generally is superior to winter triticale forage in terms of quality, but those data are not yet available. The quality data will be provided at a future date on the CARC web page (http://agresearch.montana.edu/carc/index.html).

Mean (average) grain yield of Ray winter wheat was 2600 lb/ac (43 bu/ac), but statistical restrictions (i.e., CV% > 15%) suggest caution in comparing grain yield means for entries in the trial at the CARC during 2018-19. Ray (and MT 1435) were 8 to 10 inches shorter than Willow Creek, which may be an important consideration in high-moisture environments where lodging may be an important consideration if growing these winter wheat varieties for grain.

Literature Cited

Meccage-Glunk, E., P.M. Carr, M. Bourgault, K. McVay, and D. Boss. 2019. Annual forages. Crops and Soils. *In press.*

Acknowledgments

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TABLE 26: 2019 WINTER CEREAL FORAGE TRIAL, CENTRAL AG RESEARCH CENTER, MOCCASIN, MT.

CULTIVAR	CROP	CANOPY	FORAGE	FORAGE YIELD			GRAIN YIELD			TEST
		HT	MOISTURE	2018	2019	AVG	2018	2019	AVG	WT
		(in)	(%)		(t/ac)			(lb/ac)		(lb/bu)
Willow	Wheat	45	46	2.2	4.1	3.2	1980	2008	1994	61
MTF 1435	Wheat	37	48	2.9	4.0	3.5	2156	2375	2266	61
Ray	Wheat	35	49	2.8	4.1	3.5	3425	2600	3013	61
T 14	Triticale	**55**	**53**	2.8	3.8	3.3	1984	1499	1742	55
T 1310-218	Triticale	**55**	49	2.4	**4.6**	3.5	2650	2035	2343	51
T 1310-221	Triticale	**55**	49	2.6	4.4	3.5	2209	1804	2007	52
T 1310-230	Triticale	**56**	**50**	3.3	3.9	3.6	2218	1660	1939	52
Trical 102	Triticale	**50**	**52**	2.6	3.6	3.1	2171	1794	1983	50
WCF 0013	Triticale	**58**	**50**	3	**5.0**	4.1	2284	1830	2057	51
WCF 1020	Triticale	**56**	49	2.6	**4.5**	3.6	2573	2024	2299	51
FX 1001	Triticale	**57**	**50**	3	**5.6**	4.3	2628	1869	2249	51
WCF 1078	Triticale	**57**	**50**	2.7	4.1	3.4	2403	1517	1960	51
PI 197732	Wheat	44	**50**	--	3.5	--	--	2210	--	59
Mean		51	50		4.2			1940		54.2
CV%		4.7	4.7		18.2			25.2		2.1
LSD (.050)		3.4	3		1.1			NS		
P-value		<0.01	0.04		0.03			0.11		<0.01

Bold = statistically equivalent to top performer(s); [1]Fisher's protected LSD not significant when CV% > 15 (YIELD only) and/or P-Value > 0.05

SPRING CEREAL FORAGE TRIAL

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Summary

There is interest in growing annual crops for high-quality forage to supplement traditional sources (e.g., alfalfa). Spring barley is the most widely grown, spring-planted annual forage in the state. Spring barley along with emmer, oat, and triticale were evaluated for both forage and grain production at Bozeman, Conrad, Corvallis, Havre, Moccasin, and Sydney in 2019. Forage dry matter (DM) yield averaged 1.7 t/ac across the crop treatments in the trial at the MSU Central Ag. Research Center (CARC). There was a trend ($P = 0.08$) for Haybet barley along with Otana oat, Goliath oat, Hayden oat, Hays oat, and an oat experimental line to be among the top forage producers. High variability in grain yield (CV% > 15) prevented top performing cultivars/varieties and experimental lines from being identified, though Haybet barley had the largest mean grain yield (2149 lb/ac).

Introduction

Spring-seeded cereals can be an alternative source of high-quality forage when traditional forage sources are in short supply. Much of the focus on annual spring-seeded forages centers on barley in the state, but there are other annual grasses that can be grown (e.g., spring oat). Four commercial barley cultivars/varieties along with five experimental lines were compared for forage DM yield and quality at the CARC during 2018, along with emmer, oat, and triticale cultivars and one oat experimental line. The five barley experimental lines are part of a larger group being evaluated for possible release as new cereal forage options for farmers and ranchers in the state.

Methods

Plots were direct planted on 25 April into a field with a previous lentil/pea cover crop that was killed using a glyphosate plus 2,4-D burndown in 2018. Entries were compared for plant height, forage moisture content, forage DM and grain yield, and grain test weight. Forage also is being evaluated for quality but those data are not yet available.

Results and Discussion

Plant height ranged from <22 inches for Red Rock barley to 41 inches for Trítical 141 at the time of forage harvest (Table 27). Other relatively tall crop treatments included TriCal Surge (39 inches) and Pronghorn triticale (39 inches). Goliath oat was relatively tall (36 inches) but was shorter than the three triticale cultivars ($P < 0.01$). There was not a strong relationship between plant height and forage yield, as was true in 2018. Though differences in forage yield were not detected among cultivars ($P < 0.05$), there was a trend ($P = 0.08$) for forage yield to be greater for Haybet barley (2.1 t/ac) than for the three tall triticale cultivars (< 1.7 t/ac).

Acknowledgments

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Table 27: 2019 spring cereal forage trial, Central Ag Research Center, Moccasin, MT.

CULTIVAR	CROP	CANOP	FORAGE	FORAGE YIELD			GRAIN YIELD			TEST
		HT	MOISTUR	2018	2019	AVG	2018	2019	AVG	WT
		(in)	(%)		(t/ac)			(lb/ac)		(lb/bu)
40461	Oats	22	58.9	--	1.8	--	--	661	--	37.9
Goliath	Oats	35.7	59.4	--	1.9	--	--	1470	--	41
Haybet	Barley	30.4	61.9	2.9	2.1	2.5	1603	2149	1876	**50.8**
Hayden	Oats	31.3	62	--	1.9	--	--	1746	--	41.1
Hays	Barley	24.6	62.3	2.9	1.8	2.4	2150	1959	2054	47.4
Lavina	Barley	24.9	61.1	2.6	1.7	2.2	2018	1874	1946	**48.8**
Lucille	Emmer	29.9	54.8	2.8	1.5	2.2	1649	1342	1496	**45.9**
MT16F01601	Barley	23.9	61.4	2.7	1.8	2.3	2136	1747	1942	**52.2**
MT16F01602	Barley	24.5	59.7	--	1.7	--	--	1685	--	**49.7**
MT16F02408	Barley	23.4	60.2	--	1.6	--	--	1478	--	**49.9**
MT16F02902	Barley	27.1	61.4	--	1.7	--	--	1884	--	**50.8**
MT16F02903	Barley	26.9	60.1	2.8	1.4	2.1	1896	1372	1634	<u>**52.3**</u>
Otana	Oat	32.8	61.6	3	1.9	2.5	1922	1698	1810	39.4
Pronghorn	Triticale	39.3	59.1	2.6	1.7	2.2	1656	1174	1415	**51.6**
Red Rock	Barley	21.8	61.1	--	1.6	--	--	1584	--	**50.8**
TriCal Surge	Triticale	39.2	57.9	--	1.4	--	--	1044	--	**48.4**
Tritical 141	Triticale	40.9	56	--	1.7	--	--	853	--	**50.7**
Mean		29.3	59.9		1.7			1512.9		47.6
CV%		7.5	3.5		16.9			24.6		13.3
LSD (.050)		3.1	3.0		NS			NS		9.0
P-value		<0.01	<0.01		0.08			<0.01		0.01

<u>**Bold**</u> = top performer(s)

Bold = statistically equivalent to top performer(s)

[1] Fisher's protected LSD not significant when CV% > 15 (YIELD only) and/or P-Value > 0.05

PRODUCTION

HEMP SEEDING DATE BY VARIETY TRIAL

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Summary

Interest has surged in growing hemp for seed. Agronomic research on hemp began at the Central Ag Research Center near Moccasin and in Bozeman during 2018. This effort was expanded to include the Eastern Agricultural Research Center in 2019. A hemp cultivar (CRS-1 and Katani) by seeding date (26 April, 10 May, and 24 May) study was conducted at all three locations. Seeding date failed to affect seed yield (P = 0.25) at the CARC. Likewise, seed yield was similar beween CRS-1 (651 lb/ac) and Katani (590 lb/ac). Preliminary results indicate that hemp can be planted at an earlier (late-April through early May) than recommended (late-May) seeding date with no negative impact on yield.

Introduction

Broadleaf crops can be used to diversify wheat-based cropping systems. Recently, interest in growing hemp has exploded in central Montana among farmers searching for higher-value crops than those presently being produced. Research was initiated at Montana State University to determine the seed yield potential of commercial hemp varieties by conducting a small cultivar (i.e., variety) trial at the CARC and in Bozeman during 2018. In 2019, this effort was expanded to include the Eastern Agricultural Research Center at Sydney and to include a planting date variable.

Methods

CRS-1 and Katani hemp varieties were direct planted on 26 April, 10 May and 30 May at the CARC in a field where foxtail millet was grown under dryland management the previous year. Vida spring wheat was included as a cool-season crop check. Seed was planted in four, 5 by 15 ft plots in an experimental design (RCB in a split plot pattern with seeding dates as whole plots and cultivars as subplots) that allowed data to be analyzed statistically. Entries were compared for ease of establishment, plant height, and seed yield.

Results and Discussion

Planting date failed to affect hemp crop density (P = 0.16; Table 28). Hemp plant density was less (8 plants/sq. ft.) than that targeted (10-12 plants/sq. ft.). The lower-than-expected hemp plant stand probably was a result of the large amount of millet residue that interfered with planting, causing straw pinning and poor seed-to-soil contact in several places within planted rows. Taller plants occurred when planted earlier than at later planting dates. However, no advantage in seed yield was detected when planted earlier versus later (P = 0.25). Vida spring wheat produced more grain/seed (1456 lbs/ac; 24 bu/ac) than either CRS-1 (651 lbs/ac) or Katani (590 lbs/ac) hemp cultivars. Research on hemp will be continued and expanded in future years.

Acknowledgments

We are grateful to the Montana Agricultural Experiment Station for providing funding for this research through the USDA National Institute of Food and Agriculture, Hatch project 1012796, to Ian Foley at the MT Department of Agriculture for his assistance in providing hemp for the trial, and to the Vice-President of Agriculture and the Director of the MSU Ag. Exp. Stat. in providing additional funding for this study.

TABLE 28: 2019 HEMP SEEDING DATE BY VARIETY TRIAL, CENTRAL AG RESEARCH CENTER, MOCCASIN, MT.

PLANTING DATE	PLANT STAND (no./ft^2)	PLANT HEIGHT (inches)	SEED YIELD (lb/ac)
26 April	10	**26**	966
10 May	11	**24**	886
30 May	12	23	844
Mean	11	25	892
LSD	NS	2.7	NS
P-value	0.16	<0.05	0.25
CROP VARIETY			
CRS-1 hemp	7	**28**	651
Katani hemp	9	21	590
Vida spring wheat	**17**	25	**1456**
Mean	11	25	899
LSD	2.3	2.4	**185**
P-VALUE	<0.01	<0.01	<0.01

Bold = top

Bold = statistically equivalent to top performer(s)

[3]Fisher's protected LSD at P < 0.05.

LENTIL UNDERGROUND AGRONOMY TRIALS

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Summary

Lentil surged to >700,000 acres in Montana in 2017 on the strength of good price forecasts for lentil and poor for wheat. Due to the historical small acreage for lentil in Montana, there has been very little agronomic research invested at the local scale. Plant pathologists have noted that disease infection levels in seed samples submitted to Montana State University over the years are increasing in pulse crops. Concerns are especially high regarding the knowledge void for fusarium root rot of lentil, a very damaging and persistent soil-borne pathogen. Agronomic field trials are underway to determine the impact of different agronomic practices on lentil performance and fusarium root rot.

Methods

In this ongoing study, three trials are being conducted at four locations in Montana (i.e., Bozeman, Moccasin, Sidney, and Havre) and at three locations in North Dakota. A fourth study is being held at three of the four Montana locations (Sidney excluded). The trials include a fertility trial, a fungicide seed treatment trial, a variety trial and, at the three Montana locations, a seeding rate x rolling timing trial. A comprehensive summary of multi-location management information and results will be made available in a subsequent report. Only the Moccasin trials are summarized here. The fertility trial, the seed treatment trial, and the variety trial were all seeded on 25 April using a double disc plot drill. The fertility and seed treatment trials were harvested on 28 August, and the variety trial was harvested 21 August. Millet inoculated with fusarium root rot was planted with each entry of the seed treatment and variety trials. The three trials were established in a field that was planted to Willow Creek winter wheat in 2018. Rather than being harvested for forage, the 2018 Willow Creek crop was taken to seed and harvested with a stripper header, leaving behind extremely high amounts of residue. A single application of RT3 (i.e., glyphosate) was made prior to planting. Multiple flushes of volunteer winter wheat throughout the 2019 growing season necessitated frequent hand-weeding. Moderate chemical damage was observed early in the season, though lentils recovered with no apparent performance impacts. The seeding rate x roll timing trial was planted on 10 May and harvested on 28 and 29 August. This trial was established in a field that was continuously cropped to spring wheat for three consecutive years. A single application of RT3 (i.e., glyphosate) was made prior to planting, and plots were hand-weeded thereafter.

Results and Discussion

Plot-scale variability in physiological maturity was particularly severe in 2019, leading to highly variable lentil seed moistures, delayed harvest, and potentially higher-than-normal harvest losses. Treatment effects were not statistically significant for the fertility and seed treatment trials, with the exception of flowering date differences in the fertility trial. The unfertilized treatment inoculated with a granular product (2 July), the unfertilized treatment inoculated with a seed coat product (3 July), and the inoculated, unfertilized control (3 July) flowered earlier than all other treatments. Fusarium root rot infections in the seed treatment and variety trials were minimal (data not shown), despite cool and wet conditions persisting for most of the growing season. In the latter trial, four varieties yielded statistically equivalent to the top yielder, Pardina (1,232.2 lb/ac). These were Avondale (1,141.2 lb/ac), Eston (1,113.2 lb/ac), CDC

Maxim (1,103 lb/ac) and Brewer (1,090 lb/ac). Rosetown (65.2 lb/bu) and Pardina (65 lb/bu) had the highest test weights in the trial. Brewer and CDC Maxim were the tallest in the trial at 15.1 inches, with Avondale, Richlea, and ND Eagle exhibiting no statistical differences at 14.7, 14.4, and 14.2 inches tall, respectively. Poor establishment was observed for Richlea (5.8 plants/ft^2), ND Eagle (5.2 plants/ft^2) and Sage (4.4 plants/ft^2) relative to Rosetown (7.3 plants/ft^2). Results of the seeding rate x rolling trial were inconclusive. Averaged across seeding rates, test weights were statistically lower when lentils were rolled at planting (62.7 lb/bu) versus emergence (62.9 lb/bu), but these differences were very minor (0.2 lb/bu). Seed yields were statistically equivalent across rolling treatments, exhibiting only a 116 lb/ac difference between the minimum (rolled at six-leaf stage = 1,226 lb/ac) and maximum (rolled at emergence = 1,342 lb/ac) treatment means.

Acknowledgments

We are grateful to the USDA Specialty Crop Research Initiative for funding this research.

TABLE 29: 2019 MONTANA STATE UNIVERSITY SPRING LENTIL FERTILITY TRIAL SUMMARIZED RESULTS FROM THE CENTRAL AGRICULTURAL RESEARCH CENTER, MOCCASIN, MT.

TREATMENT	COUNT (sqft)	FLWR DATE (julian)	CNPY HT (in)	MATR DATE (julian)	YIELD (lb/ac)	TEST WT (lb/bu)
Control	7.1	**194.6**	15.4	226.2	1167	62
Granular inoculant w/ K (25 lb/ac of 0-0-60)	6.2	194.8	14	226	1166	61.8
Granular inoculant w/ K + S (30 lb/ac of 0-0-50-18)	6.6	195	15.8	226.8	1308.4	61.9
Granular inoculant w/ K + S and foliar micronutrient	6.9	194.8	14.8	226	1054	61.9
Granular inoculant w/o K or S	7.2	<u>**193.8**</u>	14.8	225.8	1233.6	62.3
Seed-coat inoculant w/ K	6.9	195	14.8	226.4	1167	62.1
Seed-coat inoculant w/ K + S	6.3	195.2	15	226.2	1194.6	62
Seed-coat inoculant w/o K or S	6.5	**194.6**	15	225.8	1151	62.1
Mean	6.7	194.7	14.9	226.2	1180.2	62
CV%	14.2	0.3	6.3	0.3	10.7	0.4
LSD	NS	0.8	NS	NS	NS	NS
P-Value	0.5846	0.0404	0.1963	0.2793	0.1603	0.0913

<u>**Bold**</u> = top-performing treatment; **Bold** = statistically equivalent to top-performer; Yield adjusted to 13% moisture

TABLE 30: 2019 MONTANA STATE UNIVERSITY SPRING LENTIL SEED TREATMENT TRIAL SUMMARIZED RESULTS FROM THE CENTRAL AGRICULTURAL RESEARCH CENTER, MOCCASIN, MT.

SEED TREATMENT	COUNT (ft^2)	CNPY HT (in)	YIELD (lb/ac)	TEST WT (lb/bu)	100 SEED WT (g)
Apron Maxx	6	15.2	1326	62.2	4.7
Control	6.4	15.1	1487	62.4	4.7
CruiserMaxx VP	7	14.7	1416.5	62.4	4.7
EverGol Energy	7.1	14.9	1453.2	62.3	4.6
GDC S3202aa	7	15.2	1372.5	62.5	4.7
Obvius	7.7	15.2	1233	62.2	4.5
Rancona Summit	6.8	15.6	1468.8	62.5	4.7
Rizolex/V10465	7.2	15.4	1403	62.4	4.7
S2399/V10465	7	14.8	1286.2	62.3	4.5
Trilex 2000	7.2	15.6	1347	62.6	4.6
Mean	6.9	15.2	1379.3	62.4	4.6
CV%	17.5	3.7	8.9	0.3	2.1
LSD	NS	NS	NS	NS	NS
P-Value	0.7845	0.3586	0.118	0.3326	0.2432

Bold = top-performing treatment; **Bold** = statistically equivalent to top-performer; Yield adjusted to 13% moisture

TABLE 31: 2019 MONTANA STATE UNIVERSITY SPRING LENTIL VARIETAL FUSARIUM TOLERANCE TRIAL SUMMARIZED RESULTS FOR THE CENTRAL AGRICULTURAL RESEARCH CENTER, MOCCASIN, MT.

CULTIVAR	COUNT (ft^2)	CNPY HT (in)	YIELD (lb/ac)	TEST WT (lb/bu)	100 SEED WT (g)
Avondale	**6.7**	**14.7**	**1141.2**	62.5	4.5
Brewer	**6.4**	<u>**15.1**</u>	**1090**	60.4	4.7
CDC Maxim	**6.2**	<u>**15.1**</u>	**1103**	64.2	3.6
CDC Redberry	**6.1**	13.7	776.8	64.2	3.5
Eston	**6.9**	13.8	**1113.2**	64.5	3
ND Eagle	5.2	**14.2**	820.2	64	3.3
Pardina	**6.2**	13.2	<u>**1232.2**</u>	**65**	3.2
Richlea	5.8	**14.4**	919.2	61.6	<u>**4.9**</u>
Rosetown	<u>**7.3**</u>	13.4	974.5	<u>**65.2**</u>	2.3
Sage	4.4	13.7	664.2	64.4	3.4
Mean	6.1	14.1	983.5	63.6	3.6
CV%	14.8	5.5	14.1	0.3	2.2
LSD	1.3	1.1	200.6	0.3	0.1
P-Value	0.0054	0.0125	<0.001	<0.001	<0.001

<u>**Bold**</u> = top-performing treatment; **Bold** = statistically equivalent to top-performer; Yield adjusted to 13% moisture

TABLE 32: 2019 MONTANA STATE UNIVERSITY SPRING LENTIL ROLLING X SEEDING RATE STUDY SUMMARIZED RESULTS FOR THE CENTRAL AGRICULTURAL RESEARCH CENTER, MOCCASIN, MT, GROUPED BY SEEDING RATE.

SEED RATE (PLS/ft^2)	COUNT (ft^2)	FLWR DATE (julian)	CNPY HT (in)	YIELD (lb/ac)	TEST WT (lb/bu)	MOISTURE (%)
5.6	3.8	207.6	15.6	974	**<u>62.9</u>**	**<u>11.1</u>**
8.4	5.3	207.5	15.5	1143	**<u>62.9</u>**	**11.0**
11.1	6.9	**207.3**	15.7	1206	**<u>62.9</u>**	**10.9**
16.7	10.0	**207.1**	15.4	**1505**	62.7	10.8
22.3	**<u>12.5</u>**	**<u>206.5</u>**	16	**<u>1620</u>**	62.7	10.7
Mean	7.7	207.2	15.7	1290	62.8	10.9
CV%	23.3	0.5	6.5	15.2	0.3	1.8
HSD (Seed Rate)	1.6	0.8	NS	154	0.1	0.2
P-Value (Rep)	0.7161	0.0011	<0.001	<0.001	0.4962	<0.001
P-Value (Roll Time)	0.3404	0.8053	0.1100	0.3666	0.0197	0.0083
P-Value (Seed Rate)	<0.001	0.0012	0.3834	<0.001	<0.001	<0.001
P-Value (Roll Time:Seed Rate)	0.0117	0.0636	0.5087	0.4099	0.0645	0.0578

<u>Bold</u> = top-performing treatment;

Bold = statistically equivalent to top-performer

Yield adjusted to 13% moisture

Table 33: 2019 Montana State University Spring Lentil Rolling x Seeding Rate Study summarized results for the Central Agricultural Research Center, Moccasin, MT, grouped by roll time.

ROLL TIME	COUNT (ft^2)	FLWR DATE (julian)	CNPY HT (in)	YIELD (lb/ac)	TEST WT (lb/bu)	MOISTURE (%)
None	7.4	207.2	15.4	1316	**62.8**	**10.9**
Planting	7.2	206.9	16.1	1289	62.7	10.8
Emerge	8.2	207.2	15.7	1342	**62.9**	**11.0**
Two-leaf	7.9	207.2	15.7	1276	**62.8**	**10.9**
Six-leaf	-	207.4	15.4	1226	**62.9**	**11.0**
Mean	7.7	207.2	15.7	1290	62.8	10.9
CV%	24.8	0.6	4.8	15.8	0.4	1.5
HSD (Roll Time)	NS	NS	NS	NS	0.2	0.1
P-Value (Rep)	0.7161	0.0011	<0.001	<0.001	0.4962	<0.001
P-Value (Roll Time)	0.3404	0.8053	0.1100	0.3666	0.0197	0.0083
P-Value (Seed Rate)	<0.001	0.0012	0.3834	<0.001	<0.001	<0.001
P-Value (Roll Time:Seed Rate)	0.0117	0.0636	0.5087	0.4099	0.0645	0.0578

Bold = top-performing treatment

Bold = statistically equivalent to top-performer

Yield adjusted to 13% moisture

EVALUATING MICROBIAL INOCULANT PERFORMANCE IN SMALL GRAINS AND PULSES

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Summary

Inoculant trials were established with winter wheat, spring wheat, barley, peas, and chickpeas to evaluate the effectiveness of biological treatments on the agronomic performance. In general, inoculants the inoculants evaluated this year provided little yield benefit relative to the control for most treatments. At Denton, winter wheat treated with TerraMax Micro-AZ ST yielded 62.9 bu/ac which statistically higher than the control at 57.4 bu/ac. Yellow peas treated with Lalfix Duo Granular were significantly taller compared to the control and yielded 2409.2 lb/ac compared to the control which yielded 1976.0 lb/ac. No yield differences were observed with the other treatments.

Introduction

Several microbial inoculant trials were performed at Moccasin and off-station locations to evaluate inoculants with putative plant beneficial characteristics. Inoculant formulations in these studies contained species of the genera *Bradyrhizobium, Azospirillum, Bacillus, Rhodococcus*, and complex multispecies blends of potential plant beneficial microorganisms. These organisms are known to provide a variety of plant beneficial functions, but more research is needed to evaluate their performance in the field. These organisms perform a variety of functions. Many members of the genera *Bradyrhizobium* are capable of nitrogen fixation in legumes and may have additional plant beneficial properties. *Azospirillum* are free-living nitrogen-fixing organisms that are believed to stimulate root growth in addition to fixing nitrogen. Inoculants containing phosphate solubilizing organisms were also evaluated. Some beneficial *Bacillus* and *Rhodococcus* strains are believed to contribute to increased nutrient uptake and increased early season root growth and root mass. The purpose of this work was to evaluate the effectiveness of these inoculants on the agronomic performance of winter wheat, spring wheat, and barley. Additional trials were performed to evaluate rhizobia performance on pea and chickpeas.

Methods

Inoculant formulations were applied following manufacturer's recommendations. Three replicate plots were arranged in a randomized complete block experimental design so that differences from the treatments could be separated from other effects. Seeding dates for winter wheat were 16 October at Moccasin and 25 October at Denton and Geraldine. Seeding dates for spring wheat were 23 April at Moccasin, 9 May at Geraldine, and 10 May at Denton. The seeding date for the barley inoculant trial was 25 April. Seeding dates for the pulse inoculant trials were and 26 April for peas and 29 May for chickpeas. Planting depth was 1 inch at a rate of 20 kernels/ft^2. Starter fertilizer, 20-30-20-10 NPKS, was applied at seeding at a rate of 50 lb/ac. An additional 120 lb/ac of ESN (44:0:0) was broadcast applied on to the winter wheat and spring wheat trials and 60 lb/ac of ESN (44:0:0) was applied to the barley trial on 23 May. Broadleaf and grass weeds were controlled with a burndown of glyphosate at 1.25 pt/ac before planting. Trials were also sprayed 23 May with Vendetta at a rate of 24 oz/ac to control field pennycress, flixweed, kochia, and prickly lettuce. Winter wheat plots were harvested with a small-plot harvester on 14

August at Moccasin and 28 August at Geraldine, and 4 September at Denton. Spring wheat plots were harvested 13 September at Moccasin, 28 August at Geraldine, and 16 September at Denton. The barley inoculant trial was harvested 3 September while peas were harvested on 26 September and chickpeas on 8 October.

Results and Discussion

No significant differences were observed between treatments and the control in winter wheat at Moccasin or Geraldine. At Denton, TerraMax Micro-AZ ST was statistically higher than the control at 62.9 bu/ac (Tables 36). This represented a 5.5 bu/ac yield advantage compared to the control. No significant differences were observed in test weight or protein at any of the locations. No significant differences in yield, test weight, or protein were observed with any of the spring wheat treatments at any of the locations. No significant differences were observed with any of the barley treatments. Yellow peas treated with Lalfix Duo Granular were significantly taller compared to the control and yielded 2409.2 lb/ac compared to the control which yielded 1976.0 lb/ac (Table 41). No significant differences in plant height or yield were observed between the control and treatments in the chickpeas.

Acknowledgments

We are grateful to the Montana Agricultural Experiment Station for providing funding for this research through the USDA National Institute of Food and Agriculture, Hatch project 1015780.

TABLE 34: 2019 WINTER WHEAT INOCULANT TRIAL, MOCCASIN, MONTANA

Treatment	Height (in)	Test Weight (lb/bu)	Protein (%)	Grain Yield (bu/ac)
Control	31.7	61.4	9.9	60.5
TerraMax Micro-AF ST	32.0	61.4	9.9	60.3
TerraMax Micro-AZ ST	33.7	61.5	10.0	65.4
TerraMax PSB-ST	31.3	61.7	10.3	64.1
TerraMax Vertex	32.0	61.3	10.3	55.8
Visjon Exceed HSD	32.7	61.5	10.1	65.7
Visjon Exceed SAR	32.3	61.5	10.0	66.6
Average	32.2	61.5	10.1	62.6
LSD (0.05)	2.3	0.6	0.4	12.9
CV (%)	4.1	0.5	2.5	11.7
P-value	0.4670	0.7680	0.2240	0.5560

Bolded and underlined values are the highest mean. Bolded values are not different from the highest

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 35: 2019 WINTER WHEAT INOCULANT TRIAL, GERALDINE, MONTANA

Treatment	Height (in)	Lodging score	Test (lb/bu)	Protein (%)	Grain Yield (bu/ac)
Control	32.3	2.0	60.7	11.6	81.0
TerraMax Micro-AF ST	32.3	1.3	60.7	11.6	81.1
TerraMax Micro-AZ ST	32.3	1.3	60.6	11.7	77.3
TerraMax PSB-ST	31.7	1.3	60.6	11.8	80.4
TerraMax Vertex	32.7	1.0	60.6	11.7	80.2
Visjon Exceed HSD	32.3	1.3	60.7	11.7	82.9
Visjon Exceed SAR	32.3	1.3	60.4	11.6	81.2
Average	32.3	1.4	60.6	11.7	80.6
LSD (0.05)	2.3	0.9	1.0	0.4	7.7
CV (%)	4.0	36.3	0.9	1.7	5.4
P-value	0.9820	0.4250	0.9940	0.8360	0.8320

Bolded and underlined values are the highest mean. Bolded values are not different from the highest

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 36: 2019 WINTER WHEAT INOCULANT TRIAL, DENTON, MONTANA

Treatment	Height (in)	Lodging score	Test (lb/bu)	Protein (%)	Grain Yield (bu/ac)
Control	27.3	2.0	57.7	11.8	57.4
TerraMax Micro-AF ST	29.0	2.7	57.9	11.6	59.7
TerraMax Micro-AZ ST	28.3	2.7	57.6	11.6	**<u>62.9</u>**
TerraMax PSB-ST	28.3	2.7	58.0	11.5	57.4
TerraMax Vertex	28.7	3.0	57.8	11.4	55.9
Visjon Exceed HSD	29.0	3.0	58.2	11.1	57.6
Visjon Exceed SAR	29.0	2.7	57.9	11.5	57.4
Average	28.5	2.7	57.9	11.5	58.3
LSD (0.05)	2.3	1.4	0.9	0.9	4.1
CV (%)	4.6	29.6	0.9	4.4	3.9
P-value	0.7000	0.7720	0.8480	0.7930	0.0490

Bolded and underlined values are the highest mean. Bolded values are not different from the highest

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 37: 2019 SPRING WHEAT INOCULANT TRIAL, MOCCASIN, MONTANA

Treatment	Heading date	Height (in)	Test (lb/bu)	Protein (%)	Grain Yield (bu/ac)
Control	26-Jun	30.3	56.4	11.9	56.4
Earthfort Provide-Revive	27-Jun	31.0	56.8	11.8	55.1
Nutrio High Gear II	27-Jun	30.3	57.7	12.3	59.8
Tainio	26-Jun	30.7	57.0	11.8	53.2
TerraMax AF-ST	27-Jun	31.3	57.3	11.8	53.9
TerraMax Micro AZ-ST	27-Jun	30.0	56.8	12.0	48.7
TerraMax PSB-ST	27-Jun	31.0	56.6	12.1	49.2
TerraMax Vertex-ST	27-Jun	30.3	56.4	12.6	59.5
Visjon Exceed HSD	26-Jun	30.0	55.8	12.9	55.3
Visjon Exceed SAR	26-Jun	31.3	55.9	12.5	52.7
Average	27-Jun	30.6	56.7	12.2	54.4
LSD (0.05)	0.9	1.4	1.5	1.6	14.5
CV (%)	0.3	2.7	1.5	7.6	15.6
P-value	0.517	0.3990	0.2280	0.8480	0.8040

Bolded and underlined values are the highest mean. Bolded values are not different from the highest
Note: Study averages include experimental lines not listed
N.S. = Not Significant

TABLE 38: 2019 SPRING WHEAT INOCULANT TRIAL, DENTON, MONTANA

Treatment	Height (in)	Test Weight (lb/bu)	Grain Yield (bu/ac)
Control	27.3	58.6	48.7
TerraMax AF-ST	28.7	58.4	45.7
TerraMax Micro AZ-ST	28.0	58.5	46.4
TerraMax PSB-ST	28.0	58.0	43.8
TerraMax Vertex-ST	27.7	58.7	44.5
Average	27.9	58.4	45.8
LSD (0.05)	1.4	0.6	8.5
CV (%)	2.7	0.6	10.1
P-value	0.3420	0.2140	0.7290

Bolded and underlined values are the highest mean. Bolded values are not different from the highest
Note: Study averages include experimental lines not listed here.
N.S. = Not Significant

TABLE 39: 2019 SPRING WHEAT INOCULANT TRIAL, GERALDINE, MONTANA

Treatment	Height (in)	Test (lb/bu)	Protein (%)	Grain Yield (bu/ac)
Control	28.7	60.7	12.3	57.6
Liquid MicroSurge	29.0	60.4	12.2	55.8
Liquid MicroSurge + Micronutrient Talc + dry Incepive	28.3	60.1	12.7	52.5
Micronutrient Talc dry + Wheat MicroSurge	29.0	60.3	12.0	56.3
Micronutrient Talc dry + Wheat MicroSurge + dry	29.3	60.4	12.1	56.1
TerraMax AF-ST	28.7	60.7	12.6	56.7
TerraMax Micro AZ-ST	29.0	60.5	12.4	54.8
TerraMax PSB-ST	28.7	60.7	12.5	56.7
TerraMax Vertex-ST	28.7	60.2	12.3	55.4
Visjon Exceed HSD	28.7	60.2	14.7	51.7
Visjon Exceed SAR	27.0	60.8	12.1	50.9
Average	28.6	60.5	12.5	55.0
LSD (0.05)	1.6	1.1	2.7	6.3
CV (%)	3.3	1.1	12.5	6.8
P-value	0.3440	0.9100	0.7100	0.4150

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 40: 2019 BARLEY INOCULANT TRIAL, MOCCASIN, MONTANA

Treatment	Height (in)	Test Weight (lb/bu)	Plumps (%)	Grain Yield (bu/ac)
Control	24.3	56.5	85.8	62.0
Exceed SAR	25.0	55.7	90.0	67.5
Exceed HSD	24.3	56.1	86.4	67.0
Average	24.6	56.1	87.4	65.5
LSD (0.05)	1.7	1.3	5.3	11.5
CV (%)	3.2	1.1	2.9	8.3
P-value	0.5390	0.4050	0.1930	0.4530

Bolded and underlined values are the highest mean. Bolded values are not different from the highest

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 41: 2019 PEA INOCULANT TRIAL, MOCCASIN, MONTANA

Treatment	Height (in)	Test wt (lb/bu)	Grain Yield (lbs/ac)
Control	25.8	62.6	1976.0
Lalfix Duo Granular	**29.3**	62.6	**2409.2**
Lalfix Duo Peat	25.0	62.7	**2263.7**
Average	26.7	62.6	2263.7
LSD (0.05)	2.5	0.6	351.0
CV (%)	5.9	0.6	9.5
P-value	0.0110	0.8850	0.0330

Bolded and underlined values are the highest mean. Bolded values are not different from the highest

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 42: 2019 CHICKPEA INOCULANT TRIAL, MOCCASIN, MONTANA

Treatment	Height (in)	Test wt (lb/bu)	Grain Yield (kg/ha)
Control	16.0	59.6	1043.9
Lalifix Duo Granular "A"	16.5	59.7	1198.2
Lalifix Duo Granular "AB"	15.8	59.7	991.5
Lalifix Duo Peat	15.0	59.6	1144.3
Average	15.8	59.6	1094.5
LSD (0.05)	1.2	1.2	197.4
CV (%)	4.7	1.2	11.3
P-value	0.1030	0.9970	0.1450

Bolded and underlined values are the highest mean. Bolded values are not different from the highest

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

CROP MATRIX TRIAL

Patrick Carr (Principal Investigator)

Sherry Bishop, Heather Fryer, Simon Fordyce, Sally Dahlhausen, and Darryl Grove, Central Agricultural Research Center, Moccasin; Darrin Boss, John Miller, and Julie Prewett, Northern Triangle Agricultural Research Center (Co-Principal Investigators)

Montana State University, Dep. Research Centers

Summary

Lentil and pea are popular choices to insert into wheat-based cropping systems so crop rotation benefits can be realized. Canola is becoming a popular cool-season, broadleaf crop in central Montana. The impact that these three broadleaf crops have on subsequent crops in a diverse cropping system, and the effect of previous crops on canola, lentil, and pea performance, should be considered, particularly over time. Canola along with barley, lentil, pea, and spring wheat were established in plots at both the MSU Central Agricultural Research Center (CARC) near Moccasin during 2018, and at the MSU Western Triangle Agricultural Research Center (WTARC) near Conrad. In 2019, all possible 2-yr crop sequences (e.g., canola-barley and spring wheat-pea) were established in a matrix by planting these same crops in a perpendicular direction to the planting direction used in 2018, for a total of 25, 2-yr crop sequences. Previous crop (2018) generally failed to affect grain yield of the subsequent crop (2019) at either location. This study will be continued through at least 2021 to determine if crop sequence/rotation impacts grain yield and quality over time.

Introduction

Montana farmers are seeking broadleaf crops that can be used to diversify wheat-based cropping systems. Lentil and pea are widely planted and canola is another cool-season broadleaf crop that is growing in popularity. This is reflected in the area dedicated to canola production, which has increased from 7500 acres during 2008 to 143,000 acres in 2019, down slightly from 155,000 acres in 2017. Our goal is to conduct determine how these three crops impact the performance of wheat and barley, and vice-versa, in two-year crop sequences and longer-duration crop rotations.

Study Description

Canola, lentil, and pea were direct seeded in 4, 15- by 75-ft strips along with barley and spring wheat in a replicated and randomized experimental design at both the CARC and WTARC in 2018. The crop strips were oriented in a north-south direction. These same five crops were planted in strips of identical dimension (i.e., 15- by 75-ft) during 2019, but in a perpendicular direction (i.e., east-west) to the planting direction of strips in 2018, creating a matrix consisting of 25 different, 2-yr crop sequences.

Results and Discussion

Previous crop (2018) failed to affect grain yield of the subsequent crop (2019) at either location, with three exceptions. At the CARC, canola following pea produced more seed (625 lb/ac) than following barley (425 lb/ac) or spring wheat (482 lb/ac), while spring wheat produced more grain following canola (1273 lb/ac), lentil (1299 lb/ac), and pea (1267 lb/ac) than following barley (929 lb/ac) or spring wheat (951 lb/ac) (Table 43). At the WTARC, barley produced more grain following spring wheat (3173 lb/ac) and pea (3095 lb/ac) than following barley (2428 lb/ac) and lentil (2448 lb/ac) (Table 44). This study will be continued through 2021, and perhaps even longer.

Acknowledgments

We are grateful to the Cargill Corporation for providing funding for this research, as well as the Montana Agricultural Experiment Station through the USDA National Institute of Food and Agriculture, Hatch project 1012796.

TABLE 43: GRAIN YIELD (LB/AC) OF FIVE CROPS DURING 2019 FOLLOWING FIVE CROPS GROWN DURING 2018 (LISTED IN LEFT COLUMN) AT THE MSU CENTRAL AGRICULTURAL RESEARCH CENTER NEAR MOCCASIN.

	Crop	Barley	Canola	Lentil	Pea	Spring wheat
2018 Crop	Barley	1488	425	978	1798	929
	Canola	1700	**521**	987	1526	**1273**
	Lentil	1627	**549**	974	1810	**1299**
	Pea		___			**1267**
	Spring wheat	1699	482	1107	1763	951
	Mean	1644	520	1001	1669	1144
	CV%	26.3	15.6	16.4	11.7	12.1
	$LSD_{0.05}$	NS	132	NS	NS	214
	P-value	0.94	<0.05	0.69	0.06	<0.05

TABLE 44: GRAIN YIELD (LB/AC) OF FIVE CROPS DURING 2019 FOLLOWING FIVE CROPS GROWN DURING 2018 (LISTED IN LEFT COLUMN) AT THE MSU WESTERN TRIANGLE AGRICULTURAL RESEARCH CENTER NEAR CONRAD.

		Barley	Canola	Lentil	Pea	Spring wheat
2018 Crop	Barley	2428	605	1347	510	2803
	Canola				446	
	Lentil	2448	903	1384	361	2821
	Pea	**3095**	1027	1723	596	2860
	Spring wheat	**3173**	860	1446	682	2344
	Mean	2802	809	1439	519	2665
	CV%	11.2	25.8	14.7	49.4	21.4
	$LSD_{0.05}$	482	NS	NS	NS	NS
	P-value	<0.05	0.07	0.09	0.47	0.64

WARM SEASON CROP SEQUENCE STUDY

Patrick Carr (Principle Investigator)

Simon Fordyce, Heather Fryer, Sherry Bishop, and Sally Dahlhausen (Co-Principle Investigators)

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Summary

Wheat-based cropping systems must be diversified to maintain economic profitability and environmental sustainability in central Montana. Twenty-two different warm-season crop species and species mixtures were screened as cover, forage, and grain/seed crops over a three-year period in four field experiments (one in 2016-17, two in 2017-18, and one in 2018-19) under no-till dryland management at the MSU Central Agricultural Research Center (CARC). Spring wheat and pea were included as cool-season crop checks, along with a 4-species, cool-season crop mixture. Fallow plots also were maintained. Wheat was grown following the first-year treatments in 2017, 2018, and 2019. Wheat grain yield was unaffected by previous crop treatment compared with fallow, with one exception. Wheat grain yield following fallow was greater (43 bu/ac) than following Hungarian and proso millet (35 and 31 bu/ac) in the 2016-17 field experiment. Likewise, wheat grain protein generally was unaffected by previous crop compared with fallow ($P > 0.05$). These results indicate that fallow fails to result in wheat yield benefits compared with preceding wheat with either cool- or warm-season, annual crop species in shallow soils common in central Montana.

Introduction

There is a need to diversify wheat-based cropping systems in Montana to achieve economic and environment benefits. Previous researchers have focused on cool-season broadleaf crops as a way to diversify dryland cropping systems in Montana. Research suggests that there are rotation benefits that can result when warm-season crops are included in crop diversification efforts. Only limited research on crop sequences that include wheat and warm-season crops has been conducted in Montana, particularly in the central dryland region. The purpose of this research project was to identify warm-season species that are adapted as cover, forage, and grain/seed crops at the CARC, and to determine how yield of a subsequent wheat crop is affected.

Study Description

Eighteen warm-season crops were grown along with two-crop combinations (corn + pinto beans and proso millet + pinto beans), as well as a four-crop combination (corn + sorghumXsudangrass + pinto bean + cowpea) in one field during 2016, two different fields during 2017, and one field in 2018 at the CARC. Multiple phenotypes of some cowpea (e.g., bush-type and vining growth) were included. The warm-season crop treatments were compared with two cool-season crops (spring wheat and field pea) as well as a four-species, cool-season crop combination (barley + wheat + pea + lentil) when grown as cover, forage, and grain/seed crops. A fallow check treatment also was included. The crop treatments were arranged in an experimental design so that data could be analyzed statistically. Performance of these crop treatments were reported in the 2018 Annual Report. Briefly, a subset of eight warm-season crop treatments showed greatest promise as cover and forage crops, with limited potential as grain/seed crops. The impact of these warm-season crop treatments compared to fallow on performance of a subsequent wheat crop was determined in each of the four field experiments.

Results and Discussion

Differences in wheat grain yield generally were not detected when wheat was preceded by a warm-season crop grown for cover, forage, or grain and seed compared to fallow ($P > 0.05$) (Fig. 1). Exceptions were limited to the 2016-17 field experiment where wheat grain yield was greater following fallow (43 bu/ac) than following Hungarian and proso millet (35 and 31 bu/ac). Wheat grain yield across crop treatment whole plots and management (cover, forage, or grain/seed) subplots averaged 21 and 31 bu/ac in the two field experiments during 2017-18, and 37 bu/ac in the field experiment during 2018-19. Grain-protein concentration was determined when wheat followed the 12 selected trreatments listed in Figure 1. Wheat grain-protein concentration was greater when wheat followed fallow (12.8%) than all warm-season crop treatments (≤ 12.3%) in one of the two field experiments (data not presented). Wheat grain-protein concentration also differed across management (cover/forage/grain-seed) factor in that experiment, with a stair-step decrease from cover (12.2%) to forage (12.1%) to grain/seed (11.9%). Results of the four-year field study in central Montana demonstrated that warm-season crops generally can be grown for cover, forage, or grain/seed in a two-year sequence with wheat with little if any impact on wheat yield or grain protein concentration in central Montana. Many warm-season crop species are adapted when grown as cover or forage crops in that region of the state, but are not as well adapted when grown for grain/seed in the shallow soils and the dry, cool climate that occur.

Acknowledgments

We are grateful to the Montana Wheat and Barley Committee for providing three years of funding for this research, along with the USDA National Institute of Food and Agriculture, Hatch project 1012796.

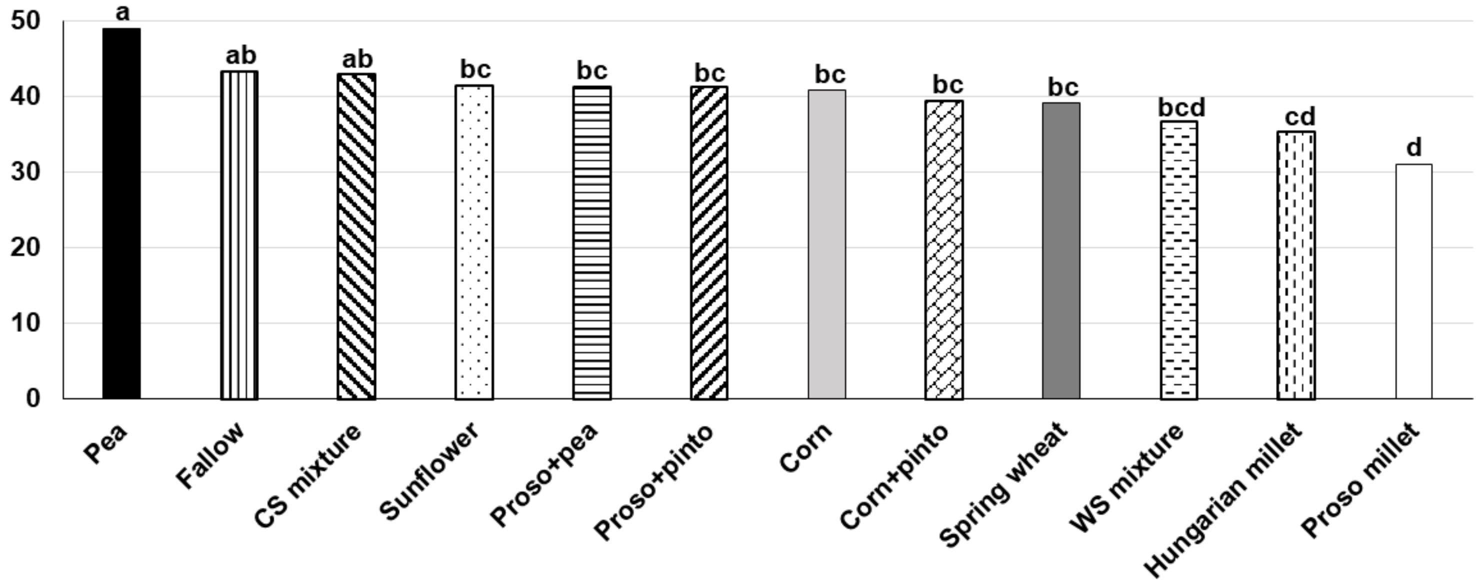

FIGURE 1. WHEAT GRAIN YIELD (BU/AC) FOLLOWING COOL-SEASON CROPS, WARM-SEASON CROPS, CROP MIXTURES, AND FALLOW AT THE CENTRAL AGRICULTURAL RESEARCH CENTER NEAR MOCCASIN IN A TWO-YEAR CROP SEQUENCE STUDY DURING 2016-17. BLOCKS WITH DIFFERENT LETTERS INDICATE DIFFERENCES IN YIELD AT THE P < 0.05 LEVEL.

ROTATION AND TILLAGE SYSTEM TRIAL

Patrick Carr (Principal Investigator)

Sherry Bishop, Tim Bishop, Heather Fryer, Darryl Grove, Simon Fordyce, and Sally Dahlhausen (Co-Principal Investigators)

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Summary

Dryland farmers need strategies to improve the profitability of wheat-based cropping systems in central Montana. Three- and four-year diverse crop rotations have been established at the MSU Central Agricultural Research Center (CARC) in both conventional-till and no-till environments to determine if agronomic and economic benefits result compared with wheat-fallow and continuous wheat systems. Growing conditions generally favored field crop production in 2019, although wet weather interfered with some planting and particularly herbicide spraying operations. Winter wheat grain yield was unaffected by crop sequence in the no-till environment ($P \geq 0.05$), while yields were higher following fallow (38 bu/ac) than lentil (28 bu/ac) or pea (26 bu/ac) in the conventional-till environment. Similarly, pea grain was greater in a safflower-spring wheat-pea sequence (23 bu/ac) than a wheat-barley-pea sequence (13 bu/ac) in the conventional-till environment, while no difference in pea yield was detected across the two crop sequences in the no-till environment ($P > 0.05$). These preliminary data indicate that crop sequence can impact grain yield of winter wheat and pea in a conventional till environment in central Montana.

Introduction

Winter wheat (*Triticum* spp.) dominates dryland grain farming in central Montana (Sommer, 2016). However, profit margins when growing wheat have shrunk or disappeared (Swenson and Haugen, 2017), supporting diversification strategies for wheat-based cropping systems. Rotating wheat with pulse and other crops has been considered previously in Montana, but generally in short 2-yr crop sequences or rotations limited to only a few crops. Three- and four-year rotations are being compared for their impact on wheat performance in central Montana.

Study Description

Five cropping systems were established in replicated and randomized plots in conventional-till and no-till environments in 2017: (1) winter wheat (wheat)-fallow; (2) wheat-lentil-barley; (3) wheat-pea-barley (4) spring wheat-pea-proso millet-safflower; and (5) wheat-spring wheat. All phases of all systems are present each year so that comparisons between different systems having a common crop (e.g., WW in systems 1, 2, 3 and 5) can be made.

Results and Discussion

In the no-till environment, winter wheat (wheat) yields were greater following fallow (33 bu/ac) in the wheat-fallow-wheat sequence than following spring wheat (19 bu/ac) in the wheat-spring wheat-wheat sequence ($P < 0.05$) during 2019 (Fig. 2). Differences were not detected between wheat yields in the wheat-spring wheat-wheat sequence and the barley-lentil-wheat sequence (30 bu/ac) or the barley-pea-wheat sequence (26 bu/ac). Soil moisture differences were not detected across different crop sequences in 2019 ($P = 0.63$), nor were there differences in crop plant density ($P = 0.21$). Likewise, soil moisture did not differ across crop sequences in the conventional-till experiment (P = 0.61) nor were there crop plant density differences (P = 0.06), even though wheat grain yield was greater in the wheat-fallow-wheat sequence (38 bu/ac) than the barley-lentil-wheat sequence (28 bu/ac), barley-pea-wheat (25 bu/ac), and wheat-spring wheat-wheat (20 bu/ac) sequences. Pea was common in two crop sequences: wheat-barley-pea and safflower-spring wheat-pea. Differences in pea yield were not detected in the no-till environment (P = 0.05), though there was a trend for more peas to be produced in the safflower-spring wheat-pea sequence (23 bu/ac) than the wheat-barley-pea sequence (18 bu/ac). Under conventional-tillage, more peas were produced in the safflower-spring wheat-pea sequence (22 bu/ac) than the wheat-barley-pea sequence (13 bu/ac) (P = 0.003). Pea plant density was higher following spring wheat (7 plants/sq. ft.) than following barley (6 plants/sq. ft.), but this statistical difference is of limited agronomic importance since pea plant stands > 6/sq. ft. are considered optimum for grain yield. Soil moisture differences were not detected between crop sequences in either environment (P > 0.2). Spring wheat was included in two sequences: spring wheat-wheat-spring wheat and millet-safflower-spring wheat (Fig. 3). No difference was detected in spring wheat yield in the no-till experiment between crop sequences (avg. yield = 29 bu/ac; P = 0.48), while grain yield was higher in the millet-safflower-spring wheat sequence (30 bu/ac) than the spring wheat-wheat-spring wheat sequence (26 bu/ac) in the conventional-till environment. These data should be considered preliminary since this long-term study will be continued through at least 2025.

Acknowledgments

We are grateful to the Montana Agricultural Experiment Station for providing funding for this research through the USDA National Institute of Food and Agriculture, Hatch project 1012796.

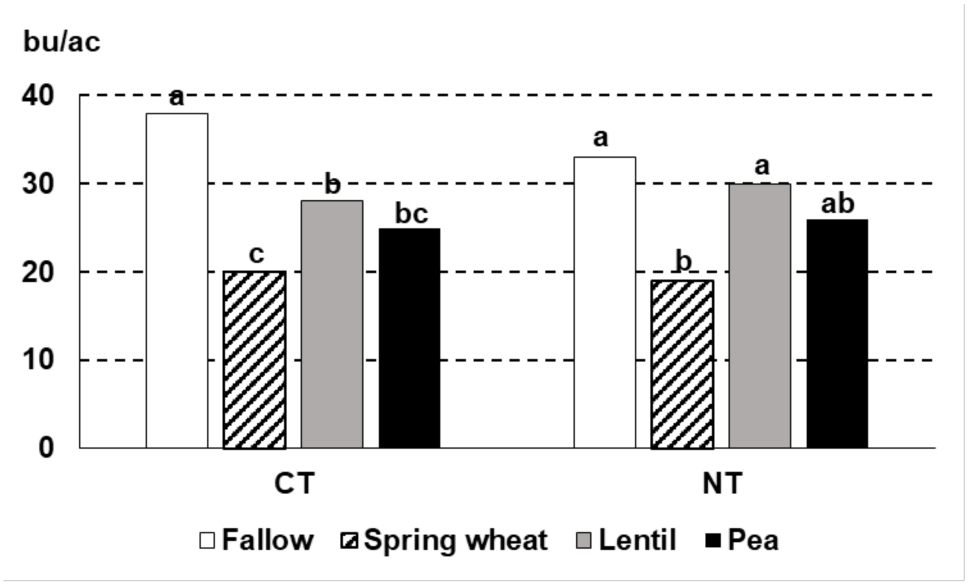

FIGURE 2. WINTER WHEAT GRAIN YIELD FOLLOWING FALLOW AND THREE CROPS AT THE MSU CENTRAL AG. RES. CENTER NEAR MOCCASIN, MT, DURING 2019. BLOCK WITH DIFFERENT LETTERS WITHIN A TILLAGE SYSTEM INDICATE DIFFERENCES AT THE *P* < 0.10 LEVEL OF SIGNIFICANCE.

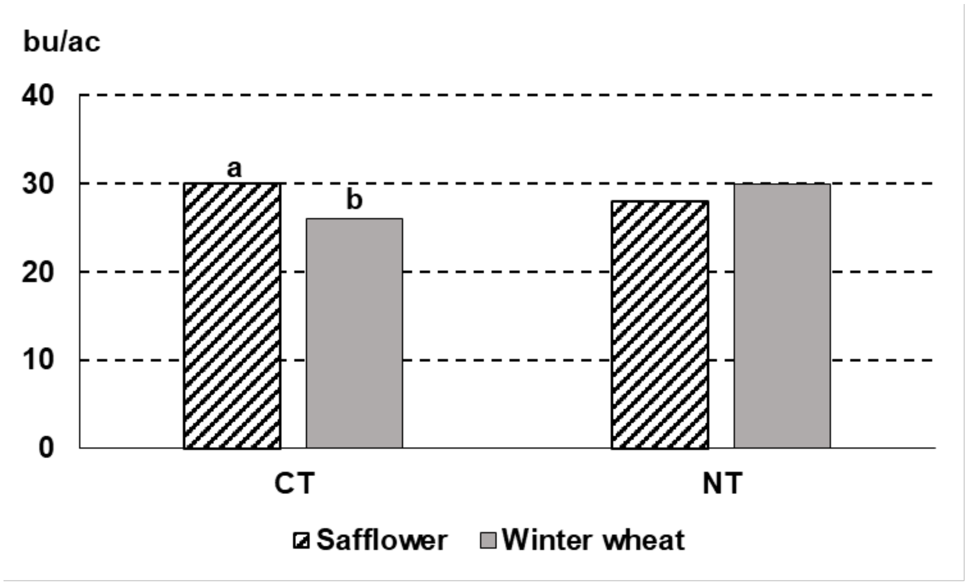

FIGURE 3: SPRING WHEAT GRAIN YIELD FOLLOWING SAFFLOWER AND WINTER WHEAT AT THE MSU CENTRAL AG. RES. CENTER NEAR MOCCASIN, MT, DURING 2019. BLOCKS WITH DIFFERENT LETTERS WITHIN A TILLAGE SYSTEM INDICATE DIFFERENCES AT THE $P < 0.10$ LEVEL OF SIGNIFICANCE.

CULTIVAR SELECTION IN ACIDIC SOILS

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Montana State University[1]; Dep. of Land Resources and Environmental Sciences[2]; Chouteau County Extension Office[3]; Dep. of Research Centers, Central Agricultural Research Center, Moccasin, MT [4]

Summary

Acidification of agricultural soils has been linked to high fertilizer inputs and no-till management. Cultivated soils of pH < 5.5 have been discovered in 23 Montana counties since the problem was first discovered in 2011. Here, we evaluated the performance of up to nine cultivars of four high-acreage crops (i.e., spring pea, spring canola, spring wheat, and spring barley) in unlimed (pH < 5.5) and limed (pH > 6.1) soils under conventional- and no-till management during the 2018 and 2019 growing seasons. The goal of this study was to assess the extent to which cultivar selection can mitigate crop performance impacts of acidic soils in Montana.

Methods

Trials were established in acidic soils (pH 4.3 - 5.1) at two locations, a no-till and a conventional-till system, in 2018 and 2019. The conventional-till system was located near Highwood, MT and the no-till system was located near Geraldine, MT. Four spring crops were assessed in these trials: canola, field pea, wheat, and barley. Nine cultivars of spring canola and eight cultivars of spring field pea were established at Highwood (2018 and 2019) and Geraldine (2018 only). Nine cultivars of spring wheat and malting barley were established at Geraldine and Highwood in 2018 and 2019. Cultivar performance was assessed in limed and unlimed conditions. Lime material (i.e., Aglime, with 99.2% passing through #100 sieve, Montana Limestone Company, Warren, MT) was applied at 5 t/ac on October 12 and 31, 2017 at Geraldine and Highwood, respectively. A Stoltzfus wet-lime applicator (Morgantown, PA) was used to broadcast the Aglime to the soil surface. The liming material was incorporated with tillage at both locations to a depth of 6” and 4-5” at Highwood and Geraldine, respectively. In this report, yield and test weight are summarized by spring wheat cultivar across years and locations. Similarly, yield and percent plumps are summarized by malting barley cultivar across years and locations. Finally, yield, test weight, and quality (e.g., oil content, protein) are summarized by spring canola and spring pea cultivar across locations in 2018 only. Seeding dates ranged from 1 May to 15 May, and harvest dates ranged from 22 August to 15 September across years and locations. A subsequent report will provide a detailed summary of all agronomic data collected in these trials, including seed quality, management, and climatic data.

Results and Discussion

In 2019, a mid-season hailstorm severely damaged pea and canola crops at Highwood. These crops were harvested, but the data were considered unusable and thus a detailed summary of their performance in 2019 was excluded from this report. Spring wheat and barley were only moderately damaged by hail in 2019. In addition to hail, canola establishment issues were observed in 2019, but these issues were confined to unlimed plots. While soil acidity likely contributed to the poor stands, there was agreement among researchers that seeding depth also had a role. The current hypothesis is that liming altered the physical properties of the surface soils, which in turn affected the depth at which the lightweight plot drill placed the seed. Canola is considered relatively sensitive to seeding depth, which may explain why stand establishment issues did not arise among the other crops assessed in these trials. Surface soils at the 2019 Highwood site were also drier than the 2018 Highwood site and the 2018-2019 Geraldine site, which may explain why seeding depth issues were not noticed in any other location-year.

Pea and Canola

In 2018, canola oil production and seed weight in the no-till system, as well as canola yield, canola test weight, pea yield, pea seed weight, and pea protein in the conventional-till system, varied by cultivar in response to lime. These results allowed for the identification of several cultivars of spring pea and spring canola which were top performers in both limed and unlimed conditions (Table 45). Canola cultivars 4187 RR and HyCLASS 930 were among the top oil producers, while cultivars 6090 RR, HyCLASS 955, and 6074 RR were among the top performers for seed weight in the no-till system under both limed and unlimed conditions. In the conventional-till system, canola cultivar CP9919RR was the top yielder in unlimed conditions (1,176 lb/ac) and among the top yielders in limed conditions (1,349 lb/ac), with no statistical differences observed across lime treatments. Cultivar DKL 70-10 was a top yielder in both limed (1,293 lb/ac) and unlimed (1,054 lb/ac) conditions and exhibited statistically higher yields in limed versus unlimed conditions. DKL 70-10 also had the highest test weight in unlimed conditions (51.5 lb/bu) and had among the highest test weights in limed conditions (52.3 lb/bu). Test weights for DKL 70-10 were statistically equivalent across liming treatments. Spring pea cultivars Delta, CDC Mozart, and Carousel were among the top yielders in the conventional-till system under both limed and unlimed conditions, while Carousel, Aggassiz, and Majoret had the highest seed weights. Agassiz was in the top performing bracket for protein in unlimed conditions, and produced the highest protein in limed conditions. Averaged across liming treatments, 6074 RR and 6090 RR yielded statistically lower than the top performing cultivars in the conventional and no-till systems in 2018 (Table 46), suggesting these cultivars may be relatively susceptible to aluminum toxicity.

Wheat and Barley

Spring wheat yield varied by cultivar in unlimed soils ($p < 0.01$) but not in limed soils ($p > 0.05$) under no-till management in 2019. With this lone exception, lime-dependent cultivar responses for yield and test weight were absent among the two cereal crops assessed in this 2-yr study. In unlimed soils under no-till management in 2019, four cultivars yielded statistically equivalent to the top yielder, Alum (2,720 lb/ac). These were Lanning (2,655 lb/ac), MT 1673 (2,560 lb/ac), MT 1621 (2,350 lb/ac), and SY Soren (2,300 lb/ac). Of these cultivars, only MT 1621 exhibited a statistical yield improvement with lime. When averaged across limed and unlimed treatments, Vida was the top yielder or yielded statistically equivalent to the top yielder in the conventional and no-till system in both years of the study (Table 49), suggesting possible low-pH tolerance relative to other tested cultivars. Only two named cultivars and one experimental line of malting barley were assessed at both locations in 2018 and 2019: Buzz, Hockett, and 11WA-107.58. Averaged across limed and unlimed treatments, Buzz and Hockett exhibited among the highest percentages of plumps in both the no-till and conventional-till systems in 2018 and 2019 (Table 48). Buzz was among the top yielders and yielded statistically equivalent to Hockett under no-till and conventional-till in 2018. Hockett outyielded Buzz in the no-till system in 2019. Aside from slightly depressed yields in the unseasonably cool and wet 2019 growing season, Buzz appears very evenly matched with Hockett in its ability to perform in low pH soils. Both cultivars have a strong capacity to produce plump kernels in soils of pH < 5.5.

Acknowledgements

We are grateful to the Western Sustainable Agriculture Research and Education Program for funding this research.

Table 45: Top performing cultivars of spring canola (light shading) and spring pea (dark shading) by target variable under three different liming scenarios. Based on results from small-plot trials established in a conventional-till system near Highwood, MT (CT) and a no-till system near Geraldine, MT (NT) in 2018. Cultivars within a given shaded region are statistically equivalent (Fisher's protected LSD), ranked by unlimed, limed, or absolute average. Lime x cultivar interaction terms were often not significant (NS).

CT				NT	
YIELD	TEST WT	SEED WT	PROTEIN	SEED WT	OIL
Top performers in unlimed conditions.					
CP9919RR HyCLASS 730 DKL 70-10 HyCLASS 955	DKL 70-10 6074 RR	NS	NS	6090 RR 6074 RR HyCLASS 955	DKL 35-23 HyCLASS 930 4187 RR
Delta CDC Mozart Agassiz Carousel	NS	Agassiz Carousel Majoret CDC Mozart	Carousel Agassiz Majoret Cruiser Delta	NS	NS
Top performers in limed conditions.					
HyCLASS 930 DKL 35-23 CP9919RR DKL 70-10	6074 RR DKL 70-10 HyCLASS 730 HyCLASS 955	NS	NS	6090 RR DKL 70-10 HyCLASS 955 6074 RR 4187 RR HyCLASS 930 HyCLASS 730	HyCLASS 955 4187 RR 6074 RR HyCLASS 730 6090 RR HyCLASS 930
Delta Aragorn CDC Mozart Carousel	NS	Carousel Delta Agassiz Majoret Aragorn	Agassiz	NS	NS
Top performers in limed and unlimed conditions.					
CP9919RR DKL 70-10	DKL 70-10 6074 RR	NS	NS	6090 RR HyCLASS 955 6074 RR	4187 RR HyCLASS 930
Delta CDC Mozart Carousel	NS	Carousel Agassiz Majoret	Agassiz	NS	NS

Table 46: Montana State University Lime x Canola Cultivar Trial established in acidic soils in a no-till system near Geraldine, MT (NT) and a conventional-till system near Highwood, MT (CT) in 2018. Spring canola yield (lb/ac), test weight (lb/bu), and oil content (%) are reported for nine cultivars, averaged across limed and unlimed conditions. Aglime was applied at 5 tons per acre in the fall of 2017.

	YIELD		TEST WT		OIL	
CULTIVAR	NT	CT	NT	CT	NT	CT
	------------(lb/ac)------------		------------(lb/bu)------------		------------(%)------------	
4187 RR	**1172**	664	51.4	51.0	**43.6**	**41.4**
6074 RR	1093	789	51.0	**51.9**	**43.0**	**41.0**
6090 RR	918	672	50.7	50.6	**42.8**	**41.5**
CP9919RR	**1239**	**1263**	50.9	51.0	41.9	39.0
DKL 35-23	**1328**	**1192**	50.9	51.1	**43.3**	39.5
DKL 70-10	**1272**	**1173**	**51.9**	**51.9**	41.5	40.0
HyCLASS 730	**1242**	**1095**	51.5	**51.6**	**42.8**	**41.1**
HyCLASS 930	**1169**	**1303**	51.4	51.4	**43.4**	**42.3**
HyCLASS 955	**1150**	**1068**	51.3	51.5	**43.4**	**41.1**
Mean	1176	1024	51.2	51.3	42.8	40.8
CV%	15.8	23.4	0.4	0.5	2.5	4.2
LSD	187	241	0.2	0.3	1.1	1.7
HSD	301	389	0.4	0.4	1.7	2.8
P-Value (Rep)	0.2578	0.0567	0.8036	0.6285	0.2683	0.1328
P-Value (Lime)	0.6558	0.0665	0.6003	0.0383	0.3226	0.1223
P-Value (Cultivar)	0.0042	<0.001	<0.001	<0.001	0.0028	0.0058
P-Value (Lime:Cultivar)	0.3776	0.0487	0.2180	0.0158	0.0021	0.5801

Table 47: Montana State University Lime x Pea Cultivar Trial established in acidic soils in a no-till system near Geraldine, MT (NT) and a conventional-till system near Highwood, MT (CT) in 2018. Spring pea yield (lb/ac), test weight (lb/bu), and protein (%) are reported for eight cultivars, averaged across limed and unlimed conditions. Aglime was applied at 5 tons per acre in the fall of 2017.

	YIELD		TEST WT		PROTEIN	
CULTIVAR	NT	CT	NT	CT	NT	CT
	------------(lb/ac)	------------	------------(lb/bu)	------------	------------(%)	------------
Agassiz	**1776**	1307	63.2	61.7	22.4	**27.6**
Aragorn	1686	1261	63.3	62.6	21.8	24.8
Carousel	1492	1327	**64.5**	63.4	21.8	**26.7**
CDC Mozart	1535	**1527**	**64.5**	**64**	20.6	25.1
Cruiser	1619	1152	63	62.3	20.6	25.5
Delta	**1999**	**1643**	**64.7**	**64.3**	21.5	25.7
Lifter	1325	1054	63.7	62.1	20.7	24.5
Majoret	1496	884	**64.2**	62.7	23.3	26.4
Mean	1616	1269	63.9	62.9	21.6	25.8
CV%	15	17.9	1	0.8	10	4
LSD	245	230	0.6	0.5	NS	1
HSD	387	363	1	0.8	NS	1.6
P-Value (Rep)	0.2773	0.5367	0.5856	0.9324	0.9343	0.1233
P-Value (Lime)	0.4963	0.5185	0.6083	0.6311	0.3722	0.0095
P-Value (Cultivar)	<0.001	<0.001	<0.001	<0.001	0.1845	<0.001
P-Value (Lime:Cultivar)	0.4786	0.0387	0.8366	0.6233	0.7908	0.0842

Table 48: Montana State University Lime x Barley Cultivar Trial established in acidic soils in a no-till system near Geraldine, MT (NT) and a conventional-till system near Highwood, MT (CT) in 2018 and 2019. Malting barley yield (lbs per acre) and plumps (%) are reported for 13 cultivars, averaged across limed and unlimed conditions. Aglime was applied at 5 tons per acre in the fall of 2017.

	2018 Yield		*2019 Yield*		*2018 Plumps*		*2019 Plumps*	
CULTIVAR	NT	CT	NT	CT	NT	CT	NT	CT
	----------------------------(lb/ac)----------------------------				-------------------------------(%)-------------------------------			
10WA-106.18	2382	**3170**	-	-	29	23	-	-
10WA-107.43	**2971**	**3410**	-	-	44	26	-	-
10WA-117.17	**2642**	2785	-	-	**51**	30	-	-
11WA-107.43	-	-	**2539**	2344	-	-	83	43
11WA-107.58	2619	**3323**	**2286**	2294	50	37	87	56
12WA-120.14	2595	**3213**	-	-	47	38	-	-
13WAM-101.2	-	-	2173	**2482**	-	-	85	51
13WAM-135.26	-	-	**2245**	2307	-	-	89	**65**
13WAM-149.2	-	-	2096	2108	-	-	87	56
Hockett	2433	2925	**2496**	1997	**51**	**48**	85	**58**
MT124027	2249	2871	-	-	43	30	-	-
Buzz	**2722**	**3250**	1907	1845	**70**	**64**	90	**63**
Odyssey	-	-	1857	**2575**	-	-	94	56
Mean	2576	3118	2200	2244	48	37	87	56
CV%	13.1	12.8	16.1	10.1	24.8	33.5	7.7	12.2
LSD	341	402	357	229	12	12	NS	7
HSD	540	636	564	362	19	20	NS	11
P-Value (Rep)	0.0413	0.0087	0.4936	0.0408	0.1468	0.0684	0.0734	0.1584
P-Value (Lime)	0.0295	0.0302	0.0485	0.3854	0.2911	0.0192	0.1239	0.0594
P-Value (Cultivar)	0.0050	0.0240	0.0023	<0.001	<0.001	<0.001	0.0821	<0.001
P-Value (Lime:Cultivar)	0.2092	0.2229	0.3845	0.5197	0.0686	0.7273	0.6903	0.6102

Bold = top-performing cultivar; **Bold** = statistically equivalent to top-performer

NT = No-till system near Geraldine, MT

CT = Conventional-till system near Highwood, MT

Table 49: Montana State University Lime x Wheat Cultivar Trial established in acidic soils in a no-till system near Geraldine, MT (NT) and a conventional-till system near Highwood, MT (CT) in 2018 and 2019. Spring wheat yield (lbs per acre) and test weight (lbs per bushel) are reported for nine cultivars, averaged across limed and unlimed conditions. Aglime was applied at 5 tons per acre in the fall of 2017.

	2018 Yield		*2019 Yield*		*2018 Test Wt*		*2019 Test Wt*	
CULTIVAR	NT	CT	NT	CT	NT	CT	NT	CT
	(lb/ac)				(lb/bu)			
Alum	2669	2027	**2708**	**1981**	**60.2**	53.9	**59.4**	59.2
Brennan	2438	2417	2089	1545	**59.4**	**56.7**	**59.5**	**60.4**
Duclair	2593	2357	2345	1752	57.6	54.5	57.3	57.8
Lanning	**3115**	2149	**2805**	1507	57.6	51.4	58.2	59.2
MT 1621	**3105**	2291	**2636**	1721	58.8	**56.3**	58.1	59.2
MT 1673	2720	2464	2460	1735	57.2	54.8	56.1	56.8
SY Soren	2554	2293	2486	1512	58.4	**56.1**	**59.0**	**60.0**
Vida	**2859**	2196	**2512**	**2038**	58.2	54.5	58.0	57.8
WB Gunnison	2473	2196	2300	**1976**	**60.0**	**57.1**	**59.6**	59.2
Mean	2725	2266	2482	1752	58.6	55.0	58.4	58.8
CV%	13.1	20.2	12.7	12.7	2.0	2.4	1.3	1.3
LSD	360	NS	316	223	1.2	1.3	0.8	0.7
HSD	581	NS	511	361	1.9	2.2	1.2	1.2
P-Value (Rep)	0.4089	0.6385	0.0251	0.1910	0.5721	0.8721	0.3245	0.0072
P-Value (Lime)	0.3158	0.4103	0.0027	0.5178	0.8383	0.2131	0.2746	0.0225
P-Value (Cultivar)	0.0011	0.6681	0.0013	<0.001	<0.001	<0.001	<0.001	<0.001
P-Value (Lime:Cultivar)	0.2131	0.8319	0.0077	0.2141	0.3978	0.2899	0.1490	0.1182

Bold = top-performing cultivar

Bold = statistically equivalent to top-performer

NT = No-till system near Geraldine, MT

CT = Conventional-till system near Highwood, MT

EFFECT OF SEED PLACED P FERTILIZER AND LIME ON DURUM AT TWO LOCATIONS WITH ACIDIC SOILS IN CHOUTEAU COUNTY, MONTANA

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Introduction

Farmers in several Montana counties are now experiencing crop growth reductions or complete crop failures as a result of soil acidification and aluminum (Al) toxicity. Historically, acidification was not a problem in Montana because the parent material of most cultivated soils exhibited a neutral to alkaline reaction. However, fertilizer ammonium-N use (including urea) by farmers has grown tremendously in recent decades and is now three-fold greater than in 1985, leading to a downward trend in soil pH. Recent studies in Montana, particularly in Chouteau County, have identified soil acidity-related crop production problems where the surface soil pH is less than 5. Lime applications provide the only long-term approach to correct soil acidity. However, lime applications can exceed $110 per acre and are quite costly when viewed over a short-term time horizon. This is significant because up to 34% of Montana's cropland is managed by farmers under a lease agreement that may last only 4-5 years (Bekkerman et al., 2018, personal communication). Hence, short-term approaches to adapt to acidic soil pH conditions need to be evaluated for Montana farmers. Research from Oklahoma (Kaitibie et al., 2002) found that phosphate fertilizers provided yield and economic benefits to winter wheat in soils affected by acidity and aluminum toxicity. These investigators concluded that risk-neutral farmers wanting to maximize returns would best apply diammonium phosphate in the seed-furrow rather than apply lime. This study was undertaken to determine if a low pH, aluminum toxicity sensitive crop like durum would benefit from seed-placed P.

Methods

Durum (cv. Alzada, WestBred, LLC, Bozeman, Montana) field plots were established at two dryland farms in Chouteau County during the 2018 and 2019 growing season. The locations were east of Highwood (47°37'53.47"N, 110°39'57.34"W in 2018; and 47°37'17.92"N, 110°39'59.57"W in 2019) and north of Geraldine (47°49'50.10"N , 110°11'7.80"W). The dominant soils series at Highwood is a Bearpaw clay (fine, smectitic, frigid Vertic Argiustolls) and Bearpaw-Vida clay fine-loamy, mixed, superactive, frigid Typic Argiustolls in 2018 and 2019; and Scobey-Kevin clay (fine, smectitic, frigid Aridic Argiustolls) at Geraldine. The field trials were a complete factorial design consisting of two lime rates (-lime, +lime, or 0- and 5-ton lime ac^{-1}) and five P_2O_5 rates (0, 15, 30, 60 and 90 lb ac^{-1}). Treatments (P rate x lime) were replicated three and four times at Highwood and Geraldine, respectively. The experimental design was a split-block or strip-block. Individual plots were 20' long and 5' wide. Seeding was conducted with a 5-row cone seeder (12" row spacing) at a seeding rate of 22 pure live seeds per foot of row. Triple superphosphate (0-45-0) was used as the P source and was applied in the seed-furrow. Nitrogen fertilizer (urea) was broadcast onto all field sites following seeding at a rate of 70 lb N ac^{-1} at Highwood and 100 lb N ac^{-1} at Geraldine. Lime material, i.e., Aglime (Montana Limestone Company, Warren, MT) with 99.2% passing through #100 sieve, was applied on October 12 and 31, 2017 at Geraldine and Highwood, respectively. A Stoltzfus wet-lime applicator (Morgantown, PA) was used to broadcast the Aglime to the soil surface. The liming material was incorporated with tillage at both locations to a depth of 6” and 4-5” at Highwood and Geraldine, respectively. Table 50 provides a summary of seeding date, harvest date, soil pH, and soil pH for the field site locations.

Results and Discussion

Durum grain yield in both 2018 and 2019 was responsive to seed-placed P fertilizer in the absence of lime at the Highwood field location (Figure 4). This occurred in spite of the fact that soil test results for the field location indicate the presence of adequate P reserves (Figure 4). Conversely, where Aglime was applied to correct soil acidity (+lime) no response to P fertilizer was observed. This P fertilizer x Aglime interaction was significant at the $P < 0.05$ level in both seasons. The economics of P applications were particularly impressive in 2018 (hail damage impacted durum production in 2019). In 2018, durum production with 60 lb/ac P_2O_5 increased 22.2 bu/acre over the 0 P fertilizer control (almost a 2x yield increase). Durum is currently priced at ~$5 per bushel, so the gross economic impact is $111 per acre. Phosphorus fertilizer sold as 11-52-0 (MAP) is currently priced at $430 per ton (or $0.41 per lb. of P_2O_5). The material cost of the 60 lbs/acre P_2O_5 rate equates to $25 per acre, so the net economic impact is about $86 per acre minus cost of application.

Durum grain yield was not responsive (P fertilizer effect was not significant) to seed-placed P at the Geraldine location in 2018 and 2019 (Figure 5). Also, grain yield was not responsive ($p > 0.05$) to application of Aglime. The absence of response to seed-placed P and/or lime (in contrast to the Highwood) was in part related to the soil pH, which was not as acidic as the Highwood location. The pH of non-limed soil pH at Geraldine was about 5.0, or 0.6-0.7 pH units higher than Highwood. Because pH is measured on a logarithmic scale, this equates to 4-5 times more hydrogen ions in the soil solution. Also, soil extractable Al levels exponentially increase as acidity falls below pH 5, hence small differences in pH can have a great effect on crop susceptibility to Al at individual field sites.

This study found that seed-place P fertilizer can benefit grain yield of durum at field sites with extremely acidic soils (pH <4.5). The results were consistent with previous studies conducted in Oklahoma by Kaitibie et al. (2002). Future research needs to be undertaken to evaluate this response in other grain crops (e.g., barley) and pulses (e.g., peas and lentil) that are common to Montana dryland agriculture.

Acknowledgements

We are grateful to Western Sustainable Agriculture Research and Education Program for funding this research.

Literature Cited

Kaitibie, S., F.M. Epplin, E.G. Krenzer, Jr., and H. Zhang. 2002. Economics of lime and phosphorus application for dual-purpose winter wheat production in low-pH soils. Agron. J. 94:1139–1145.

TABLE 50: SEEDING DATE, HARVEST DATE, SOIL PH AND SOIL P TEST (OLSEN P) AT THE FIELD SITE LOCATIONS.

Location	Year	Seeding date	Harvest date	Soil pH (0-4")		Soil P test (0-4")	
				-lime	+lime	-lime	+lime
						------- ppm -------	
Highwood	2018	May 03	August 23	4.4	6.1	48	57
	2019	May 14	Sept 17	4.3	6.8	82	82
Geraldine	2018	May 02	August 31	4.9	6.5	53	53
	2019	May 15	Sept 16	5.1	6.9	71	70

FIGURE 4: DURUM GRAIN YIELD AS AFFECTED BY PHOSPHORUS FERTILIZER ON ACIDIC SOILS AMENDED (+LIME) AND NOT AMENDED WITH LIME (-LIME) IN 2018 AND 2019. AGLIME APPLIED AT 5 TON AC^{-1}. HIGHWOOD, MONTANA. YIELD AFFECTED BY HAIL DAMAGE IN 2019.

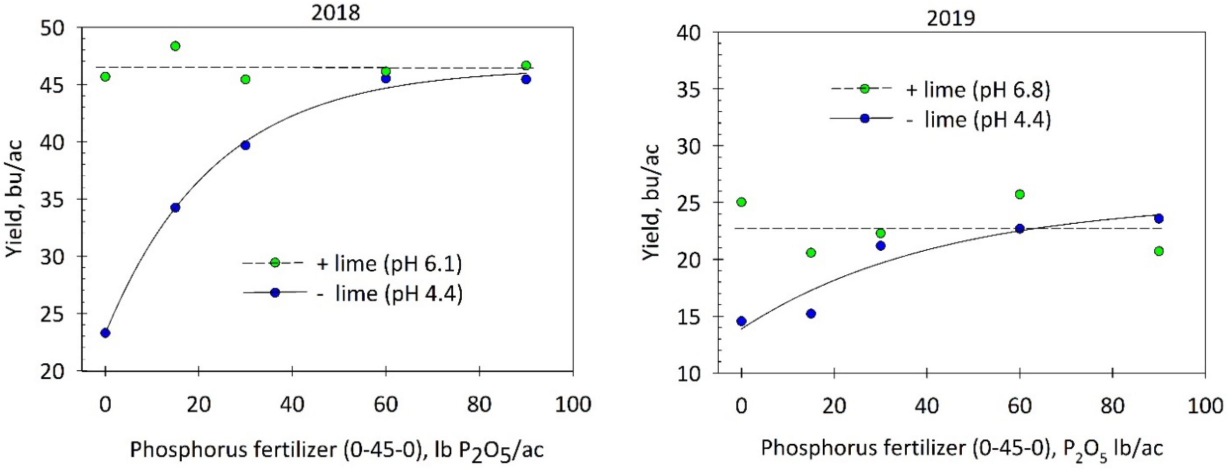
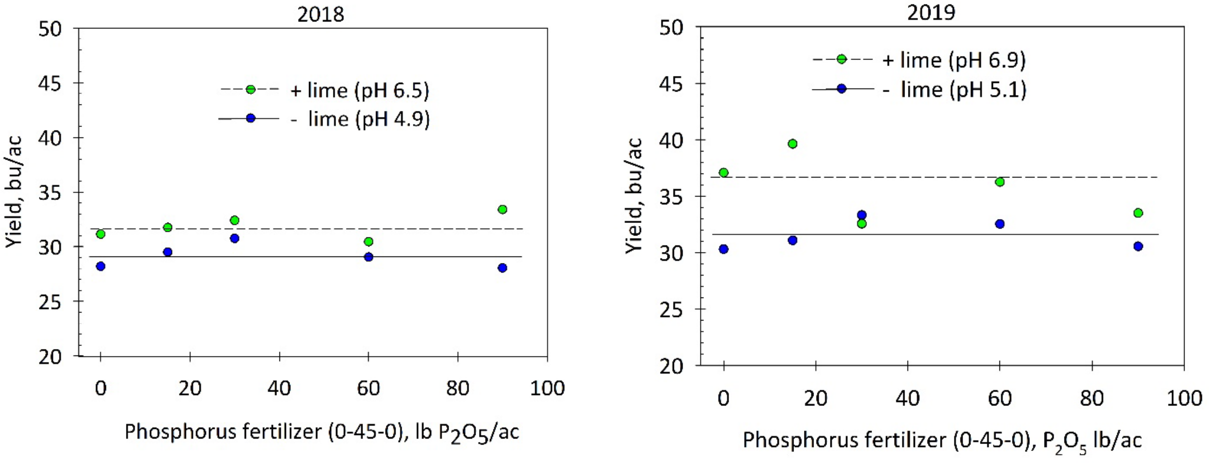


FIGURE 5: DURUM GRAIN YIELD AS AFFECTED BY PHOSPHORUS FERTILIZER ON ACIDIC SOILS AMENDED (+LIME) AND NOT AMENDED WITH LIME (-LIME) IN 2018 AND 2019. AGLIME APPLIED AT 5 TON AC-1. GERALDINE, MONTANA.



PREDICTING SOIL NITRATE CHANGES DURING WINTER MONTHS

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Summary

Soil nitrate concentrations can change dramatically during the winter months, which is one reason why soil sampling is recommended in spring versus fall. On the Moccasin Bench in central Montana, adjusting nitrogen fertilizer rates based on soil tests has a low success rate due to a combination of factors, including spatially variable shale and gravel depths, high soil organic matter contents and mineralization potentials, as well as high leaching potentials. This may help to explain why 65% of farmers in this area sample every other year or less often. To identify the major controls on soil nitrate changes on the Moccasin Bench during winter months, six commercial farms located along spatial shale and gravel depth gradients are being monitored for N mineralization potential and plant-available N from fall to spring 2018-19 and 2019-20.

Introduction

If large changes in plant-available N occur during winter months, over- or under-fertilization is likely when growing wheat, barley, and other crops. This is true whether fertilizing to past years' soil test results or to fall test results. Therefore, it is recommended that farmers and crop advisors conduct soil sampling in spring versus fall. However, springtime soil sampling is often impractical due to poor field conditions. Also, heavy springtime workloads often prohibit soil sampling efforts during this time. Even if spring soil sampling is successful, test results may be delayed or fertilizer may not be available, leading to added stress for the farmer. Thus, there is a need to forewarn farmers when large overwinter soil nitrate changes have occurred, and in which direction.

Methods

A Giddings hydraulic soil probe was/will be used to collect soil cores at 12 randomly assigned locations within six 1-ac subfields on the Moccasin Bench during winter months in 2018-19 and 2019-20. A weighed amount of subsample was/will be removed from all bulk soil samples. Subsamples will be analyzed with cell viability, urease activity, and acid phosphatase assay kits at the Central Ag Research Center Soil Microbiology Lab in Moccasin, MT. Aerobic incubations will also be performed for additional estimates of mineralizable nitrogen. Bulk soil samples will then be shipped to Ward Laboratories, Inc. for texturing and basic chemical analyses. Samples will be analyzed for total nitrogen, total carbon, pH, buffer pH, soluble salts, organic matter, Olsen phosphorus, total phosphorus, cation exchange capacity, potassium, calcium, magnesium, sodium, sulfate-sulfur, nitrate-nitrogen, and ammonium-nitrogen.

Results and Discussion

Results of this ongoing study will be summarized in a subsequent report. Importantly, this work builds on previous research conducted at the Central Agricultural Research Center, which monitored overwinter soil nitrate changes in shallow (0-8 in) and deep (> 8 in) soils (Fig 6a,d) following several different crops (Fig 6b,e) from 2007-2010 (Fig 6c,f). Soil samples were taken from the same locations (within 1 ft) in fall, mid-winter, and spring and then analyzed for nitrate.

Large increases in soil nitrate were observed from fall to mid-winter in 2008-09 and 2009-10, while nitrate was virtually unchanged over this period in 2007-08 (Fig 6c), suggesting conditions were favorable to N mineralization and nitrification in fall-winter of 2008-09 and 2009-10 relative to 2007-08. It is possible that conditions were favorable to nitrification in fall-winter 2007-08, but that leaching/denitrification losses were relatively higher. However, virtually unchanged 8-inch soil moisture during this period suggests the opposite is true. Furthermore, average daily temperatures in 2007 dropped steadily from about 75°F to 40°F from September through November, then dipped below freezing and more or less stayed there until April of 2008. A preliminary assessment of 2019 soil respiration data suggests most microbial activity in these soils occurs above ~55 °F. It follows that conditions in early fall 2007 would have been conducive to nitrification, but by mid-fall nitrification rates would have declined drastically. There were more days with air temperatures above 55 °F and temperatures were generally more variable in the falls of 2008 and 2009, which could explain the soil nitrate increases from fall to mid-winter in these years.

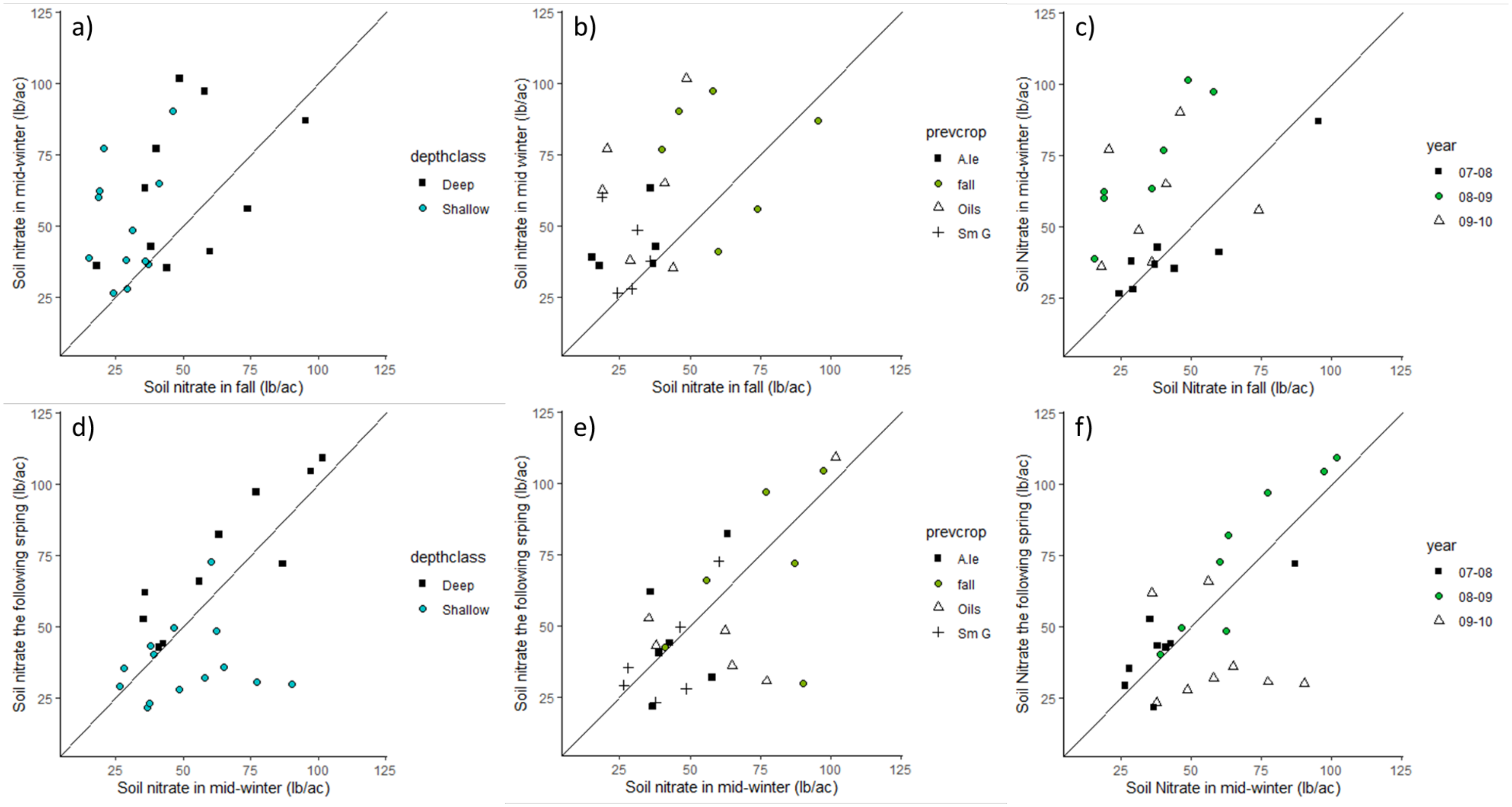
From mid-winter to spring, large nitrate losses were observed in 2009-10, but virtually no changes were observed over this period in 2007-08 or 2008-09 (Fig 6f). Losses to leaching/denitrification may have been higher or inputs from nitrification may have been lower in 2009-10. However, Fig 6d shows that most soils losing nitrate from mid-winter to spring 2009-2010 were less than 8 inches deep, suggesting that leaching was the main contributor to the 2009-10 losses rather than suppressed nitrification. In early March of 2010, air temperatures rose to well above freezing and stayed there through April. These thawing conditions may have been conducive to leaching, which would help explain the losses from mid-winter to spring in 2009-10.

Conclusions given here regarding controls on soil nitrate change during the winter months are still largely speculative in nature. Results from the current study are intended to provide more context for this dataset and eliminate much of this guesswork. Year-to-year variability has confounded past efforts to predict soil nitrate changes during the winter months. Collecting soil nitrate data at higher spatial and temporal resolutions during the winter months will facilitate the development of a reliable model for predicting overwinter soil nitrate changes locally and regionally.

Acknowledgments

We are grateful to the Western Sustainable Agriculture Research and Education Program for funding this research.

Figure 6: Soil nitrate changes from fall to mid-winter (a-c) and from mid-winter to spring (d-f) at the Central Agricultural Research Center in Moccasin, MT. Color and shape indicate soil depth (shallow = 0-8 inches; deep > 8 inches) previous crop (A.le = annual legume; fall = fallow; Oils = oilseed; Sm G = small grain), or year. Solid line indicates 1:1 (adapted from Jones et al., 2011. Measured and predicted temporal changes in soil nitrate-N levels from late summer to early spring in Montana. Western Nutrient Mgmt Conference. Vol 9).



EVALUATING MICROBIAL INOCULANT PERFORMANCE IN SMALL GRAINS AND PULSES

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Summary

Inoculant trials were established with winter wheat, spring wheat, barley, peas, and chickpeas to evaluate the effectiveness of biological treatments on the agronomic performance. In general, inoculants the inoculants evaluated this year provided little yield benefit relative to the control for most treatments. At Denton, winter wheat treated with TerraMax Micro-AZ ST yielded 62.9 bu/ac which statistically higher than the control at 57.4 bu/ac. Yellow peas treated with Lalfix Duo Granular were significantly taller compared to the control and yielded 2409.2 lb/ac compared to the control which yielded 1976.0 lb/ac. No yield differences were observed with the other treatments.

Introduction

Several microbial inoculant trials were performed at Moccasin and off-station locations to evaluate inoculants with putative plant beneficial characteristics. Inoculant formulations in these studies contained species of the genera *Bradyrhizobium, Azospirillum, Bacillus, Rhodococcus*, and complex multispecies blends of potential plant beneficial microorganisms. These organisms are known to provide a variety of plant beneficial functions, but more research is needed to evaluate their performance in the field. These organisms perform a variety of functions. Many members of the genera *Bradyrhizobium* are capable of nitrogen fixation in legumes and may have additional plant beneficial properties. *Azospirillum* are free-living nitrogen-fixing organisms that are believed to stimulate root growth in addition to fixing nitrogen. Inoculants containing phosphate solubilizing organisms were also evaluated. Some beneficial *Bacillus* and *Rhodococcus* strains are believed to contribute to increased nutrient uptake and increased early season root growth and root mass. The purpose of this work was to evaluate the effectiveness of these inoculants on the agronomic performance of winter wheat, spring wheat, and barley. Additional trials were performed to evaluate rhizobia performance on pea and chickpeas.

Methods

Inoculant formulations were applied following manufacturer's recommendations. Three replicate plots were arranged in a randomized complete block experimental design so that differences from the treatments could be separated from other effects. Seeding dates for winter wheat were 16 October at Moccasin and 25 October at Denton and Geraldine. Seeding dates for spring wheat were 23 April at Moccasin, 9 May at Geraldine, and 10 May at Denton. The seeding date for the barley inoculant trial was 25 April. Seeding dates for the pulse inoculant trials were and 26 April for peas and 29 May for chickpeas. Planting depth was 1 inch at a rate of 20 kernels/ft^2. Starter fertilizer, 20-30-20-10 NPKS, was applied at seeding at a rate of 50 lb/ac. An additional

120 lb/ac of ESN (44:0:0) was broadcast applied on to the winter wheat and spring wheat trials and 60 lb/ac of ESN (44:0:0) was applied to the barley trial on 23 May. Broadleaf and grass weeds were controlled with a burndown of glyphosate at 1.25 pt/ac before planting. Trials were also sprayed 23 May with Vendetta at a rate of 24 oz/ac to control field pennycress, flixweed, kochia, and prickly lettuce. Winter wheat plots were harvested with a small-plot harvester on 14 August at Moccasin and 28 August at Geraldine, and 4 September at Denton. Spring wheat plots were harvested 13 September at Moccasin, 28 August at Geraldine, and 16 September at Denton. The barley inoculant trial was harvested 3 September while peas were harvested on 26 September and chickpeas on 8 October.

Results and Discussion

No significant differences were observed between treatments and the control in winter wheat at Moccasin or Geraldine. At Denton, TerraMax Micro-AZ ST was statistically higher than the control at 62.9 bu/ac (Table 53). This represented a 5.5 bu/ac yield advantage compared to the control. No significant differences were observed in test weight or protein at any of the locations. No significant differences in yield, test weight, or protein were observed with any of the spring wheat treatments at any of the locations. No significant differences were observed with any of the barley treatments. Yellow peas treated with Lalfix Duo Granular were significantly taller compared to the control and yielded 2409.2 lb/ac compared to the control which yielded 1976.0 lb/ac (Table 58). No significant differences in plant height or yield were observed between the control and treatments in the chickpeas.

Acknowledgments

We are grateful to the Montana Agricultural Experiment Station for providing funding for this research through the USDA National Institute of Food and Agriculture, Hatch project 1015780.

TABLE 51: 2019 WINTER WHEAT INOCULANT TRIAL, MOCCASIN, MONTANA

Treatment	Height (in)	Test Weight (lb/bu)	Protein (%)	Grain Yield (bu/ac)
Control	31.7	61.4	9.9	60.5
TerraMax Micro-AF ST	32.0	61.4	9.9	60.3
TerraMax Micro-AZ ST	33.7	61.5	10.0	65.4
TerraMax PSB-ST	31.3	61.7	10.3	64.1
TerraMax Vertex	32.0	61.3	10.3	55.8
Visjon Exceed HSD	32.7	61.5	10.1	65.7
Visjon Exceed SAR	32.3	61.5	10.0	66.6
Average	32.2	61.5	10.1	62.6
LSD (0.05)	2.3	0.6	0.4	12.9
CV (%)	4.1	0.5	2.5	11.7
P-value	0.4670	0.7680	0.2240	0.5560

Bolded and underlined values are the highest mean. Bolded values are not different from the highest

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 52: 2019 WINTER WHEAT INOCULANT TRIAL, GERALDINE, MONTANA

Treatment	Height (in)	Lodging score	Test Weight (lb/bu)	Protein (%)	Grain Yield (bu/ac)
Control	32.3	2.0	60.7	11.6	81.0
TerraMax Micro-AF ST	32.3	1.3	60.7	11.6	81.1
TerraMax Micro-AZ ST	32.3	1.3	60.6	11.7	77.3
TerraMax PSB-ST	31.7	1.3	60.6	11.8	80.4
TerraMax Vertex	32.7	1.0	60.6	11.7	80.2
Visjon Exceed HSD	32.3	1.3	60.7	11.7	82.9
Visjon Exceed SAR	32.3	1.3	60.4	11.6	81.2
Average	32.3	1.4	60.6	11.7	80.6
LSD (0.05)	2.3	0.9	1.0	0.4	7.7
CV (%)	4.0	36.3	0.9	1.7	5.4
P-value	0.9820	0.4250	0.9940	0.8360	0.8320

Bolded and underlined values are the highest mean. Bolded values are not different from the highest

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

Table 53: 2019 winter wheat inoculant trial, Denton, Montana

Treatment	Height	Lodging	Test	Protein	Grain Yield
	(in)	score	(lb/bu)	(%)	(bu/ac)
Control	27.3	2.0	57.7	11.8	57.4
TerraMax Micro-AF ST	29.0	2.7	57.9	11.6	59.7
TerraMax Micro-AZ ST	28.3	2.7	57.6	11.6	**62.9**
TerraMax PSB-ST	28.3	2.7	58.0	11.5	57.4
TerraMax Vertex	28.7	3.0	57.8	11.4	55.9
Visjon Exceed HSD	29.0	3.0	58.2	11.1	57.6
Visjon Exceed SAR	29.0	2.7	57.9	11.5	57.4
Average	28.5	2.7	57.9	11.5	58.3
LSD (0.05)	2.3	1.4	0.9	0.9	4.1
CV (%)	4.6	29.6	0.9	4.4	3.9
P-value	0.7000	0.7720	0.8480	0.7930	0.0490

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

Table 54: 2019 spring wheat inoculant trial, Moccasin, Montana

Treatment	Heading	Height	Test Weight	Protein	Grain Yield
	date	(in)	(lb/bu)	(%)	(bu/ac)
Control	26-Jun	30.3	56.4	11.9	56.4
Earthfort Provide-Revive	27-Jun	31.0	56.8	11.8	55.1
Nutrio High Gear II	27-Jun	30.3	57.7	12.3	59.8
Tainio	26-Jun	30.7	57.0	11.8	53.2
TerraMax AF-ST	27-Jun	31.3	57.3	11.8	53.9
TerraMax Micro AZ-ST	27-Jun	30.0	56.8	12.0	48.7
TerraMax PSB-ST	27-Jun	31.0	56.6	12.1	49.2
TerraMax Vertex-ST	27-Jun	30.3	56.4	12.6	59.5
Visjon Exceed HSD	26-Jun	30.0	55.8	12.9	55.3
Visjon Exceed SAR	26-Jun	31.3	55.9	12.5	52.7
Average	27-Jun	30.6	56.7	12.2	54.4
LSD (0.05)	0.9	1.4	1.5	1.6	14.5
CV (%)	0.3	2.7	1.5	7.6	15.6
P-value	0.517	0.3990	0.2280	0.8480	0.8040

Bolded and underlined values are the highest mean. Bolded values are not different from the highest

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 55: 2019 SPRING WHEAT INOCULANT TRIAL, DENTON, MONTANA

Treatment	Height (in)	Test Weight (lb/bu)	Grain Yield (bu/ac)
Control	27.3	58.6	48.7
TerraMax AF-ST	28.7	58.4	45.7
TerraMax Micro AZ-ST	28.0	58.5	46.4
TerraMax PSB-ST	28.0	58.0	43.8
TerraMax Vertex-ST	27.7	58.7	44.5
Average	27.9	58.4	45.8
LSD (0.05)	1.4	0.6	8.5
CV (%)	2.7	0.6	10.1
P-value	0.3420	0.2140	0.7290

Bolded and underlined values are the highest mean. Bolded values are not different from the highest

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 56: 2019 SPRING WHEAT INOCULANT TRIAL, GERALDINE, MONTANA

Treatment	Height (in)	Test Weight (lb/bu)	Protein (%)	Grain Yield (bu/ac)
Control	28.7	60.7	12.3	57.6
Liquid MicroSurge	29.0	60.4	12.2	55.8
Liquid MicroSurge + Micronutrient Talc + dry Incepive	28.3	60.1	12.7	52.5
Micronutrient Talc dry + Wheat MicroSurge	29.0	60.3	12.0	56.3
Micronutrient Talc dry + Wheat MicroSurge + dry	29.3	60.4	12.1	56.1
TerraMax AF-ST	28.7	60.7	12.6	56.7
TerraMax Micro AZ-ST	29.0	60.5	12.4	54.8
TerraMax PSB-ST	28.7	60.7	12.5	56.7
TerraMax Vertex-ST	28.7	60.2	12.3	55.4
Visjon Exceed HSD	28.7	60.2	14.7	51.7
Visjon Exceed SAR	27.0	60.8	12.1	50.9
Average	28.6	60.5	12.5	55.0
LSD (0.05)	1.6	1.1	2.7	6.3
CV (%)	3.3	1.1	12.5	6.8
P-value	0.3440	0.9100	0.7100	0.4150

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 57: 2019 BARLEY INOCULANT TRIAL, MOCCASIN, MONTANA

Treatment	Height (in)	Test Weight (lb/bu)	Plumps (%)	Grain Yield (bu/ac)
Control	24.3	56.5	85.8	62.0
Exceed SAR	25.0	55.7	90.0	67.5
Exceed HSD	24.3	56.1	86.4	67.0
Average	24.6	56.1	87.4	65.5
LSD (0.05)	1.7	1.3	5.3	11.5
CV (%)	3.2	1.1	2.9	8.3
P-value	0.5390	0.4050	0.1930	0.4530

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 58: 2019 PEA INOCULANT TRIAL, MOCCASIN, MONTANA

Treatment	Height (in)	Test wt (lb/bu)	Grain Yield (lbs/ac)
Control	25.8	62.6	1976.0
Lalfix Duo Granular	<u>**29.3**</u>	62.6	<u>**2409.2**</u>
Lalfix Duo Peat	25.0	62.7	**2263.7**
Average	26.7	62.6	2263.7
LSD (0.05)	2.5	0.6	351.0
CV (%)	5.9	0.6	9.5
P-value	0.0110	0.8850	0.0330

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

TABLE 59: 2019 CHICKPEA INOCULANT TRIAL, MOCCASIN, MONTANA

Treatment	Height (in)	Test wt (lb/bu)	Grain Yield (kg/ha)
Control	16.0	59.6	1043.9
Lalifix Duo Granular "A"	16.5	59.7	1198.2
Lalifix Duo Granular "AB"	15.8	59.7	991.5
Lalifix Duo Peat	15.0	59.6	1144.3
Average	15.8	59.6	1094.5
LSD (0.05)	1.2	1.2	197.4
CV (%)	4.7	1.2	11.3
P-value	0.1030	0.9970	0.1450

Bolded and underlined values are the highest mean. Bolded values are not different from the highest value based on the Least Significant Difference (LSD) test

Note: Study averages include experimental lines not listed here.

N.S. = Not Significant

OUTREACH

COMMUNICATING THROUGH SOCIAL MEDIA

Heather Fryer

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Summary

The Central Agricultural Research Center (CARC) is one of seven remote research centers in the Department of Research Centers in Montana State University's College of Agriculture and the Montana Agricultural Experiment Station (MAES). The CARC addresses production challenges, supports research and outreach programs, explores grain varieties and alternative crops and conducts soil microbiology research. All of the research centers have individual website pages housed at agresearch.montana.edu. Since 2016, the CARC has been striving to enhance outreach through social media by creating Facebook and Twitter accounts. The goal is to educate the public about our research, and social media provides opportunities to share our work with an audience in ways that were not available prior to 2006.

Introduction

Faculty and staff at MSU agricultural research centers, including CARC, serve farmers and ranchers in the local area as well as the broader needs of Montana agriculture through research and outreach programs. Social media tools can be used effectively to disseminate knowledge to agriculturalists and others interested in farming and ranching. The CARC is located on the plains of central Montana and is fairly remote. Therefore, we need use outreach tools effectively to provide timely messages, disseminate important research results and stay in touch with Montanans and the agriculture community.

Methods

Our methods of communication include a website page, Facebook and Twitter account. We feel these tools are used by a growing number of scientists, farmers, and local community members. The CARC website, http://agresearch.montana.edu/carc/, was revamped by organizing and updating all of its pages in 2016. The CARC created a Facebook and Twitter account under the same user name during that same year: Central Ag Research @CentralAgCenter.

Results and Discussion

To date, our Facebook page has 384 followers and our Twitter account has 457 followers. We are hopeful that these numbers will continue to grow and, to that end, are dedicated to improving content with timely and up-to-date information for followers.