MONTANA STATE UNIVERSITY

MONTANA AGRICULTURAL EXPERIMENT STATION

Alternative Crops and Cropping Systems Field Day

Noon Meal sponsored by Cargill, Stricks Ag, & JM Grain

Thursday, July 12, 2018

Central Agricultural Research Center

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MSU Central Agricultural Research Center
2018 Summer Field Tour
12 July
Agenda

8:15 to 8:45 AM	Coffee, tea, rolls, registration
8:45 to 9:05 AM	Welcome Patrick Carr, CARC Superintendent & Cropping Systems Agronomist Darrin Boss, NARC and WTARC Superintendent and Head, Department of Research Centers
9:05 to 9:20 AM	Load wagons and travel to WSCS study
9:20 to 9:35 AM	Warm-season crop sequence study Patrick Carr
9:35 to 9:45 AM	Load wagons and travel to safflower field
9:45 to 9:50 AM	Safflower production Patrick Carr
9:50 to 10:00 AM	Travel to canola variety trial
10:00 to 10:15 AM	Canola Varieties Simon Fordyce, Cropping Systems Research Associate
10:15 to 10:20 AM	Load wagons and travel to RATS
10:20 to 10:35 AM	Getting a handle on nitrogen mineralization Jed Eberly, CARC Assistant Professor, Agron./Microbiology
10:35 to 10:40 AM	Load wagons and travel to pulse trials
10:40 to 11:00 AM	Pea, lentil, and chickpea varieties Kevin McPhee, MSU Professor and Pulse Crop Breeder
11:00 to 11:20 AM	Fitting chickpeas into crop rotations Kent McVay, SARC Associate Professor and Extension Cropping Systems Specialist
11:20 to 11:30 AM	Travel to Barley Rotation Study
11:30 to 11:50 AM	Barley, crop rotation, and nematodes Andy Burkhart, MSU grad student
11:50 AM to noon	Return to CARC headquarters for lunch
12:20 to 12:35 PM	Comments from Dr. Charles Boyer Vice President, Dean and Director, College of Agriculture & Montana Agricultural Experiment Station

Table of Contents

Central Agricultural Research Center Staff

Administration

- Charles Boyer, Ph.D. — Vice President of Agriculture
- Darrin Boss, Ph.D. — Head, Department of Research Centers

Crop Management Program Staff

Permanent

Faculty

- Patrick Carr, Ph.D. — Superintendent and Associate Professor – Cropping Systems
- Jed Eberly, Ph.D. — Assistant Professor – Agronomy and Soil Microbiology

Professional

- Lorrie Linhart — Administrative Associate III
- Simon Fordyce — Research Associate – Cropping Systems
- Sally Dahlhausen — Research Assistant III – Cropping Systems
- Heather Fryer — Research Associate – Ag. Economist & Cropping Systems
- Sherry Bishop — Research Assistant III/Grain, Forage, Weather Processing
- Eva Magnuson — Research Associate – Agronomy and Soil Microbiology
- Darryl Grove — Farm Operations Manager
- Tim Bishop — Farm Mechanic

Temporary

- Jenni Hammontree — Agronomy and Soil Microbiology

University student interns (major)

- Heidi Harris — Andrews University, Michigan (International Agriculture)

High school students

- Hayden Hammontree — 2018 Graduate - Hobson H.S.
- Alyssa Thomas — 2018 Graduate - Hobson H.S.
- Zackary Thomas — Hobson H.S.
- Jordan Nees — Moore H.S.

We thank the following individuals for serving on the advisory boards and cooperating in the on-going research directed by scientists located at the Central Agricultural Research Center:

CARC Advisory Board Members

- Janelle Bergum (Garneill)
- Dale Cederberg (Hobson)
- Chuck Davis (Geraldine)
- Terry Econom (Winifred)
- Rod Linhart (Moccasin)
- State Advisory Delegate Pam Linker (Coffee Creek)
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- Ryan Hansen (Denton)
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- Kent Squires (Geraldine)
- Toby Stahl (Roundup)
- Keith Weinheimer (Moore)

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- Richard Barber (Denton)
- Chuck Davis (Geraldine)
- Andy and Ron Long (Highwood)
- Bill Summers (Geraldine)
- Kent Squires (Geraldine)

County Extension Agent Cooperators

- Emily Standley (Fergus County Extension Agent)
- Katie Hatlelid (Judith Basin County Extension Agent)
- Tyler Lane (Chouteau County Extension Agent)
- Rose Malisani (Cascade County Extension Agent)
- Mandie Reed (Wheatland County Extension Agent)

Weather Summary
(1 September, 2017 – 28 June, 2018)

Simon Fordyce, CARC

Above-normal rainfall in September ushered in the 2018 crop year, ending a three-month drought that devastated 2017 spring crops. Though drought relief was welcome, these wet conditions delayed harvest of late maturing crops like safflower and prevented timely planting of 2018 winter crops. Effects of this late planting were evident despite favorable conditions throughout winter and spring. The CARC received 13.93 inches of precipitation from September through May, or 4.9 inches above normal. Heading dates for winter crops in 2018 were on average one week behind those of 2017. Late planting, coupled with cold soil and air temperatures in April, are likely the main contributors to delayed maturity of winter crops. A wetter-than-average spring also delayed planting of 2018 spring crops, though above average temperatures in May seem to have compensated for any maturity effects, with heading/flowering dates of April-seeded crops on track with those of last year despite later planting dates. On June 11, temperatures dropped below 35°F at the CARC, with reports of freezing temperatures nearby. Certain canola and lentil varieties may have been impacted at the CARC, though effects on yield were likely minimal.

Winter Wheat Variety Trials

Jed Eberly and Eva Magnuson, CARC
Phil Bruckner and Jim Berg
MSU Dept. Plant Science and Plant Pathology

Problem

Montana is a major producer of winter wheat. Growers are constantly facing challenges to production due to drought, disease, and pests. New and improved varieties are needed to meet these challenges and to ensure economically sustainable wheat production in the state. The objective of this ongoing study is to identify varieties that are superior to those currently being grown for yield, quality, and resistance to disease and pests.

Study Description

The study is located in a field at CARC that had a pea/lentil cover crop in 2017. Additional trials are in place at Belt, Highwood, Geraldine, and Denton. Over 170 varieties and experimental lines are being compared for heading date, height, lodging, yield, test weight, and protein content. Each variety was planted in four 5 by 11 ft plots in a randomized experimental design to determine differences between varieties. Agronomic data collected throughout the growing season includes heading date, plant height, lodging, disease and insect reactions. Experimental plots will be trimmed, measured, and harvested with small plot combines. The grain will be weighed for yield and test weight. The winter wheat trials were sprayed with Curtail M to control broadleaf weeds and Canada

thistle. Power Flex HL was also applied for the control of cheat grass. Nitrogen was applied in the fall at planting as a pop-up fertilizer at a rate of 10 lbs per acre along with 15 lbs of phosphate and 10 lbs of potassium per acre. An additional 180 lbs of urea per acre was applied in the spring.

Applied Questions: **What was the average yield of the entries in the trial in 2017?**

The average yield for all winter wheat trials (including experimental lines) at Moccasin in 2017 was 60.3 bu/acre. Average yield at the Belt, MT location was 51.1 bu/ac. while Highwood was 56.7 bu/ac. Average yield at Geraldine for all varieties was 80.1 bu/acre while Denton averaged 39.6 bu/acre.

What were the top performing varieties in 2017?

Differences in yield were not statistically significant between varieties at CARC or Belt last year. The top performing varieties at Highwood were SY Clearstone 2CL (68.0 bu/ac), Decade (67.5 bu/ac), and SY Monument (65.0 bu/ac). Top performing varieties at Geraldine were SY Wolf (93.6 bu/ac), Keldin (90.4 bu/ac), SY Monument (88.1 bu/ac), and Yellowstone (85.1 bu/ac), while the best performing at Denton were SY Wolf (50.5 bu/ac), Brawl CLP (49 bu/ac), Keldin (46 bu/ac), and CDC Falcon (44.3 bu/ac).

Spring Wheat Variety Trials

Jed Eberly and Eva Magnuson, CARC
Luther Talbert, MSU Dept. Plant Science and Plant Pathology

Problem

Spring wheat is an important crop throughout central Montana. Ongoing breeding programs are focused on improving the performance of spring wheat varieties. Performance targets include yields that are superior to the most commonly grown varieties, higher protein content, and increased resistance to pathogens and insects.

Study Description

The study is located in a field at CARC that had a pea/lentil cover crop in 2017. Over 145 varieties and experimental lines are being compared for heading date, height, lodging, yield, test weight, and protein content at CARC and at other locations. Each variety was planted in four 5 by 11 ft plots in a randomized experimental design to determine differences between varieties. Agronomic data collected throughout the growing season includes heading date, plant height, lodging, disease and insect reactions. Experimental plots will be trimmed, measured, and harvested with small plot combines. The grain will be weighed for yield and test weight. The spring wheat trials were treated with Curtail M to control broadleaf weeds and Canada thistle. Power Flex HL was also applied for control of cheat grass. Nitrogen was applied at planting at a rate of 10 lbs per acre along with 15 lbs of phosphate and 10 lbs of potassium per acre. An

additional 80 lbs of urea per acre was applied after emergence.

Applied Questions: **What was the average yield and protein for entries in the 2017 trial?**

At Moccasin the average yield for spring wheat was 32.0 bu/ac. Average yield at Highwood was 32.5 bu/ac while the average yield at Denton was 20.0 bu/ac. Average protein at Moccasin was 17.1%. Average protein at Highwood was 15.6% while Denton was 17.2%.

What were the top performing spring wheat varieties in 2017?

Differences in yield were not statistically significant between varieties at CARC or Denton last year. Some of the top performing varieties at Highwood were Lanning (40.3 bu/ac), Oneal (38.9 bu/ac), and Sy Ingmar (37.8 bu/ac).

Barley Variety Trials

Jed Eberly and Eva Magnuson, CARC
Jamie Sherman and Liz Elmore
MSU Dept. Plant Science and Plant Pathology

Problem

Barley is an important agriculture commodity in Montana for feed, food, and malt. Barley ranks second only to wheat in the total number of acres grown in the state. The MSU barley breeding program is focused on developing improved varieties of both hulled, hull-less, and winter barley varieties for food and feed. Winter barley is of particular importance since incorporating more fall planted crops in rotation spreads the work load, allows for earlier harvest the following spring and, in the case of barley, may increase the likelihood of meeting malt quality standards.

Study Description

The study in 2018 is being managed almost identically as the study in 2017. That year, the barley variety trial tested the agronomic performance and potential of 72 varieties and experimental lines. An additional study contains 16 hull-less barley varieties and experimental lines. A winter barley trial is also in place this year with preliminary results expected this fall. All studies were located in a field at CARC that had a pea/lentil cover crop in 2017. Barley variety trials also are located off-station.

The barley variety trials were treated with Curtail M to control broadleaf weeds and Canada

thistle. Power Flex HL was also applied for control of cheat grass. Nitrogen was applied at planting at a rate of 10 lbs per acre along with 15 lbs of phosphate and 10 lbs of potassium as a starter fertilizer per acre. An additional 30 lbs of urea per acre was applied after emergence.

Applied Questions: **What was the average yield of the entries in the trial in 2017?**

At Moccasin the average yield for barley was 34.3 bu/ac. Average yield at Highwood was 28.4 bu/ac while the average yield at Denton was 27.8 bu/ac. The average protein concentration for all varieties at Moccasin in 2017 was 13.6%. Among those with the lowest protein was Champion at 12.4%. If growing for feed, those with the highest grain protein concentration included Growler (15.0%) and Metcalfe (15.0%). Average protein at Denton was 18.4% while Highwood averaged 16.7%.

What were the top performing barley varieties in 2017?

Differences in yield were not statistically significant between varieties at CARC or Highwood last year. Some of the top performing varieties at Denton were Champion (32.6 bu/ac), Haxby (31.9 bu/ac), and Metcalfe (31.6 bu/ac).

Spring Field Pea Variety Trial

Yesuf Mohammed and Chengci Chen, EARC
Simon Fordyce, Sally Dahlhausen, and Patrick Carr, CARC

Problem

Field pea can improve soil fertility and break pest cycles when incorporated into rotations with wheat and other cereals. Montana led the nation in total dry pea acreage in 2017, but the state's production on a per acre basis lagged behind Oregon, Washington, Idaho, North Dakota, South Dakota, and Nebraska. This yield depression in 2017 was likely due to drought conditions across the state, but another reason may be the failure to grow pea varieties adapted to Montana growing conditions. The objective of this ongoing study is to identify spring pea varieties that are superior to those currently being grown for yield and protein in the state.

Study Description

The study is located in a field that was planted to forage barley in 2017. Peas were planted on 25 April at a depth of 1 inch and at a rate of 8 PLS/ft^2 using a double-disc drill. Soil temperature at time of planting was 42°F. Broadleaf and grass weeds were controlled with a pre-plant burn down of glyphosate (i.e., Roundup) at 1.25 pt/acre, and plots were hand-weeded thereafter. Grizzly Too at 1.9 oz/ac was applied on 17 May for the control of pea leaf weevil.

Thirty-one varieties and experimental lines are being compared for height, propensity to lodge, vine length, date of 50% flowering, grain yield, protein, test weight, and kernel weight. Each variety was planted in four, 4.5 by 15 ft plots in an experimental design to determine varietal differences.

Applied Questions

What are the top performing spring pea varieties at CARC?

Yield and quality data for the 2018 trial will not be available until after harvest. Last year, Jetset (20 bu/acre), DS Admiral (19 bu/acre), and Nette 2010 (19 bu/acre) were among the highest-yielding yellow peas, while CDC Raezer (19 bu/acre) was among the highest-yielding green peas.

How have long-term yields of grain peas compared at CARC?

Only two yellow pea varieties have been grown at CARC for three consecutive years: DS Admiral (30 bu/acre) and Delta (27 bu/acre). Likewise, only two varieties of the green cotyledon type have been grown at CARC over this period: Majoret (28 bu/acre) and Arcadia (24 bu/acre).

Spring Lentil Variety Trial and Nurseries

Yesuf Mohammed and Chengci Chen, EARC
Kevin McPhee, MSU Cool-Season Pulse Breeder
Simon Fordyce, Sally Dahlhausen, and Patrick Carr, CARC

Problem

In 2017, Montana led the nation in total lentil acreage, but the state's production on a per acre basis fell to fourth place, behind Washington, Idaho, and North Dakota. Identifying superior performing varieties for Montana is one way to close the yield gap. The development of new and improved varieties is also important for enhancing the economics of lentil production in the state. The objective of these trials is to identify varieties that are superior to those currently being grown in the state of Montana.

Study Description

The trials are located in a field that was planted to forage barley in 2017. Lentils were planted on 25 April at a depth of 1 inch and at a rate of 12 PLS/ft^2 using a double-disc drill. Soil temperature at time of planting was 42°F. Broadleaf and grass weeds were controlled with a pre-plant burn down of glyphosate (i.e., Roundup) at 1.25 pt/acre, and plots were hand-weeded thereafter.

Sixty-nine varieties and experimental lines in three separate trials are being compared for height, propensity to lodge, vine length, date of 50% flowering, grain yield, test weight, and kernel weight. Each variety was planted in four,

4.5 by 15 ft plots in an experimental design to determine varietal differences.

Applied Questions

What are the top performing spring lentil varieties at CARC?

Yield and quality data for the 2018 trials will not be available until after harvest. In 2017, CDC Impress CL (827 lb/acre), CDC Richlea (824 lb/acre) and Avondale (801 lb/acre) were among the highest-yielding varieties. The yield of all varieties in the variety trial averaged 702 lb/acre in 2017, down from 1326 lb/acre in 2016.

What varieties have produced the highest average yields at CARC over the past three years?

Only two lentil varieties have been grown at CARC long term. These varieties (with 8-year averages) are CDC Richlea (1373 lb/acre) and Avondale (1262 lb/acre).

Acknowledgements

We are grateful to the Montana Pulse Advisory Committee and the Montana Agriculture Experiment Station for funding this research.

Chickpea Variety Trial and Nursery

Yesuf Mohammed and Chengci Chen, EARC
Kevin McPhee, MSU Cool-Season Pulse Breeder
Simon Fordyce, Sally Dahlhausen, and Patrick Carr, CARC

Problem

In 2017, Montana surpassed Washington to become first in the nation in total chickpea production. Chickpeas can be a challenging crop for growers due to problems with fungal diseases, particularly during periods of cool, wet conditions. However, if managed successfully, the crop can be highly lucrative. In these studies we aim to identify varieties that are adapted to growing conditions in the state of Montana.

Study Description

The trials are located in a field that was planted to forage barley in 2017. Chickpeas were planted on 9 May at a depth of 1 inch and at a rate of 5 PLS/ft^2 using a high-disturbance hoe drill. Broadleaf and grass weeds were controlled with a pre-plant burn down of Roundup at 1.25 pt/acre.

Thirty-nine varieties and experimental lines in two separate trials are being compared for height, propensity to lodge, vine length, date of 50% flowering, grain yield, protein, test weight, and kernel weight. Each variety was planted in four, 4.5 by 15 ft plots in an experimental design to determine varietal differences.

Applied Questions

What are the top performing chickpea varieties at CARC?

Yield and quality data for the 2018 trials will not be available until after harvest, and the trials were abandoned in 2016 and 2017 due to grazing by antelope. However, in 2015, CDC Orion (1477 lb/acre) and CDC Frontier (1337 lb/acre) were among the top-yielders, though yield differences in this trial were not significant. The yield of all varieties in the 2015 trial averaged 1155 lb/acre, up from 871 lb/acre in 2014.

What varieties have produced the highest average yields at CARC over the past three years?

No variety has been grown at CARC for the past three years, and only three varieties have been grown at CARC for three consecutive years since 2013. These varieties (with 3-year averages) are as follows: CDC Orion (1427 lb/acre), Myles (1374 lb/acre), and CDC Frontier (1259 lb/acre).

Acknowledgements

We are grateful to the Montana Pulse Advisory Committee and the Montana Agriculture Experiment Station for funding this research.

Spring Canola Variety Trial

Simon Fordyce, Sally Dahlhausen, and Patrick Carr, CARC

Problem

In 2017, Montana ranked third in total canola acreage and production behind North Dakota and Oklahoma. Canola acreage in Montana increased 128% from 2016 to 2017. In this study we aim to identify spring canola varieties that will outperform those currently being grown for yield and oil content in the state. By evaluating agronomic performance of multiple varieties and breeding lines at several locations across Montana, we hope to provide growers with reliable information regarding canola production in the state's many unique environments.

Study Description

Spring canola variety trials are established at six locations across the state, including one at CARC. The CARC study is located in a field that was planted to barley in 2017. Canola was planted on 26 April at a depth of 0.75 inches and at a rate of 14 PLS/ft^2 using a double-disc drill. Broadleaf and grass weeds were controlled with a pre-plant burn down of Roundup at 1.25 pt/acre. Stinger at 8 oz/acre was applied for in-crop broadleaf control, and plots were hand-weeded multiple times throughout the growing season.

Thirteen varieties and experimental lines are being compared for height, propensity to lodge, days to 50% flowering, grain yield, test weight, kernel weight, and percent oil. Each variety was planted in four, 4.5 by 15 ft plots in a

scientifically valid experimental design to determine varietal differences.

Applied Questions

What are the top performing spring canola varieties at CARC?

Yield and quality data for the 2018 trial will not be available until after harvest. In 2017, a combination of late spring frosts and high summer temperatures depressed grain yields, with the trial averaging just 8.4 bu/acre. HyCLASS 955 (11.1 bu/acre), InVigor L230 (10.5 bu/acre), and DKL 35-23 (10.4 bu/acre) were among the top yielding varieties in the 2017 trial.

Acknowledgments

We are grateful to Bayer CropScience, BrettYoung™, Cibus™, Dekalb®, Cargill® Global Edible Oil Solutions, and CROPLAN® by Winfield® for funding this research.

Hemp Variety Trial

Patrick Carr CARC
Perry Miller, Dep. Land Environ. Sci.
Ian Foley, MT Department of Agriculture
Jeff Kostuik, Hemp Genetics International

Problem

Hemp is a crop with many potential uses. It is often confused with a closely related plant – marijuana – but **hemp and marijuana are not the same**! Tetrahydrocannabinol, THC, is the primary psychoactive constituent of marijuana. It has been removed from hemp by plant breeders, resulting in a crop with many industrial and even some food uses, but of no value as a recreational drug.

Hemp remains a closely regulated crop because it looks identical to marijuana when grown. Because of its industrial and food value, the Montana Department of Agriculture established a pilot program in 2017 where a select number of Montana farmers were allowed to grow hemp to gain some familiarity with it. A few agronomists at MSU have started exploring the agronomics of hemp production as well.

Study Description

Hemp variety trials are being conducted by MSU agronomists; one trial is in central Montana and one is in the Gallatin Valley.

Applied Questions

What do MSU agronomists hope to learn from the hemp variety trials in 2018?

MSU agronomists have no previous history growing hemp in Montana and so want to learn what the best agronomic practices are when growing this crop in the state. Obviously, the goal of the trial is to identify what variety, or varieties, is/are best adapted to growing conditions in Montana.

How many varieties are being compared?

This is the first year that MSU agronomists are conducting research on hemp so it is a relatively small variety trial with a limited number of entries. We hope to expand the number of entries in the future.

Acknowledgments

We are grateful to Hemp Genetics International for providing seed through the Montana Department of Agriculture, as well as partial funding for this research.

Proso Millet Variety Trial

Patrick Carr, Sherry Bishop, and Heather Fryer, CARC
Dipak Santra, University of Nebraska

Problem

Fewer than 6000 acres of proso millet was grown in Montana for grain in 2017. Still, proso millet is a potential rotational grain crop with wheat and other cool-season crops. Past research on proso millet in the state suggests it is poorly adapted to growing conditions in central Montana. However, that research was based on old proso millet varieties that do not perform as well as newer varieties released by millet breeders at the University of Nebraska. The objective of this research is to determine if modern proso millet varieties are adapted to growing conditions in central Montana.

Study Description

The study is located in a field that was planted to flax and lentil in 2017. Untimely rains and equipment problems delayed planting of safflower plots until 21 June, roughly three weeks later than would be the earliest target date for planting millet in central Montana. A planter with low-disturbance disk openers was used to seed 7 commercial proso millet varieties along with 18 experimental lines. A pre-plant burndown of glyphosate at 2 pt/ac was used to control grass and broadleaf weeds prior to seeding plots.

Applied Questions

Is proso millet adapted to central Montana growing conditions when grown for grain?

Yields will be determined this fall for 2018 after the plots are harvested. However, newer varieties have consistently produced higher yield than 'Dawn', a variety released back in 1975 by the University of Nebraska. Dawn is considered the first of the 'modern' proso millet varieties developed in the U.S. and is the parent of many proso millet varieties released in the U.S. since that time. Dawn was the variety planted in earlier research suggesting that growing proso millet for grain was a risky venture for central Montana farmers.

What markets exists for proso millet growers?

Much of the proso millet grown in the U.S. is used as an ingredient in bird seed. 'Plateau', a variety released by the University of Nebraska in 2015, is a waxy proso millet – the first waxy type released in the U.S. It can be sold in the traditional bird seed market but also has potential as a specialty food item in Asian markets. Plateau is included in the trial at Moccasin.

Acknowledgments

We are grateful to Dipak Santra at the UN Panhandle Research and Extension Center in Scottsbluff, NE, for supplying seed for this study and for the Montana Agricultural Experiment Station for providing funding for this research.

Spring Safflower Variety Trial

Patrick Carr, Sherry Bishop, and Heather Fryer, CARC

Problem

Montana ranked second behind only California in safflower production in 2017. That year, safflower production in the state totaled 34,000 acres (compared to 52,000 thousand for California). While a minor crop compared to wheat, barley, and several other crops in the state in terms of acreage, it has particular value as a rotational crop. It has a deep taproot that can extract water and nutrients from greater soil depths than many other grain/seed crops that are grown in the state, it is harvested later than many other crops so labor conflicts can be avoided, and it is a full-season crop that is well adapted to growing conditions in central Montana. The objective of this trial is to identify superior performing safflower varieties under dryland management in central Montana.

Study Description

The study is located in a field that was planted to barley and harvested for forage in 2017. Untimely rains and equipment problems delayed planting of safflower plots until 21 May, roughly a month later than is optimal. A planter with low-disturbance disk openers was used to seed 12 different safflower varieties into a no-till seedbed at 18-20 lb PLS/ac. A pre-plant burndown of glyphosate at 2 pt/ac was used to control grass and broadleaf weeds prior to seeding plots.

Applied Questions

What are the top yielding safflower varieties in the trial?

Yields will be determined this fall for 2018 after the plots are harvested. Results from the past two years have been disappointing. Drought and other factors resulted in low yields across plots both in 2016 (avg. yield = 700 lb/ac) and 2017 (avg. yield = 776 lb/ac). Besides drought, grazing by antelope and deer caused an estimated 30% yield loss in 2017. Thus far, safflower plots look good in 2018, even though planted late. We are hopeful that favorable weather conditions and yields in the 1500 to 2000 lb/ac range are produced in 2018.

What are the top safflower oil producers at CARC?

NutraSaff golden safflower has produced seed with the highest oil content in both 2016 (48%) and 2017 (47%). STI 1201 also produced seed with relatively high oil content (44%), though less than NutraSaff. By comparison, seed oil content of entries in the trial averaged 36%.

Acknowledgments

We are grateful to the Montana Agricultural Experiment Station for providing funding for this research study, and to North Dakota State University for providing seed and analyzing oil content of entries in this trial.

Fertilizer Management and Malt Quality in Low Protein Barley

Jamie Sherman, MSU Dep. Plant Science and Plant Pathology
Patrick Carr, Heidi Harris, Sherry Bishop, Heather Fryer, CARC
Kent McVay, SARC

Problem

Montana was the second-leading state for barley production in 2017, behind only Idaho and ahead of North Dakota. The craft brewing industry continues to grow and, with it, a need for low-protein malt barley. Producing malt barley that is low in protein and high in kernel plumpness can be difficult under dryland management in central Montana because of the dry, hot conditions that generally develop in mid-summer. The challenge is producing low-protein barley can be exacerbated by the application of N-fertilizer needed to optimize grain yield. A further factor complicating malt barley production in central Montana is that many soils are low in sulfur. This study is exploring how combinations of low-protein barley cultivars/lines, nitrogen (N) and sulfur (S) fertilizers can be combined to optimize production of malt barley production in central Montana.

Study Description

Nitrogen was drilled in bands as urea at 0, 0.5, 1.0, and 1.5 times the recommended rate of 1.2 lb N/bu, and S as gypsum at 0 and 20 lb/ac, in all possible combinations in plots where three low-protein, experimental barley lines along with the variety 'Hockett' was no-till seeded on 15 and 16 May, 2018. Bronate was applied for broadleaf

weed control. Grain will be harvested and yield along with grain quality will be determined.

Applied Questions

Will barley respond to N applications?

Barley did respond to N applications in the previous two years that this study was conducted (2016 and 2017); soils were low in N (< 25 lb N/acre in the top two feet). Unfortunately, drought conditions in both years depressed barley yields, confounding the desired impact of N fertilizer applications on yield and protein. Yields were depressed so more N ended up in the grain, driving up grain protein content. Thus far, growing conditions have been more favorable for high barley yields in 2018, even though the barley plots were planted much later than we had wanted because of untimely rains and equipment challenges.

Does barley respond to applications of S as gypsum?

We have seen an S response following applications of gypsum, suggesting that at least some soils in central Montana are deficient in sulfur and that applications of ammonium sulfate or some other S-containing fertilizer may be needed to optimize barley performance.

Acknowledgments

We are grateful to the Montana Fertilizer Tax Fund as well as the Montana Agricultural Experiment Station for providing funding for this research study.

Impacts of barley cropping systems on nematode community structure

Andy Burkhardt, Jack Martin, and Jamie Sherman
MSU Dept. Plant Science and Plant Pathology
Shabeg Briar, Olds College, Olds, Alberta
Patrick Carr, CARC

Problem

Nematodes have been suggested as a potential indicator of soil quality and function. Fluctuations in their community structure can be impacted through rotation, tillage, fertility, and other management practices. Understanding these fluctuations may be a key factor to managing for healthier soil and potentially managing plant parasitic nematodes without the need for expensive nematicides or having to develop resistant varieties. The objective of this study is to determine how cropping system impacts soil nematode communities.

Study Description

Four no-till barley cropping systems were estabished in two, 3-year field trials at the research center: barley-fallow, continuous barley, barley-pea, and barley-pea brown manure. One experiment was planted using double disc openers to minimize soil disturbance; a second experiment was planted with furrow knife openers to simulate moderate soil disturbance. Barley was fertilized with urea based on a 50 bu/A yield goal (based on the CARC 5-year average yield for 'Hockett'). Soil was sampled prior to planting in the spring and following harvest in the fall to quantify and assess the soil nematode community.

Applied Questions

Do cropping systems that include a rotational crop positively impact nematode community structure?

Data 2018 still are being collected and won't be analyzed until fall. Previous results indicate that there were significantly more herbivorous nematodes under barley-fallow versus all 3 annually cropped systems in the moderately disturbed seedbed where knife how openers were used, suggesting that annual cropping may be able to reduce plant parasitic nematodes. Herbivores in this study were primarily species of economic importance (e.g. root lesion nematode).

Conditions at CARC in 2016 and 2017 were dry. As a result, yields were depressed from drought (2016 maximum barley yield = 35 bu/A, 2017 maximum barley yield = 22.5 bu/A). The lack of any significant response within the nematode community is likely due to water being a limiting factor. The studies are in their final year, so a final report will be forthcoming.

Canola Matrix Study

Patrick Carr, Sherry Bishop, and Heather Fryer, CARC
John Miller, WTARC

Problem

Canola was grown on over 146,000 acres in Montana last year, making it the sixth most widely grown grain/seed crop in the state. Growth in canola acreage is expected to continue, and breeding is underway to develop canola hybrids/varieties that are adapted to Montana growing conditions. With canola's future bright in the state, a question is now being asked more frequently: what crop should precede canola in a rotation, and what crop should follow the oilseed crop? Our objectives are to determine how canola performance is affected by the crop(s) coming before it in a rotation, and how it affects that crop that follows.

Study Description

Canola along with barley, lentil, spring pea, and wheat were planted following chem-fallow into a no-till seedbed in 75-ft plots on 09 May at a 1-in depth at the research center. These same crops were planted at the MSU Western Triangle Ag. Res. Ctr. a few weeks later. In 2019, these five crops will be planted in a direction perpendicular to that used in 2018 so that each crop follows itself (e.g., canola-canola) and all other crops in a 2-yr sequence (e.g., barley-canola, lentil-canola, pea-canola, wheat-canola, …). A total of 25, 2-yr crop sequences will be represented in 2019. These sequences will then be repeated in 2020-21 so that four successive years of the same crop (e.g.,

canola-canola-canola-canola) and 2-year rotations (e.g., barley-canola-barley-canola) will occur. Grain/seed yield, disease, soil nutrient content, and other data will be collected.

Applied Questions

Which crop is best for canola to follow in a rotation?

We won't be able to begin to answer that question until after the 2019 growing season. However, we suspect that, initially, canola might do well following lentil and pea, just as many other crops do. However, we suspect that, over time, canola will perform better following grass (i.e., barley and wheat) than broadleaf (e.g., lentil and pea) crops in 'tight' 2-yr rotations because of a build up in broadleaf disease and weed pressure. We anticipate disease and weed pressure to build up on the 4-yr continuous canola monoculture compared with the other cropping systems over time.

How will wheat do following canola compared with other crops?

We suspect that wheat will do best following the two pulse crops (i.e., lentil and pea), then canola, then barley, and finally wheat. Time will tell.

Acknowledgments

We are grateful to Cargill Inc. for providing funding for this study, as well as the Montana Agricultural Experiment Station.

Long-term Alternative Systems Trial (LAST)

Patrick Carr, Simon Fordyce, Sally Dahlhausen, Darryl Grove, Tim Bishop, CARC

Problem

Wheat dominates dryland crop production in central Montana. The benefits of diversifying wheat-based cropping systems is well documented, and many Montana farmers are growing chickpea, lentil, and pea in rotation with wheat. The goal of this project is to compare several alternative cropping systems for their economic returns and environmental impact.

Study Description

More than 20 acres at the research center are being set aside for this long-term, crop rotation trial. Nine different cropping systems will be established, as funding becomes available: (1) winter wheat (WW)-brown (i.e., chemical) fallow; (2) WW-green fallow (a multi-species cover/soil improvement or dual use cover/soil improvement/forage polyculture or "cocktail" will be planted and terminated mid-season); (3) WW-pea-barley-canola; (4) spring wheat-winter pea-corn or proso millet-safflower; (5) WW-winter lentil-proso millet; (6) WW-pea-corn or sorghum-millet-safflower-spring wheat; (7) perennial grass/forb pasture; (8) perennial mixed grass pasture; and (9) forage WW-foxtail millet. All crop phases of each system will be in place each year, so there will be a total of 25 plots arranged in a scientifically valid experimental design RCB design with system by crop phase combinations replicated at least four times.

Applied Questions

What criteria were used in choosing the cropping systems that are represented?

We wanted to include 'traditional' wheat-based cropping systems (e.g., wheat-fallow), diverse 3- to 6-yr crop rotations, and systems with a focus on forage production. It was important that WW was common to as many of the cropping systems as possible, since it dominates dryland farming in central Montana.

Why include forage-based cropping systems if an important goal was to include WW in the system, if possible?

Previous research done elsewhere suggests that perennial plant systems, i.e., grazed perennial pasture, impart soil health benefits that cannot be duplicated by grain/seed based cropping systems. We want to determine if this is true in central Montana, so perennial forage systems are included. We also have included a forage-based system comprised of annual crops to help us separate out the impact that forages and livestock have on the cropping systems landscape, versus the crop type (annual or perennial species) that comprise the forage system.

Efforts continue to find sustained funding for this long-term project.

Rotation and Tillage Systems Study (RATS)

Patrick Carr, Darryl Grove, Tim Bishop, Heather Fryer
Simon Fordyce, Sally Dahlhausen, CARC

Problem

Wheat (*Triticum* spp.) has dominated dryland grain farming in central Montana and similar regions across the U.S. Great Plains for well over a century. However, profit margins have shrunk significantly in the past few years and this trend is expected to continue. Chickpea, lentil, and other alternative crops can be attractive alternatives for wheat farmers facing tight profit margins. The goal of this long-term trial is to identify crops that improve the economics when incorporated into rotations with wheat in central Montana.

Study Description

No-till and conventional-till strips were established in two fields at the research center in 1996, with comparisons of different cropping systems in them begun in 2004. The RATS study was established in this strips in 2017. Five cropping systems are being compared: (1) winter wheat (WW)-fallow; (2) WW-lentil (spring and winter subplots)-barley; (3) WW- pea (spring and winter subplots)-barley (4) WW-spring pea-safflower-proso millet; and (5) WW-spring wheat. All crop phases occur each year. Individual plots dimensions are 7.3 by 24.4 m (24 by 80 ft.). The fallow phase of the WW-fallow system (1) is split into 'green' and 'brown' subplots; a multi-species polyculture is planted in

the green subplot while nothing is planted in the brown subplot (i.e., chem-fallow).

Applied Questions

Which cropping system(s) is(are) the most profitable?

It is too early to tell; all phases of each cropping systems was established for the first time in 2017, a year when persistent drought occurred. A 4-yr rotation is included in the trial, so it won't be until 2021 that all five cropping systems will have cycled through each crop phase at least once.

Will diverse rotations aid in the control of cheatgrass?

Several plots were infested with cheatgrass when the RATS study began; a remnant on the tillage strips of earlier studies where winter wheat was grown frequently. In particular, the 4-yr WW-spring pea-safflower-proso millet rotation is designed to help with control of cheatgrass as well as other winter annual weeds, since spring/summer seeded crops are grown in three of the four years. Time will tell if that is the case.

Acknowledgments

We are grateful to the Montana Agricultural Experiment Station for providing funding for this research study.

Warm-Season Crop Sequence Study

Patrick Carr, Simon Fordyce, Sally Dahlhausen, Sherry Bishop and Heather Fryer, CARC

Problem

There is a need to diversify cropping systems in Montana to improve economic profitability and soil management. Lentil, chickpea, canola, and other crops are being incorporated into rotations with wheat. Less effort is being made to incorporate warm-season crops like corn. Our objective is to determine if warm-season crop species are suited to growing conditions in central Montana and if they can be followed by wheat in a crop sequence.

Study Description

Eighteen different warm-season crops were planted at the CARC along with two, 2-crop combinations and two, 4-crop combinations in 2016, 2017, and 2018. The planting date ranged from 21 to 30 May in 2018, depending on the crop. Two cool-season crops (spring wheat and field pea) and a fallow treatment were included as checks. Wheat will be planted following harvest of the warm-season crops, just as it was after they were harvested in 2016 and 2017.

Applied Questions

Which warm-season crops performed best when grown for cover, forage, and grain/seed?

Data are not yet available for 2018. Corn and sunflower have shown greatest promise the past two years when grown for cover or forage compared with other warm-season species, based on dry matter production. Sunflower produced

over 1 ton/ac of dry matter when grown as a cover crop, and corn produced over 2 tons/ac of dry matter when grown for forage. Buckwheat and proso millet also showed promise as cover crops, and proso millet along with a 4-species, warm-season mixture when grown for forage.

Grain yields were low for warm-season crop treatments in 2016 and 2017, with several species failing to produce any harvestable grain/seed in either year (e.g., cowpeas). Generally, less than 1000 lb/ac of harvestable grain/seed was produced by those warm-season species which reached physiological maturity. Drought, particularly in 2017, and grazing damage by antelope and deer take their toll on grain/seed yield. So far, growing conditions have been much better in 2018, and we also fenced the trial to prevent (we hope) grazing damage.

For the most part, wheat grain yield following fallow, pea, and spring wheat has not been any higher than following warm-season crops, including corn and sunflower. Warm-season crops may have a fit in rotations with wheat and other crops in central Montana.

Acknowledgments We are very grateful to the Montana Wheat and Barley Committee for providing funding for this study, as well as the Montana Agricultural Experiment Station.

Understanding Acidification and Management of Montana Soils

Rick Engel, Clain Jones, and Scott Powell
MSU Dept. Land and Environ Science
Simon Fordyce, Sally Dahlhausen, and Patrick Carr, CARC
Tyler Lane, Extension Educator, Choteau County

Problem

In 2011, County Extension and Montana Agricultural Experiment Station faculty members were approached by central Montana farmers about declining crop performance in fields under long-term cultivation. Eventually, the problem was identified as aluminum toxicity caused by soil acidification. Since then, cultivated soils of pH <5.5 have been discovered in twenty Montana counties.

Study Description

Nine cultivars of spring canola, spring pea, spring barley, and spring wheat were established in acidic soils under limed (5 ton/acre) and unlimed conditions in an experimental design to determine the efficacy of sugar beet lime for remediation of acidic soils. Additionally, a single cultivar of durum wheat was established under limed and unlimed conditions at five different rates of phosphorous fertilizer to evaluate whether seed-placed phosphorus in combination with sugar beet lime can mitigate aluminum toxicity caused by acidic soils. The studies are replicated at two locations in Choteau County and will continue for two consecutive years.

Applied Questions

Which crops/cultivars can tolerate low pH soils?

Yield data will not be available until after harvest. However, visual inspection suggests poor tolerance in canola relative to spring wheat, spring barley, and spring pea. Varietal differences in low pH tolerance may be present, but cannot be verified until the study is complete.

Does phosphorous fertilizer in combination with lime improve crop performance in low pH soils?

While yield data will not be available until after harvest, visual inspection suggests a significant interaction between phosphorous and lime in durum wheat. Importantly, durum is known to be highly sensitive to low pH conditions.

Acknowledgements

We are grateful to the Montana Fertilizer Advisory Committee for funding this research.

Intra-State Barley Forage Nursery

Patrick Carr, Simon Fordyce, Sally Dahlhausen,
Sherry Bishop, Heather Fryer, CARC
Jamie Sherman, MSU Dept. Plant Science and Plant Pathology

Problem

Barley is grown for forage in the state. Generally, awnless (hooded) varieties are preferred over awned varieties when barley is hayed. Haybet and Lavina are the two most widely grown barley varieties for forage in the state, but they are old – released in 1989. Hays is a newer release but has not really caught on and still is quite old. Jamie Sherman, the MSU barley breeder, is overseeing an aggressive program to develop barley varieties for forage that are superior to Haybet, Lavina, and other varieties presently grown. Numerous experimental lines are being screened at the MSU Central Ag. Res. Ctr. as potential replacements for Haybet and Lavina.

Study Description

Fourteen experimental barley lines along with Haybet and Lavina were seeded on 27 April at the MSU Central Ag. Res. Ctr., following a burndown of glyphosate and 2,4-D, in a field where a pea-lentil cover crop was grown in 2017. Entries are being evaluated for forage yield and quality, as well as seed yield.

Applied Questions

Are there any experimental lines that compare favorably to Haybet and Lavina for forage production?

It is too early to tell; this is the first year of what we hope is a long-term effort. Thus far, the trial looks good and we hope to generate some useful data that will be an early indication of what experimental lines show particular promise in central Montana.

Acknowledgments

We are grateful to the Montana Agricultural Experiment Station for providing funding for this research study.

Spring Cereal Forage Trial

Patrick Carr, Simon Fordyce, Sally Dahlhausen, Sherry Bishop, Heather Fryer, CARC
Peggy Lamb, NARC, and Jamie Sherman, Dept. Plant Sci. and Plant Pathology

Problem

Barley probably is the most popular spring-seeded annual cereal forage in Montana. 'Lavina' is one of several awnless barley varieties that are suited for forage production in the state. There are other annual, spring-seeded cereal crops that can be grown (e.g., oat). The MSU Ag. Experiment Station continues to compare spring-seeded barley, oat, triticale, wheat, and other cereal crops for their forage potential each year with the goal of providing Montana farmers and ranchers with the information they need to make informed decisions on which crop best fits their annual forage needs.

Study Description

A total 10 entries (4 barley, 2 spring triticale, 1 oat, 1 spring rye, 1 emmer variety, and 1 spring wheat) were seeded 27 April at the MSU Central Ag. Res. Ctr., following a burndown of glyphosate and 2,4-D, in a field where a pea-lentil cover crop was grown in 2017. The trial is being duplicated in Bozeman, at the MSU Northern Ag. Res. Ctr. at Havre, and at the MSU Western Triangle Ag. Res. Center at Conrad.

Applied Questions

What were the highest yielding spring-seeded cereal species for forage in 2017?

Lavina barley produced equal or greater amounts of forage compared to other entries in the trial in 2017. However, forage yield was low for all entries (avg. yield = 1370 lb of dry matter/ac), including Lavina (yield = 1830 lb dry matter/ac) because of persistent drought. Higher yields were produced in the trial in 2016 (avg. yield = 2600 lb/ac), but there was too much variability across the study to be able to conclude with any confidence that one crop species or variety produced more forage than another species or variety.

Why has the production of oat for forage been discouraged in central Montana?

Nitrate poisoning is a concern when growing spring-seeded cereals for forage in central Montana, particularly in high-N environments. Oat is more prone to nitrate poisoning than barley and other cool-season, spring-seeded cereal crops. Barley is a safer alternative, although nitrate poisoning can occur under certain conditions. We evaluate the nitrate concentration of forage produced by entries in the trial, as well as other forage quality parameters, whenever possible.

Acknowledgments

We are grateful to the Montana Agricultural Experiment Station for providing funding for this research study.

Winter Cereal Forage Trial

Patrick Carr, Simon Fordyce, Sally Dahlhausen,
Sherry Bishop, Heather Fryer, CARC
Peggy Lamb, NARC, John Miller, WTARC,
Emily Gluck, MSU Dept. Animal & Range Science,
Zach Miller, WARC, Phil Bruckner, Dept. Plant Sci. and Plant Pathology

Problem

Annual crops can provide adequate amounts of high-quality forage for Montana ranchers. At the least, annual crop forage can be a useful supplement to traditional perennial forage sources. Some farmers/ranchers rely heavily on annual forages as their primary forage source in integrated crop-livestock systems. The MSU winter wheat breeding program has selected, and continues to select, for cultivars suited for forage production in the state. Dave Wichman, former agronomist and superintendent at the research center, selected for winter triticale lines that could be grown for forage by Montana ranchers. We continue to compare winter triticale and wheat lines/cultivars with the goal of identifying those most capable of producing large amounts of high-quality forage when grown in the state.

Study Description

Twenty-four winter wheat and winter triticale entries, including the newly released winter-wheat variety Ray, were planted following a pea-lentil cover crop at the MSU Central Ag. Res. Ctr. on 11 October, 2017. A slightly smaller version of the trial was planted in Bozeman, at the MSU Northern Ag. Res. Ctr. at Havre, the

MSU Western Ag. Res. Ctr. at Corvallis, and at the MSU Western Triangle Ag. Res. Ctr. at Conrad.

Applied Questions

How has the new winter wheat variety compared with Willow Creek?

Ray has some advantages compared with Willow Creek when grown for forage at the research center – at least so far. For example, Ray produced more forage (7104 vs. 5525 lb/ac) and grain (34 vs. 28 bu/ac) than Willow Creek in 2017, and also headed 6 days earlier, enabling an earlier harvest. Ray also was shorter, making it less susceptible to lodging. Early indications are that Ray is going to be a good choice for central MT farmers looking for a next generation forage winter wheat variety to replace Willow Creek on their farms and ranches.

Do winter triticale varieties/lines continue to out yield their winter wheat counterparts?

Winter triticale entries did tend to out yield winter wheat entries for forage in 2017, though there were exceptions. However, winter wheat entries tended to have higher forage quality. So, there is a trade-off when growing one winter type vs. the other.

Acknowledgments

We are grateful to the Montana Agricultural Experiment Station for providing funding for this research study.

Inoculant Trials

Jed Eberly and Eva Magnuson, CARC

Problem

Several microbial inoculant trials are underway at CARC. One of these trials is focused on assessing inoculants that can potentially protect against root lesion nematodes. Additional studies are underway testing evaluating other microbial inoculants for their ability to improve plant health and yield. Root lesion nematodes are parasitic, microscopic worm-like animals that use a syringe-like 'stylet' to pierce and extract nutrients from the roots of plants such as wheat. Above ground, crops are characterized by thin stands with unthrifty and/or yellowed plants, similar to the symptoms of water or nitrogen deficiency. Below ground early infection symptoms show brown root discoloration, with fewer and shorter root branches. In severe cases, plants are easily pulled from the ground as a result of root destruction. An infestation of root lesion nematodes can cause losses of over 50%.

Study Description

The study is located in a field at CARC that was planted in barley the previous year and is known to contain root lesion nematodes. The microbial inoculants are being tested for their ability to protect wheat from root lesion nematodes found in this field. Soil samples will be collected throughout the growing season to count the number of root lesion nematodes present in the

soil and crops will be assessed for vigor and performance.

Spring wheat was tested with 8 different microbial formulations along with a commercial Telon fungicide control and an untreated control. The winter wheat trial had 5 different microbial formulations and an untreated control. The plots are arranged in a randomized experimental design so that differences from the treatment can be separated from other effects.

Performance

Winter wheat root lesion nematode counts were around 600-1000 nematodes/kg of dry soil which was about half as many as were found in the untreated control. No difference in yield was observed between treatments.

Nematode counts in the spring wheat were varied from around 250-1000 nematodes/kg of dry soil. The Telon fumigant control was around 750 nematodes/kg of dry soil which was around half the number found in the untreated control. No significant yield difference was observed between treatments.

Soil Health: Understanding Microbial Processes Contributing to Nitrogen Cycling

Jed Eberly and Eva Magnuson, CARC

Problem

Microorganisms in the soil play an important role in soil health and crop health and productivity. However, it is difficult to measure their activity and to determine responses to specific agronomic practices. One of the important roles of microorganisms in the soil is nitrogen (N) cycling. Appropriate N management is essential for the economic and environmental sustainability of Montana farms. N mineralization is an important part of N cycling since it enhances N uptake by crops and increases the risk of nitrate loss through leaching. The impact of enhanced cropping system diversity on N mineralization, and consequently N availability and nitrate leaching, in dryland cropping systems is currently not well known. This work will provide insight into microbial activity throughout the year and N mineralization rates and the temporal variability of those rates in response to greater crop diversity.

Study Description

The study will be performed in an existing crop rotation study that was started in 2004. More recently, a Rotation And Tillage Systems (RATS) study was begun in 2017 to evaluate diverse cropping systems under no-till and conventional-till management. The cropping systems consist of six different cropping system replicates (see the RATS section of this report for specifics).

Soil respiration data will be collected with a soil gas flux system that will be installed at the beginning of the growing system. This will monitor changes in microbial activity in response to temperature changes and precipitation events throughout the year. These data will be used to compare differences in community activity between cropping systems and to correlate N mineralization to overall microbial activity.

Outcomes

Soil respiration measurements have just been initiated and mineralization measurements will be started next growing season. The anticipated outcome of this work is a better understanding of N mineralization under different crops which will provide a more complete N budget. Collectively, the results from this effort will provide insights into N mineralization under a variety of crops that are important to central Montana dryland agriculture. It will also improve understanding of N availability and risks of N leaching throughout the year with different types of crops, which will be useful for helping farmers choose crops to incorporate into their existing rotations. This work will also be used to guide producers both in timing and N application rates to maximize uptake by the crop while minimizing leaching.