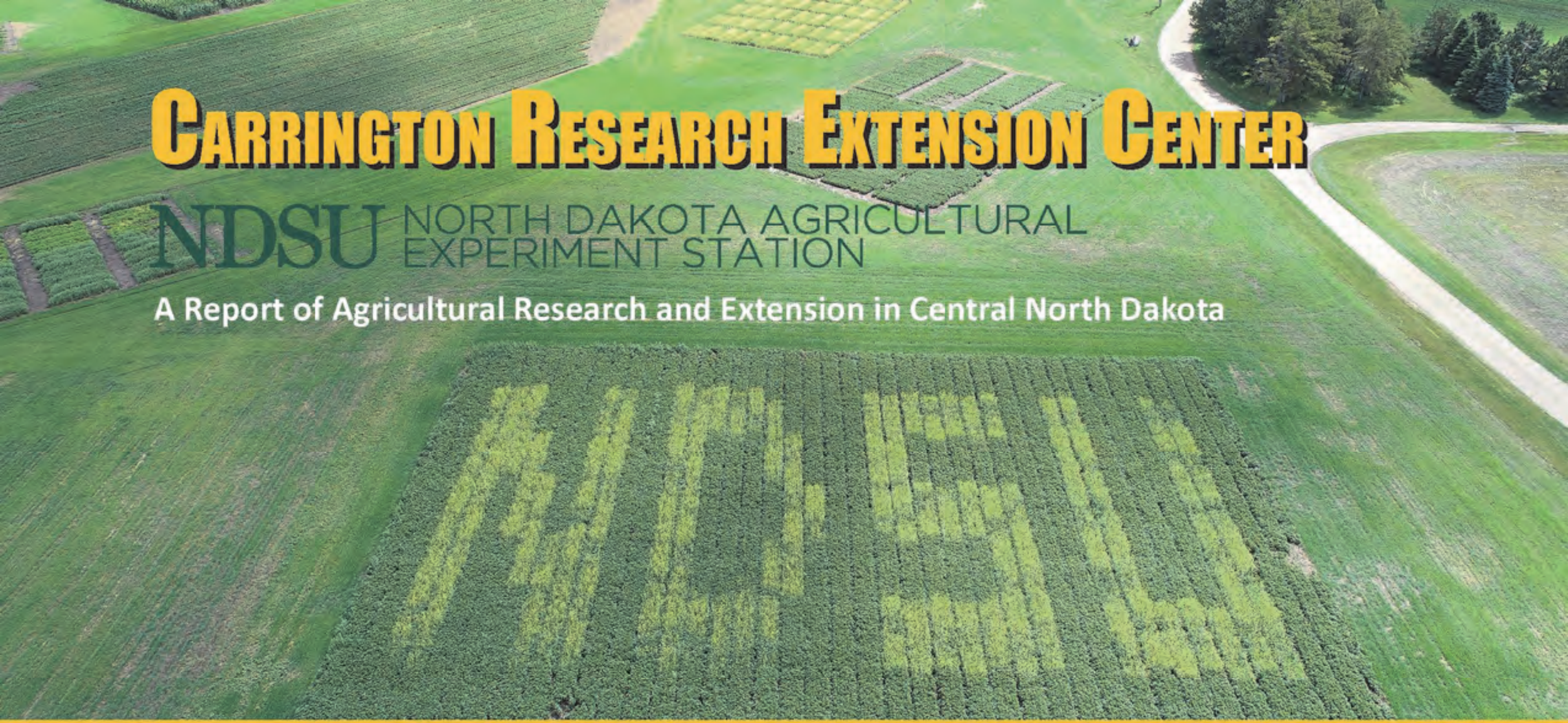
Carrington Research Extension Center

NDSU NORTH DAKOTA AGRICULTURAL EXPERIMENT STATION

A Report of Agricultural Research and Extension in Central North Dakota



Volume 61
December 2020

CONTENTS

Research Highlights from 2020

Crop Variety Comparison Data

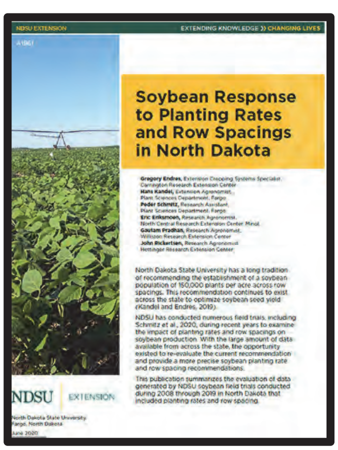
The Carrington Research Extension Center conducts research and educational programs to enhance the productivity, competitiveness, and diversity of agriculture in central North Dakota. Research activities at the CREC include scientists and support staff trained and implementing programs in Agronomy, Plant Pathology, Soil Science, Precision Agriculture and Animal Science. These program teams are able to address a broad scope of factors that impact North Dakota agriculture. The crop diversity of the state is addressed in all program areas and is further supported by the ability to conduct research under both dryland and irrigated conditions. Projects addressing organic crop production and a fruit and berry program broaden the constituency being served. The foundation seed program of the center represents an important part of the overall NDSU Foundation Seed program. The CREC is the base of operation for four Extension specialists. This report highlights a portion of the department's contributions to research and extension. Following are a few examples of highlights from our past season and significant impacts and contributions to the region's agriculture.

Coordinated initial research projects in the state surrounding the wide row (60") corn concept. This evolved to include not only replicated research trial work, but also to serve as liaison between growers who experimented on farm. This has enabled us to foster connections between producers and gain insight into how growers might implement this strategy on farm (see page 5).

Initiated research projects to better understand the role of biofortification in the wheat supply chain. The goal of the work is to evaluate fertility management of phosphorous and zinc and how that affects grain nutrient content. The goal would be for grain products to meet or exceed international market thresholds for zinc biofortification.

Concluded a final year of research to evaluate the yield impact of dicamba drift on non-DT soybeans. This wraps up a 7-year study into the effects of dicamba drift on soybeans and other sensitive broadleaf crops. The information from these studies will help producers better quantify potential yield losses in the event of dicamba drift/volatilization.

A multi-department, multi-discipline research effort was conducted in 2020 to holistically study the adoption of cover crop grazing. This involves multiple researchers from agronomy and animal science along with Extension personnel in an effort to provide data and grower support for those looking to incorporate livestock into cropping operations. The study addresses crop and animal performance, soil health, and the economics in each aspect (see page 7).



NDSU EXTENSION EXTENDING KNOWLEDGE » CHANGING LIVES

A1961

Soybean Response to Planting Rates and Row Spacings in North Dakota

Gregory Endres, Extension Cropping Systems Specialist, Carrington Research Extension Center
Hans Kandel, Extension Agronomist, Plant Sciences Department, Fargo
Peder Schmitz, Research Assistant, Plant Sciences Department, Fargo
Eric Eriksmoen, Research Agronomist, North Central Research Extension Center, Minot
Gautam Pradhan, Research Agronomist, Williston Research Extension Center
John Rickertsen, Research Agronomist, Hettinger Research Extension Center

North Dakota State University has a long tradition of recommending the establishment of a soybean population of 150,000 plants per acre across row spacings. This recommendation continues to exist across the state to optimize soybean seed yield (Kandel and Endres, 2019).

NDSU has conducted numerous field trials, including Schmitz et al., 2020, during recent years to examine the impact of planting rates and row spacings on soybean production. With the large amount of data available from across the state, the opportunity existed to re-evaluate the current recommendation and provide a more precise soybean planting rate and row spacing recommendations.

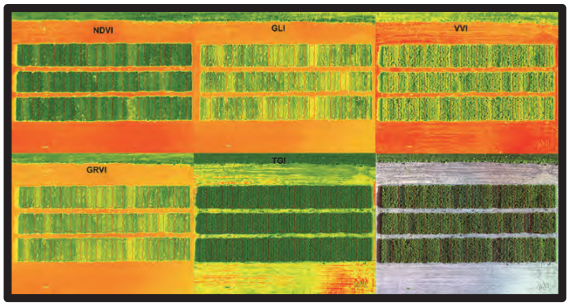
This publication summarizes the evaluation of data generated by NDSU soybean field trials conducted during 2008 through 2019 in North Dakota that included planting rates and row spacing.

NDSU EXTENSION

North Dakota State University
Fargo, North Dakota
June 2020

The NDSU Extension circular 'Soybean response to planting rates and row spacings in North Dakota' was published in June 2020. It was the result of compiling and evaluating 37 NDSU field trials conducted during the past decade on soybean seed yield impacted by planting rates and/or row spacings. The information provides a more precise guide for establishing soybean stands in the east and west regions of North Dakota (see page 20).

The CREC continued as a cooperator in 2020 with the NDSU Extension IPM crop survey program. Sean Nichols served as the scout based out of the CREC and surveyed 426 wheat, barley, soybean and sunflower fields in south-central North Dakota during June to August. Field notes were taken on crop pests (diseases and insects) and agronomic factors. In addition, traps were located in wheat, sunflower and canola fields to monitor presence of selected insects. Data from the statewide program can be viewed at the website: www.ag.ndsu.edu/ndipm.



Evaluated a novel and "scalable" non-near infrared (non-nir) vegetation index for assessment of crop plant health. While more complex, this scalable vegetation index may offer greater flexibility than traditional non-nir vegetation indexes currently in use (see page 35).

Completed the fourth and final year of a multi-location research effort assessing the impact of planting date on field pea agronomic performance under natural Fusarium and Aphanomyces root rot pressure and quantifying the returns to fungicide seed treatment relative to planting date. Results indicate that soil temperatures at planting are a critical determinant of root rot severity and field pea yield and that if timely planting is not possible in fields where root rot is a concern, peas should not be planted.

Over the past year the CREC-animal science program has evaluated the potential of soybean hulls to serve as a partial forage replacement for drylot beef cow/calf rations. Results of this study indicated that soybean hulls can be included as a replacement for a combination of corn silage, straw, and modified distillers grains at rates up to 25% without negatively impacting either cow performance or calf performance through weaning (see page 40).

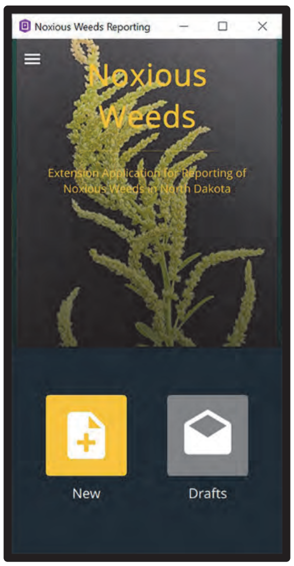
Completed the third year of field studies quantifying the impact of spray droplet size on the efficacy of fungicides, with testing conducted on multiple crops and diseases. Results indicate that droplet size must be calibrated relative to the target, with fine droplets only optimizing fungicide performance for diseases for which infection occurs primarily in the upper canopy. For white mold in soybeans, a disease that develops in the lower third to half of a canopy, coarse spray droplets optimize fungicide performance when the canopy is at or near closure.

In 2020, the Northern Hardy Fruit Evaluation Project provided distance learning for approximately 950 people through videos and video conference programs. We served over 100 people and educators in-state as well as in Iowa, Michigan, Minnesota, Montana and Tennessee through calls and email. Current research is concentrating on selecting better haskap cultivars for North Dakota conditions through collaboration with the North American breeder of Japanese haskaps (see page 47).

A study was conducted to determine the impacts of pre-weaning trace mineral exposure and post-weaning trace mineral source on animal performance and carcass characteristics of beef steers. Calves with access to trace mineral prior to weaning weighed more at weaning. Providing organic forms of trace minerals increased the rate of copper accumulation during backgrounding compared to sulfate-forms of trace minerals. Calves fed organic forms of trace minerals also had greater average daily gain during backgrounding compared to those fed inorganic sources of trace minerals. However, no differences in average daily gain were present when overall performance was evaluated at finishing.

The animal science program recently concluded a study evaluating the impacts of roughage inclusion rate on animal performance and carcass characteristics of steers fed wheat-based feedlot diets. Concurrently, a metabolism study was conducted to evaluate the impacts of roughage inclusion on overall diet digestibility and ruminal fermentation. Results of the metabolism study indicate that increased roughage supply increases ruminal pH, lessening the potential risk of ruminal acidosis, a common problem in wheat-based rations.

Conducted first field tests of newly developed, soybean-based polymer-coated biodegradable slow release N fertilizer. In assessing their impact on grain yields of corn and wheat, compared to conventional urea fertilizer and established N stabilizers, we observed better corn and wheat response to these N stabilizers than urea (see page 27).

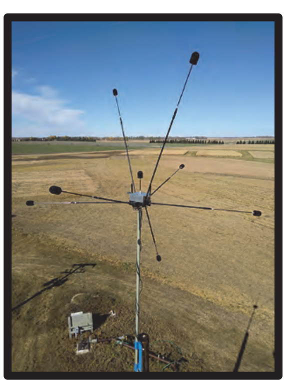


Developing a mobile application based on Geographic Information Systems (GIS) technology for real-time mapping and monitoring of Palmer Amaranth (*Amaranthus palmeri*) in North Dakota. Deployment of the application to county agricultural agents is anticipated by late winter, with field-based evaluation occurring in spring of 2021 (see page 11).

Quantified the impact of crop rotation interval on field pea agronomic performance under natural Fusarium and Aphanomyces root rot pressure. With the exception of a Canadian study which evaluated planting peas continuously versus once every second year, this is the first study conducted anywhere in the world evaluating the impact of crop rotation interval (peas grown once every 2, 3 or 6 years) on field pea agronomic performance under root rot pressure.

Finalized study that examined the impact of planting date and phosphorus fertilization of soybeans and concluded that farmers who plant soybean in the first two weeks of May are likely to always produce greater yields than planting later. Phosphorus fertilization is less likely to significantly enhance yields, and therefore may be recommended only for soils testing low in phosphorus.

Established two soybean trials to verify the possibility of detrimental effects of distillers grain application to soybean N fixation and yields and found no negative impact. Even though wet distillers grain (WDG) contains high N content, application at rates that could potentially supply about 60 lbs N or more may not affect N fixation because the N from WDG is released slowly (see page 13).



Evaluating a Detect and Avoid (DAA) technology that would identify both manned aircraft and drones within a common airspace. The objective of the project is to ensure overall air and ground safety. The project is a collaboration between the CREC, the Northern Plains UAS Test Site (NPUASTS) and Scientific Applications & Research Associates (SARA). The technology from SARA has potential to expand the integration of UAS/drones into air traffic management across the country.

Initial Evaluation of the 60-inch Corn System in North Dakota

Mike Ostlie, Kelly Cooper, and Greg Endres

In 2020 there was a lot of interest in learning more about wide row corn (usually called 60” corn). A number of growers conducted on-farm trials and many researchers tested the concept for the first time. Wide-row corn is counter to corn production trends. Over time, the optimum row spacing has decreased, and yields have increased along with it. What is the appeal of growing corn in wider rows? Does it yield more? The answer is no, it will not yield more than standard row spacings. If you want to grow the maximum of amount of corn, the narrower rows are still the recommendation. The goal of wide-row corn is get multiple uses from each acre of land. The strategy is to grow corn plus a cover crop. The cover crop may be for erosion control, equipment floatation, saline management, or grazing/chopping. The success of the system will hinge on how close the yields are between the two row spacings and the inputs that go into each.

In 2020, a research trial was initiated to investigate the feasibility of wide row corn in North Dakota. The study was focused on comparing the row spacings (30” vs. 60”) at various plant populations and also in north-south or east-west row orientations. Row orientations were an important part of the study. Wider row spacings mean that more sunlight reaches the bottom of the plants and the soil surface. In northern latitudes, this can result in differences in shading based on the direction the row is planted. In narrow rows, the effect is minimized due to the tight density of the plant canopy, but when the canopy is opened up, more differences are likely to surface. This trial also tested how the plant-plant spacing might affect yield potential. In 60” rows, the plants are half the distance from each other compared to a 30” spacing at the same plant population. This trial was comparing 32K PLS/ac on 30” rows to the same population on 60” rows. It also tested 24K and 16K PLS on 60” rows. The 16K on 60” would be the same plant-plant spacing as 32K on 30” rows. Average yield of corn grown at 32K/ac on 30” rows is presented (the check treatment), and treatment comparisons are based on the percent yield. This trial was conducted at the Oakes Irrigation Research Site and the Carrington Research Extension Center. Each treatment was replicated four times and arranged in a split plot randomized complete block design.

At Oakes, there was roughly a 13% yield reduction by planting to wide rows versus standard rows when comparing both row spacings planted to 32K PLS/ac (Table 1). With their high-yielding environment it amounted to 28 bu/a. At Carrington, in a lower yielding environment, the yield reduction was 5-6%, resulting in a roughly 6.5 bu/ac difference. Yields were further reduced by lowering the plant population. At Carrington, the yields were reduced by an average of 88 and 77% by reducing plant population to 24K and 16K, respectfully. At Oakes, the reduction was 89 and 73% less yield at 24K and 16K.

Table 1. Corn performance at Oakes and Carrington when comparing three plant populations and two row orientations.

Oakes			Carrington		
60" Row Population	Row Orientation N/S	E/W	60" Row Population	Row Orientation N/S	E/W
plants/ac	% yield	% yield	plants/ac	% yield	% yield
16k	80.7	66.1	16k	74.0	80.8
24k	95.8	83.3	24k	85.0	91.9
32k	100.0	100.0	32k	100.0	100.0
60" vs. 30" @ 32k	87.2	86.9	60" vs. 30" @ 32k	95.0	93.4

Check yield = 216 bu/ac

Check yield = 133.2 bu/ac

The two row orientations did not differentiate themselves in percent yield reduction. At Carrington, there was no true yield difference between row orientations. At Oakes, on average the north/south rows yielded 12 bu/ac less. The largest difference was between 30” rows, where the east/west out-performed north/south rows by 28 bu/ac. At Oakes the yield stability was greater on north/south compared to east/west rows in the wide row spacing, meaning that the yield reduction was less severe on north/south rows.

To compete with narrow rows, the wide-row corn strategy needs to compensate by producing more or bigger cobs than narrow rows at the same population. At Carrington, cob length and the number of kernel rows were measured. Cob length was not affected by row spacing, but the wide row corn had an average of roughly two more kernel rows per cob. Plant and ear heights did not change as a result of any of the treatments.

The final piece to consider is the cover crop establishment. The cover crops were planted with a three-point offset John Deere 71 Flex planter on July 1 at the V6 growth stage at both row spacings in Carrington. The cover crop was a mix of turnip, radish, and lentils. In the wide row spacings, the establishment was about 40% of expected in very dry conditions. With the narrower rows, the establishment was only 14% of expected. The higher the plant population, the lower the establishment at either row spacing. Row orientation did not impact the success of cover crop establishment. Establishment was hindered by the addition of field peas that were planted at the same time as the corn. This was to take advantage of the ‘skip’ row that results when every other row unit is not planting to achieve a 60” spacing. The field peas grew well enough but lodged and shaded out a good portion of the area intended for cover crops, defeating part of the purpose of growing the cover crop. This contributed to relatively low cover crop establishment on the 60” spacing.

Cover crop establishment on 30” row corn, left, and 60” row corn, right.

There is still much to learn about how to manage wide-row corn in North Dakota. There are things that could be done differently to increase the effectiveness of the strategy. Hybrid selection will be key component to this system; at Oakes, preliminary data was collected that indicated large yield differences between hybrids at 60” spacings. A large portion of the tested hybrids still yielded less at 60” than 30” spacings, but a portion of the tested hybrids had similar yields at both spacings. There are likely some key traits that determine how well a hybrid will perform on wide rows. Fertilizer placement and input management are also good future research topics as ways to capture more value out of the system. There is also some evidence that if twin rows are used, rather than single rows, the yield loss may be decreased. As it stands, most researchers and farmers are seeing some degree of yield loss from wide-row corn. If grazing is the goal, this may acceptable if it is a small difference in yield, since the cows can capture additional value on that land. With the yield gap as it is presently, this strategy should be approached with caution and tested on a small acreage before making a large investment into the practice. An alternative would be to utilize a mixed strategy, where 60" rows were used on marginal field areas. This would allow the higher productivity areas to produce up to expectation, and hills or saline spots seeded to wide rows with cover crops for soil health improvement and less yield loss.

Partial funding for this project was provided by the North Dakota Corn Utilization Council.

A Preview of Grazing Cover Crops in North Dakota Cash Cropping Systems

Mike Ostlie, Bryan Neville, Jasper Teboh, Szilvia Yuja, Ezra Aberle, Steve Zwinger, Mary Keena, Joel Lemer, Dean Steele, and Doug Landblom

Livestock integration into cash cropping systems is a way to gain multiple use of each acre of land per year. If a reliable system is identified, it is a way to reduce land requirements and increase synergy between crop and livestock enterprises. There are barriers to adopting this practice in North Dakota, including limited heat units, water deficit, and time or equipment availability. Overcoming these barriers can require creativity since no two growing seasons are the same. It is also difficult to find the right type of information needed to make decisions specific to our region, particularly when considering cost/benefit to both crop and livestock enterprises. To counter this, a large collaborative project was initiated in 2019, through funding from the North Central Region Sustainable Agriculture Research and Education (NCR-SARE) grant program to test cover cropping systems and how they affect soil health properties, animal performance, and ultimately, the bottom line. This project is unique in that it covers applied research and outreach in a holistic manner for both crop and livestock systems.

Planting cover crops into corn.

Large plot research and on-farm experiments were in initiated in 2019 and continued into 2020 to better understand the impacts of cattle integration in cash cropping systems. The research plots consisted of growing either wheat or corn as the primary crop. After harvest, spring wheat plots were direct-seeded with a cover crop mix consisting of turnip, radish, lentils and contained volunteer wheat. Corn plots were seeded to turnip, radish, lentil, barley, and rye at the corn V5-6 growth stage using a modified and off-set plate planter. Grazing of these plots occurred in late fall (late Oct. to mid-Nov.). Separate plots were established that either had no cover crops or had cover crops but were not grazed. Some of the agronomic research questions being studied during this time include changes that occur in the soil microbial community, soil compaction, nutrient composition, or crop yield changes by including livestock (vs. only cover crops or no cover crops). From the cattle perspective, we are testing performance of animal grazing compared to a drylot setting, both in terms of daily gain and marbling quality. In the end, these treatment combinations allow us to calculate the economic cost/benefit of the different enterprises. Concurrently, on-farm demonstrations occurred at three locations to test feasibility of adopting cover crop grazing. The goal of these demonstrations was to encourage the adoption of cover crop grazing in corn to learn more about the success rate, challenges, and limitations that occur in our region.

Cattle grazing corn stalks and cover crops.

While COVID-19 has significantly altered the plans for outreach over the last year, there will be concerted efforts to increase the knowledge sharing and lessons learned from this project as more results and impacts are known. As it turns out, these two growing seasons have presented a wide array of conditions that are sure to teach us a lot about the factors that determine success for livestock integration. Stay tuned to learn more in the coming months!

Partial funding for this project was provided by the North Central Region Sustainable Agriculture Research and Education.

Cover Crop Response to Soybean Herbicides

Greg Endres, Kirk Howatt, Joseph Mettler and Mike Ostlie

Numerous considerations are needed to plan and utilize cover crops as part of farm management. Besides setting goals for cover crop use, field history of herbicides needs to be considered to avoid loss of cover crop stands due to herbicide residuals in the soil.

Previous research coordinated by the Carrington Research Extension Center resulted in a table that displayed various risk levels with planting cover crops on ground previously treated with wheat herbicides that have soil residues. A similar study followed, to build a database indicating cover crop tolerance to soybean herbicides with potential soil residuals.

In 2016, an initial trial was conducted in Fargo to determine the tolerance of common cover crops to selected corn and soybean herbicides. The soybean data from the trial were considered as a formal study was conducted at Carrington and Fargo during 2018 to 2020. The study included nine soybean herbicides and eight cover crops.
Soil and post-emergence herbicides were applied at labeled rates and timings to soybean. The crop was mowed during August (seed-fill stages) and cover crops direct planted into the soybean stubble generally late August to early September. Visual evaluation of injury (biomass and/or stand reduction) began generally in late September (3-4 months after application of herbicides).

The study resulted in a six site-year database that was summarized in the following table. The table will be published in the NDSU 2021 ND Weed Control Guide.

Field pea injury from soybean herbicides.

Risk of cover crop injury due to soybean herbicides with soil residual, Carrington and Fargo, 2016-20.[1]

		Risk of cover crop injury							
Site-years	Herbicide	Barley	Winter Rye	Field Pea	Flax	Radish	Turnip	Lentil	Rapeseed/ Canola
	Soil								
6	Sencor 75 DF	Low	Low	Low	Low	Medium	Medium	Low	Low
6	Spartan 4F	Low	Low	Low	Low	High	Medium	Medium	Medium
6	Valor SX	Low	Low	Low	Low	High	High	Low	High
6	Zidua SC	Low	Low	Low	Low	Medium	Low	Low	Medium
5	Pursuit	Low	Low	Low	High	High	High	Low	Low
	POST								
5	Engenia	Low	Low	Low	Low	Low	Low	Low	Low
6	Flexstar	Low	Low	Low	Low	High	Medium	Low	Medium
2	Liberty 280	Low	Low	Low	Low	Low	Low	Low	Low
2	Raptor	Low	Low	Low	Low	Low	Low	Low	Low

[1]Low risk = 0-20% injury; Medium risk = 21-50% injury; and High risk = >50% injury. Greatest injury recorded for each treament was used to determine risk level.

All herbicides, except Liberty 280, injured cover crops. Barley, winter rye and field pea had the greatest tolerance to herbicides. Radish, turnip and rapeseed/canola generally had the least tolerance to herbicides. The following herbicides potentially have high risk of injury for specific cover crops. Spartan = radish; Valor = radish, turnip and rapeseed/canola; Pursuit = flax, radish and turnip; and Flexstar = radish.

Partial funding for this project was provided by the North Dakota Soybean Council.

Assessment of Canola Response to Top-dress Nitrogen and Sulfur

Jasper M. Teboh, Mike Ostlie, Szilvia Yuja, and Ezra Aberle

Introduction

Nitrogen (N) and sulfur (S) fertilizers are vital in canola production. Farmers in the Northern Great Plains have long been interested in strategies to enhance the efficient use of these fertilizers. These strategies, which include split application of N, application timing, and use of enhanced efficiency N fertilizers (EENFs), have not been widely adopted because of inconsistencies in their impact on canola productivity. While it is a common practice to apply S fertilizer all at planting, some European studies have recommended application of S at bolting to maximize canola uptake and use efficiency.

Objectives

1. Assess whether canola yield response to split N fertilization varies with rate of S.
2. Compare the yield response from N top-dress with SuperU (EENF) versus conventional urea.
3. Assess whether S application at bolting will enhance canola yield versus preplant fertilization.

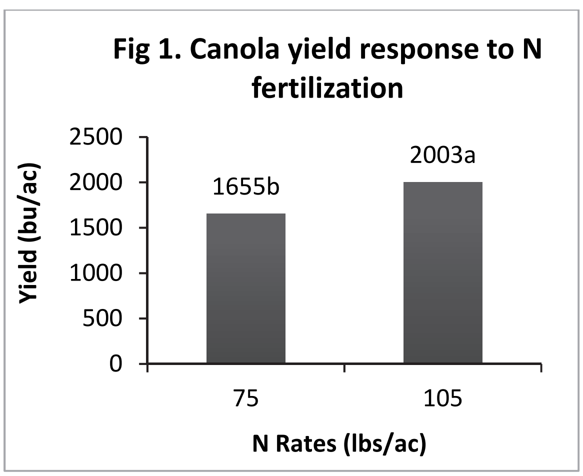
Methods

The trial was conducted at Carrington. There were 18 fertilizer treatments consisting of nine N treatments at 15 lbs S, and the same N treatments at 30 lbs S. Soil N was 45 lbs at Carrington.

- Treatments 1-4: Two N rates at 120 lbs and 150 lbs N each fertilized with 15 or 30 lbs S.
- Treatments 5-12: Six split N treatments; urea was applied at 35 lbs and 65 lbs N/ac; three plots were top-dressed with urea and the other three with SuperU at 40 lbs N. S rates were 15 and 30 lbs.
- Treatments 13 to 18: compared different split urea N rate combinations (105/0, 65/40, 45/60 lbs N) for a total N application of 105 lbs/ac at 15 lbs S and 30 lbs S that was applied at bolting.

Results

Average yield was significantly greater at 105 lbs N compared to 75 lbs N/ac (Fig 1). Yields were not significantly different between 15 and 30 lbs S, which was likely due to soil S availability during the growing season. This probably explains why yields were not different between treatments that received S fertilizer before planting and those that only received S at bolting.



[ab] different letters depict significant differences ($P < 0.05$).

Yields were neither different between split N application and single application as a starter, nor were they different between the different amounts of starter N. Yields from N top-dress with urea were also not different from yields with SuperU top-dress. Prolonged drought that lasted about one week during bolting stage, when N was top-dressed (on dry topsoil), may not have resulted in an important loss of N from urea compared to SuperU, thus explaining the lack of yield impact.

Conclusion

Yields were improved by 105 lbs N, which is the NDSU recommendation rate. There was no impact of split-N application, S application at planting versus at bolting, and no yield differences between 15 and 30 lbs S. Nonetheless, the canola S recommendation of 25 or 30 lbs is the best option for farmers to ensure S is not deficient for the crop. More studies are needed to determine if less S may be needed when low preplant N rates are applied.

A Mobile Web-mapping Application for Real-time Monitoring of Palmer Amaranth in North Dakota

David Kramar

Introduction: The increase and continued expansion of noxious weeds in North Dakota represents a potential danger to the region's agricultural markets. North Dakota state law (NDCC § 4.1-47-02) mandates that weeds identified or listed as noxious and troublesome must be controlled. Currently, North Dakota offers regular updates and recommendations for chemical control for a variety of troublesome and noxious weeds. In addition, information pertaining to biological control may be found by contacting the North Dakota Department of Agriculture or local staff of the United State Department of Agriculture - Animal and Plant Health Inspection Service. The recent expansion of palmer amaranth (*Amaranthus palmeri*) throughout the state is of concern given its propensity to develop herbicide resistance, prolific seed production, and rapid rate of growth. Moreover, palmer amaranth can contribute to decreased yields, and gained its notoriety as it impacted the cotton industry in the southern United States. In North Dakota, palmer amaranth is a threat to the state's primary crops including soybean, sugar beet, and corn. Purdue University estimates that palmer amaranth has the potential to reduce soybean yields by up to 79%.

In addition to traditional reporting methods, it is important to monitor the presence and proliferation of noxious weeds in a spatial context. Whereas eradication efforts are often conducted when noxious weeds such as palmer amaranth are identified, the mapping of locations will aid in further understanding the spread of such weeds, as well as the environmental factors that drive such spread. To this end, Extension staff at the Carrington Research Extension Center have started development of a mobile-based tool that will facilitate the acquisition of spatial data as it pertains to palmer amaranth and other noxious weeds within the state. Current technology provides a robust framework within which to develop this mobile application. Utilizing both the Android and IOS Software Development Kits (SDK), as well as Geographic Information System (GIS) technology, this mobile application can be rapidly deployed and utilized via a traditional "smartphone" environment. Furthermore, the application will be "scalable" meaning that the application will be updated as new threats emerge. This relatively new technology offers an efficient and lightweight method of monitoring the presence and spread of noxious weeds within the state, and will contribute to ongoing mitigation efforts as required under state law. The current beta version allows the user to document one of four different noxious weeds, and stores the GPS location, a photograph, the county within which it is located, and the relative prevalence. Further attributes will be defined based on discussions with Extension staff and weed specialists.

Application Framework: The spatial databases will be developed utilizing the ArcGIS Geodatabase model. This particular spatial model provides a mechanism to create a menu-driven form in the mobile application, while simultaneously storing the spatial (location-based) information related to the distribution of noxious weeds within the state.

Attribute information is stored in the “Noxious_Weeds” feature class (Figure 1) that is contained within the “Noxious_Weeds” Geodatabase. This feature class will be populated by the mobile application, and subsequently consumed by the online web map, and associated online dashboard. The web map and dashboard will utilize either the North Dakota State University ArcGIS Online (AGOL) organizational account or North Dakota State University’s ArcGIS Enterprise Server licensing and an associated PostGreSQL spatial database. The beta version of this application utilizes AGOL for ease of use and the rapid manner in which a “proof of concept” can be developed. Moreover, the feature class will be updated via the mobile application, which will be developed using the ArcGIS AppStudio Developer’s Edition and will run on both Android and IOS mobile devices. The Android and IOS devices will need to install ArcGIS AppStudio Player which will allow the application to run prior to deployment as a full executable software installation.

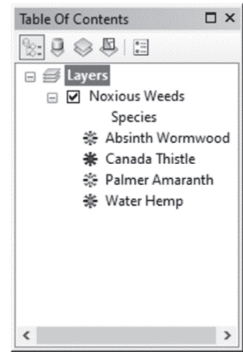


Figure 1: Feature Class layer with four species of noxious weeds.

The mobile application itself allows the user to navigate several screens with ease, and integrates the internal GPS chip found in modern Android and IOS devices (Figure2). The final dashboard and web map allow for near real-time updating and monitoring of distribution across the state.

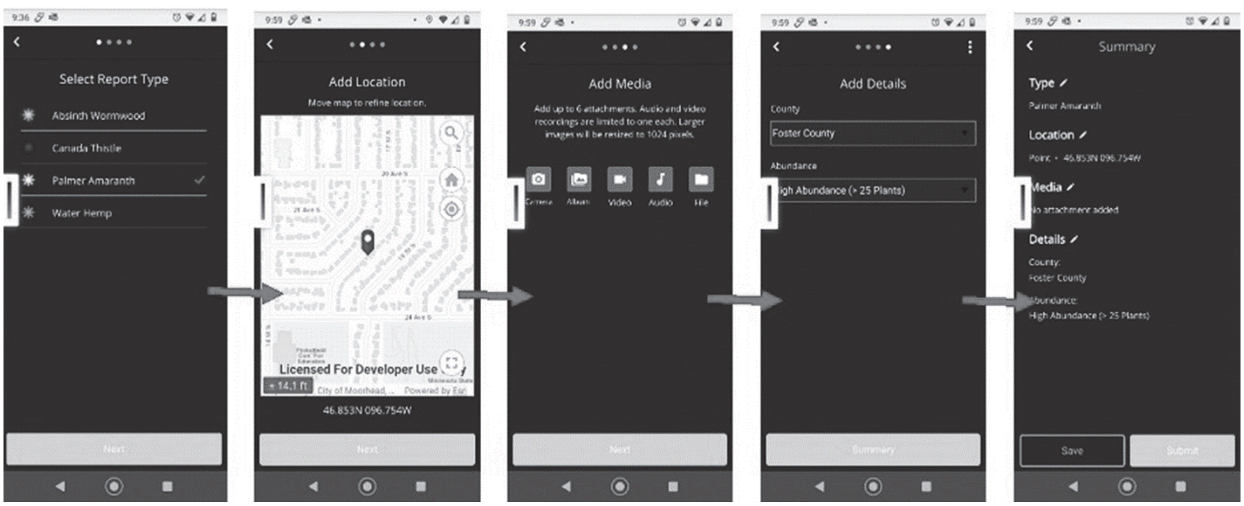


Figure 2: The application has the user step through 5 screens. The first screen sets the report type, the second screen collects the GPS location, the third screen allows the user to capture an image or other media, the fourth allows input of attributes, and the fifth screen allows the user to review the data and submit the information directly to the web map and dashboard.

Summary: The relative ease with which the application can be downloaded and deployed will facilitate more reliable collection of data as it pertains to noxious weeds in the state. Moreover, data that are collected will integrate with the current state-wide efforts to monitor noxious weeds throughout the state. The architecture upon which the application is designed allows for a scalable solution that can evolve as the needs and focus change. It is expected to go directly to field evaluation this spring with Extension agents utilizing the application in instances where palmer amaranth or other noxious weeds are identified. Further development will occur upon consultation with state weed scientists to determine the appropriate attributes that should be collected.

Assessment of N Fixation and Soybean Yield Response to the Application of Distillers Co-Products

Jasper M. Teboh, Szilvia Yuja, Mike Ostlie, and Blaine G. Schatz

Introduction

During ethanol production, wet distillers grains (WDG) and condensed distillers solubles (CDS) or syrup, are produced and sold mainly as feed for livestock. However, an alternative use of distillers grains as sources of phosphorus (P) and nitrogen (N) has been demonstrated in studies where grain yields and protein of corn and wheat were enhanced by WDG and CDS.

Because of their higher N content relative to P, application of distillers grains as a source of P to soybeans on a low P testing soil could potentially contribute more N than would be recommended for soybeans, potentially impacting N fixation.

Objectives

1. Determine the impact on seed yield and quality.
2. Assess N fixation of soybeans following application of distillers grains.

Treatments

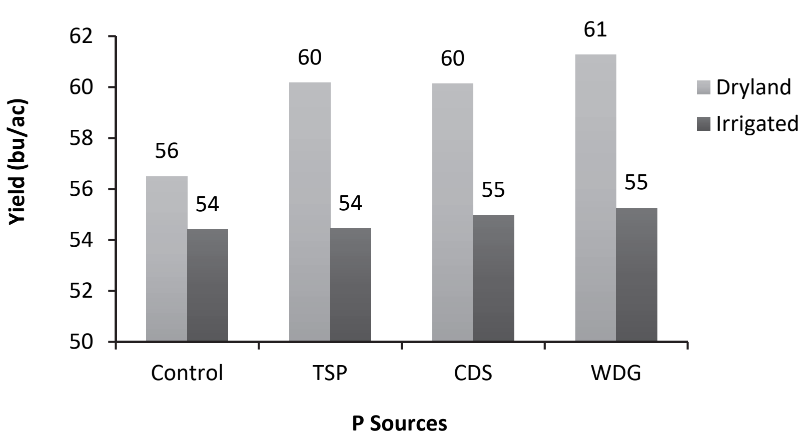
Soybean was grown in Carrington on dryland and under irrigation and subjected to four fertilizer treatments: 40 lbs P as granular TSP (triple super phosphate), 40 lbs P as CDS, and 40 lbs P as WDG, plus a control (no P applied), left on the surface, or incorporated for a total of eight treatments. Half of each plot had the urea applied to the TSP and control plots at 30 lbs N, which was equivalent to 30 lbs N supplied by CDS. WDG supplied 66 lbs N. Nitrogen fixation was assessed by analysis of the ureide content and nitrate-N (NO_3-N) in the leaves at 5-trifoliolate growth stage.

Results

Phosphorus fertilization did not significantly impact yields at either site.

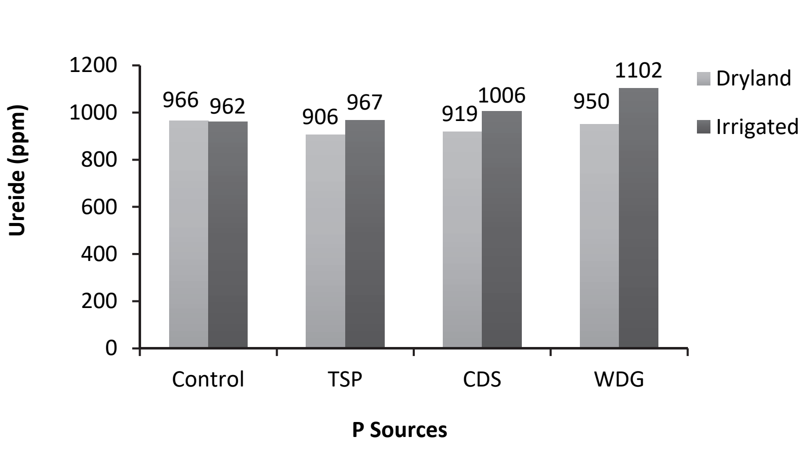
Average yield on dryland was 60 bushels. This was about five bushels greater (Figure 1) than yields at the irrigated site, probably due to an early frost (September 8 and 9) at R5 growth stage that negatively impacted yields for the irrigated crop. The dryland crop had already attained maturity (about R8). Before R7 growth stage, soybean yields are still susceptible to adverse impact of frost.

Fig 1. Soybean yield response to distillers grains as sources applied at 40 lbs/ac



Nitrogen fixation was not significantly different between fertilizer treatments (Figure 2). Despite application of 66 lbs N with WDG compared to the 30 lbs N applied from CDS, or added to the control and to the TSP treatments, the amount was not high enough to cause differences in N fixation. This was likely due to low initial soil N at planting (12 lbs on dryland and 48 lbs under irrigation), and probably due to the slow release rate of N from WDG. Strangely, ureide-N content was low for every treatment, well below the critical range of 1200-1500 ppm. Despite low ureide-N, which ranged from 962 ppm for the check to 1102 ppm for WDG under irrigation, and 906 ppm for TSP to 966 ppm for the check plot on dryland, grain protein was average (on dryland) to high (under irrigation). This suggests that N fixation may have picked up after a slow start, before leaves were sampled at the 5-trifoliolate stage, producing enough N for protein synthesis.

Fig 2. Effect of distillers grains on leaf ureide content of soybean at 5 trifoliolate



Partial funding for this project was provided by the North Dakota Soybean Council.

Effects of Nitrogen Top-dress at Tasseling on Corn

Jasper M. Teboh, Szilvia Yuja, Mike Ostlie, Kelly Cooper, and Heidi Eslinger

Objectives:

1. Verify whether nitrogen (N) fertilization at tasseling (VT) would improve corn yields in North Dakota.
2. Assess whether yield response to split N will differ between dryland and irrigated corn.
3. Determine if improved yields would justify the cost of late N application.

Methods

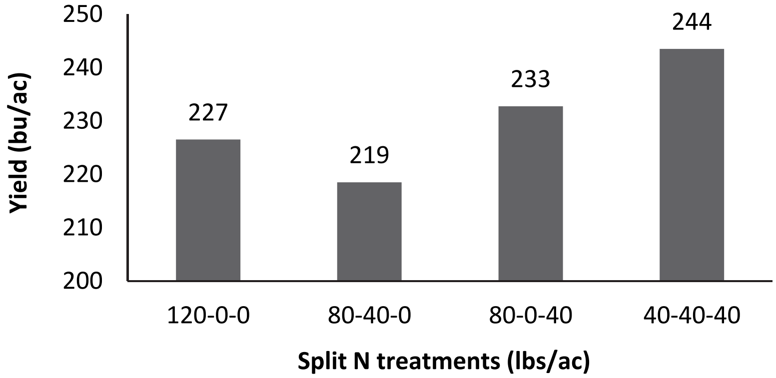
This trial was conducted at three sites: an irrigated and dryland site at Oakes, ND, and an irrigated site at Carrington, ND. Fourteen fertilizer treatments were applied. The first six treatments received only pre-plant N at 0, 40, 80, 120, 160, and 200 lbs N/ac. Eight other treatments were splits that either received 0, 40, or 80 lbs N as starter, plus 40 lbs N top-dress at either V8 or at tasseling (VT).

Results

- Yields responded positively to N at Oakes. Yields did not respond to N at Carrington; thus, the split N results were not important.
- Maximum yield at Oakes was 259 bushels at 200 lbs N under irrigation, and 195 bushels at 200 lbs N on dryland. Yields were not significantly different between 200 and 120 lbs N either under irrigation (227 bushels) or on dryland (186 bushels).

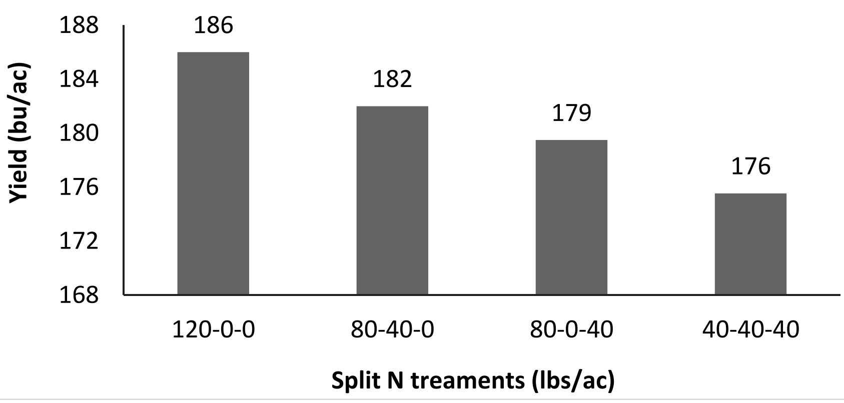
- Even though split application of N at a total rate of 120 lbs N did not result in statistical yield differences, the response to split N application was different between the irrigated and dryland sites.
- Under irrigation, split application of 120 lbs N produced higher yields than a single application at planting. The split N treatment that received 40 lbs as starter, 40 lbs at V8, and 40 lbs at VT (40-40-40) produced the best yield at 120 lbs N total (Fig 1). It is probable that when the fertilizer was split, it prevented some N loss due to leaching. The soil is well drained; frequent irrigation would have probably moved some of the N below the reach of the roots (leaching).

Fig 1. Corn yield response to N as a single or split application (V8 and VT) under irrigation at Oakes



- On dryland, application of all 120 lbs N at planting produced the highest yield when compared to split application treatments (Fig 2). Because the dryland field had received compost in fall the previous year, some of the N may have been tied up, and as a result, much N needed to be available early and throughout the growing season to overcome the effects of N tie-up.

Fig 2. Corn yield response to N as a single or split application (V8 and VT) on dryland, at Oakes



Conclusion

In environments of high rainfall or where irrigation is practiced, split application of N would be recommended to minimize N loss to leaching. Due to lack of significant yield differences between the single and split N applications it would have been uneconomical to have applied N later in the growing season. Nonetheless, split-application of N with most of the N applied at planting, and the rest around V6 to V8 remains a safe strategy to minimize N loss and enhance N fertilizer use efficiency in corn.

Partial funding for this project was provided by the North Dakota Corn Utilization Council.

Three Years of Data Addressing Rye Water Use Prior to Soybean

Szilvia Yuja and Mike Ostlie

Introduction

Rye use as a cover crop prior to soybeans is a new trend that is being adopted in North Dakota. Rye makes up for a lot of weaknesses that soybeans have in a cropping system. Some of the primary benefits include reducing soil erosion, increased weed control, additional grazing/forage material, utilization of excess soil moisture by rye, allowing soybean to be planted timely, and allowing soybeans to be planted further into former saline regions. In this system winter rye is planted the fall before soybeans. The rye is terminated prior to or shortly after soybean planting. Rye is best terminated with glyphosate.

Rye provides selective weed suppression, meaning that it is more effective against some species than others. Rye is particularly effective at suppressing kochia (up to 70% control in a heavy kochia infestation), and also does well against pigweed species, ragweed, and yellow foxtail. Rye has very little or no suppression of mint species (like lanceleaf sage) or most legumes. Thus, soybeans are not influenced by the presence of rye, except when moisture is limiting. How limiting is the rye water depletion to soybean yields and when should rye be terminated?

Project description

A trial was conducted from 2018 to 2020 to monitor soil moisture status in growing rye plots using a hydroprobe. To attribute soil moisture depletion to crops, rainfall data from the nearby NDAWN station and moisture data collected from bare ground plots scattered throughout the trial area were used. The data from the bare ground plots established a baseline soil moisture status where changes were affected only by climatic factors and soil physical properties. Because this study did not determine whether moisture lost from the bare ground plots would have been lost at the same rate from rye-planted plots, a range for the actual crop water use of rye is given. After careful calibration of the hydroprobe, data show how the growing rye affected soil moisture status throughout each growing season. In 2018, field capacity and permanent wilting point values were obtained for the trial area and were used to calculate the amount of plant-available water. In this trial, plots were planted to rye or soybean only and soybean was planted into plots where rye was grown. The main treatments in this trial were different termination dates of the rye cover crop. Termination dates started at the green-up of rye and followed on a weekly basis with the last treatment as rye that was allowed to mature in the soybean. Soil moisture data was taken weekly starting with rye green-up until rye harvest, then continued bi-weekly until soybean harvest.

This trial will likely run for one more season. This article will present the effects of rye on soil moisture changes up until maturity in comparison with the moisture status of pure soybean plots and bare ground areas. Soybean yields are presented from all rye termination treatments.

Soil moisture depletion by rye

Soil moisture depletion by rye varied greatly by year, but in each of the years the moisture level of the rye plots was significantly lower than those of the bare ground areas at rye physiological maturity (PM).

In 2018, at rye PM, the rye plots had 26% plant available water (PAW), compared to 89% in bare ground and 76% in the soybean-only plot. That year started out with a moisture deficit and only had around 55% PAW once the soil thawed (Fig. 1).

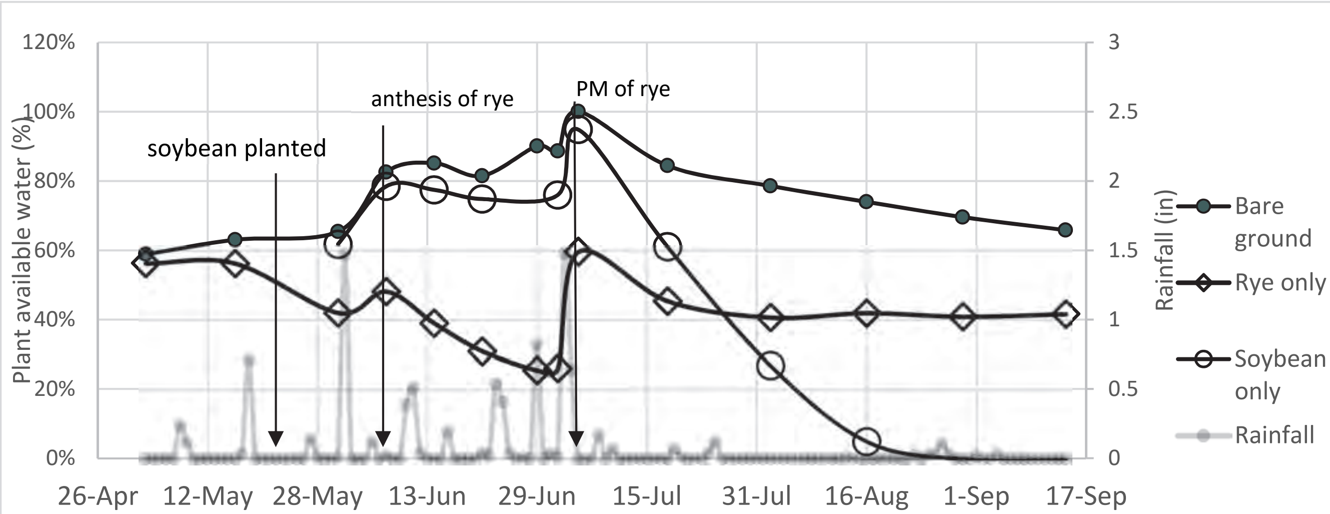


Figure 1. Plant available water status of soil under rye and soybean planted areas or bare ground, 2018.

In 2019, at rye PM, the rye plots held 27% PAW, while the bare ground had 78% and the soybean plots had 72%. The season started with 80% PAW (Fig. 2).

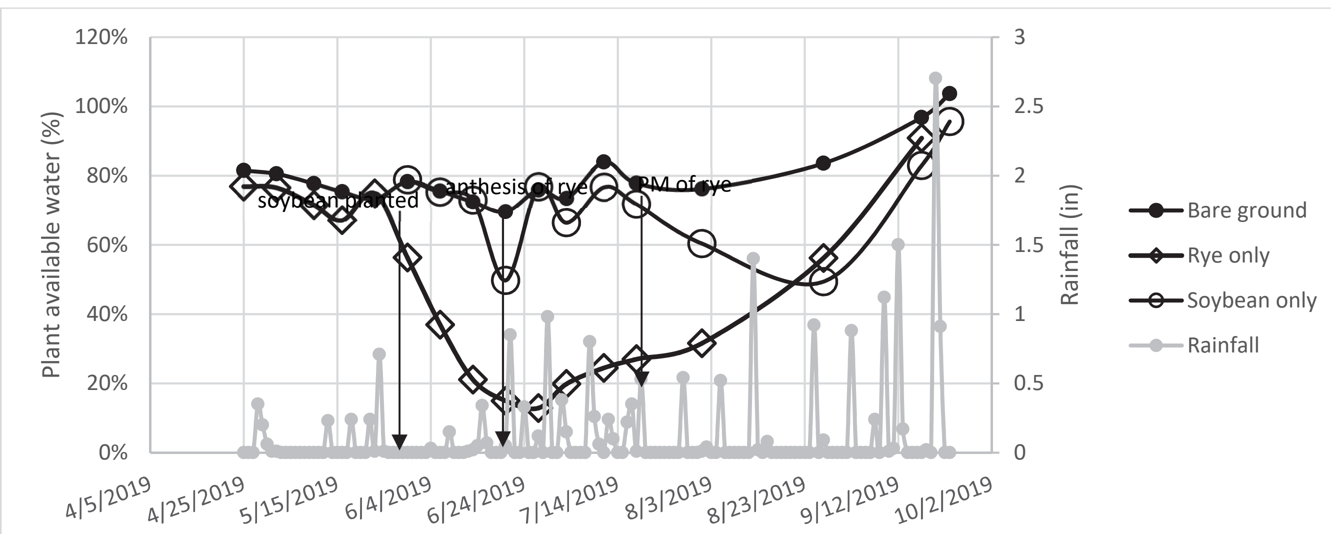


Figure 2. Plant available water status of soil under rye and soybean planted areas or bare ground, 2019.

In the spring of 2020, the soil took a long time to drain all the excess moisture that had accumulated during the previous fall and winter. That excess water drained slowly as the soil thawed while the rye was already growing on the surface. At rye PM, the rye plots held 78% PAW, while bare ground held 91% and the soybean plots held 86% (Fig. 3).

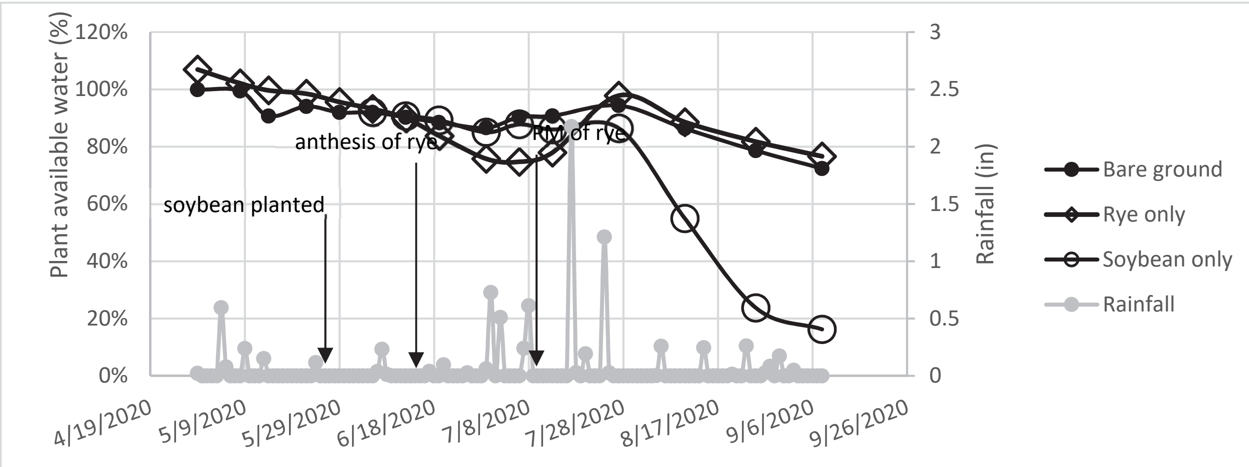


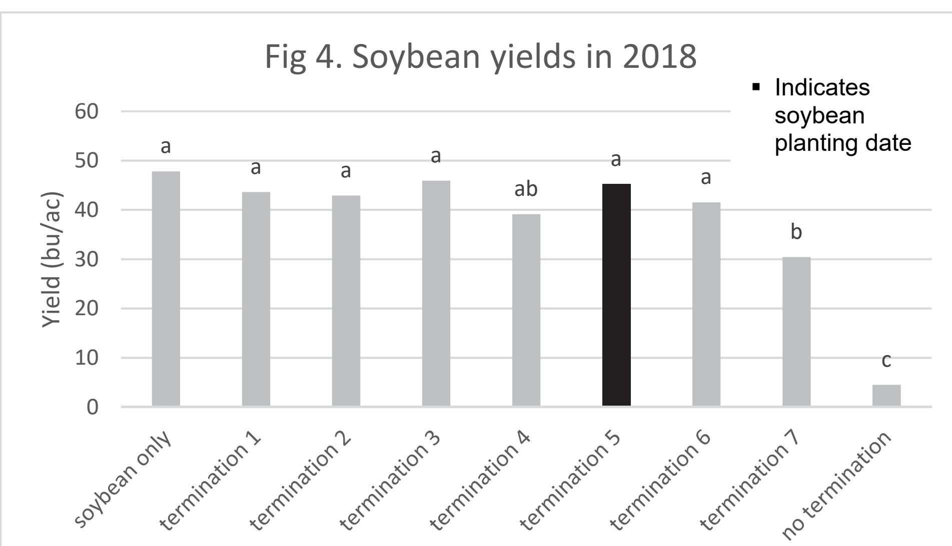
Figure 3. Plant available water status of soil under rye and soybean planted areas or bare ground, 2020.

Figures 1 through 3 show that ultimately the crop water use of rye is miniscule compared to that of the soybean crop. The reason that it's still a factor is that there is a period of time around anthesis when the rye aggressively uses water compared to the rest of its life cycle. During that time the soybean is still in its early stages of development and is vulnerable to microenvironment effects in the seed zone.

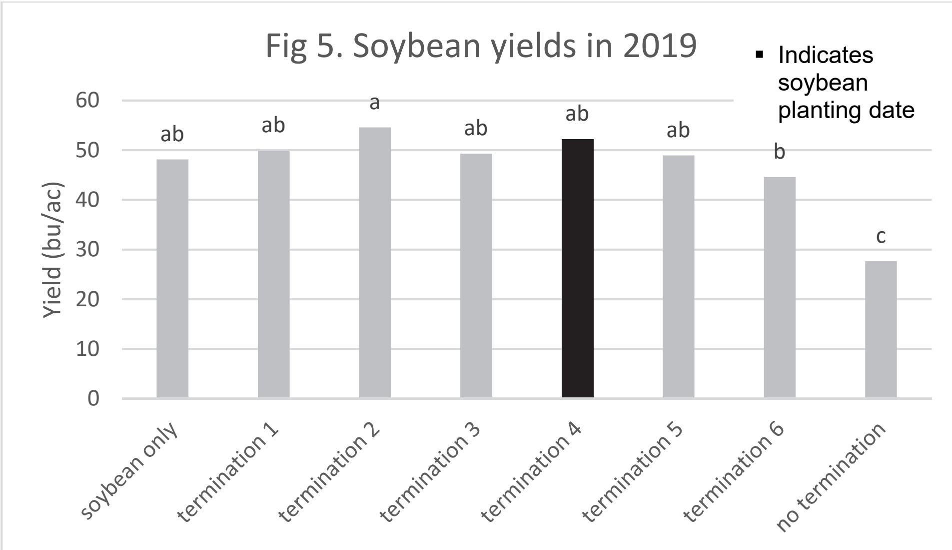
The effect of rye termination timing on soybean yields

The current recommendation is for rye cover crop termination at least 10 days before soybean planting. One of the objectives of this study and other similar studies at our location was to determine whether this recommendation should be updated.

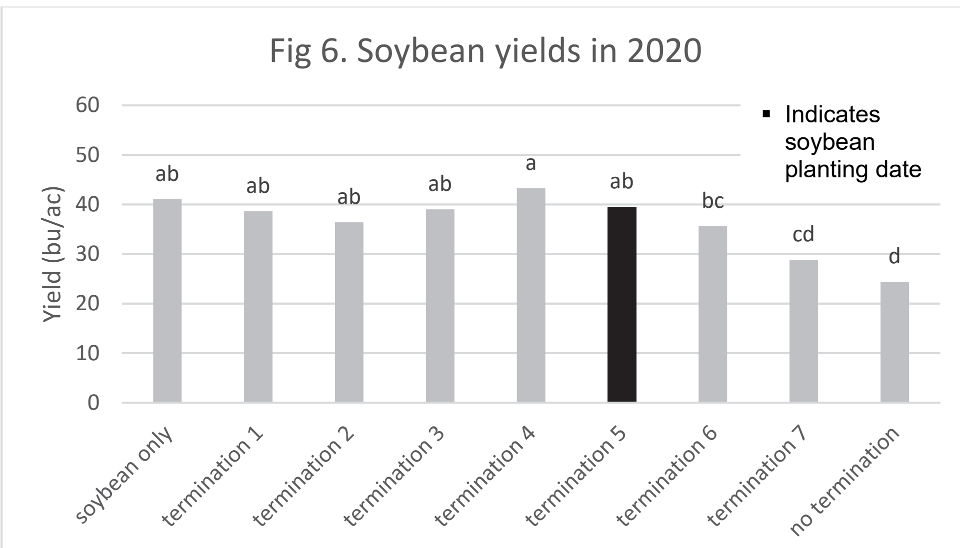
The good news is there was no significant yield difference between plots where rye was terminated at or before soybean planting in any of the trial years. On the other hand, in all three years there was a large reduction in soybean yield when the rye was allowed to reach maturity within the soybean, to the point of complete crop failure in 2018 (Fig 4-6). There was substantial yield loss even in 2020, when early-season soil moisture was abundant (Fig 3). Furthermore, in all three years, letting rye grow for two weeks after soybean planting, resulted in statistically significant yield reduction. Letting the rye grow for only 1 week also showed a decrease in yield for each of the years compared to terminating at or before planting, but this difference was not statistically significant (Fig 4-6).



[ab] different letters depict significant differences ($P < 0.05$).



ab different letters depict significant differences (P < 0.05).



ab different letters depict significant differences (P < 0.05).

So far the data from this trial show that at the climatic conditions typical in the Carrington, ND, area with 18.79 inches of average annual precipitation (US Climate Data, 2020), it is safe to allow rye to grow until soybean planting. However, letting it grow even a week beyond that can be risky, and letting it get to full maturity within the soybean can lead to crop failure in some years.

Soybean Yield Response to Planting Rates and Row Spacings in North Dakota

Greg Endres and Hans Kandel

North Dakota State University has been conducting field research on soybean planting rates and/or row spacing for decades. NDSU also has had the long-term recommendation for soybean plant stand of 150,000 plants per acre across row spacings. In 2020, data was compiled and evaluated from 37 NDSU trials conducted during 2008 through 2019 across the state. The objective was to provide a more precise guide for establishing soybean stands, using seed yield response data among regions in the state, based on the combination of planting rates and row spacings. This work resulted in publishing the NDSU Extension circular A1961 'Soybean response to planting rates and row spacings in North Dakota'. The following is a summary of the research data.

Individual factors

Across North Dakota and row spacings, the planting rate of about 170,000 pure live seeds (PLS) per acre optimized soybean seed yield. In eastern North Dakota trials, 8% of planted PLS per acre did not develop into viable soybean plants. Assuming 8% of PLS does not result in established plants across North Dakota, and using 170,000 PLS per acre, about 155,000 plants per acre would be expected to maximize yield. Within regions, optimum yield occurred with 180,000 and about 140,000 PLS per acre in eastern and western North Dakota, respectively.

Across North Dakota or by regions, narrow rows (less than 15 inches) consistently provided greatest soybean yield.

Factor combination (by regions)

- In eastern North Dakota, the combination of narrow rows (12 to 14 inches) and planting rates of about 170,000 PLS per acre provided optimum yield. If planting in wide rows (24 to 30 inches), planting rates to reach the optimum yield were about 190,000 PLS per acre.
- In western North Dakota, the combination of narrow rows (7 to 10 inches) and planting rates of about 150,000 PLS per acre provided optimum yield.

See table for estimated early season plant stands based on PLS per acre planting rates minus selected percentages of plants not established due to field loss.

Table. Estimated soybean plant stands after deductions of field loss based on planting rates and row spacings by North Dakota regions.

North Dakota region	Row spacing	PLS/acre planting rate	PLS/acre planting rate minus field loss deductions: 8%	10%	15%
			Estimated early season plants/acre		
East	narrow	170,000	156,500	153,000	144,500
East	wide	190,000	175,000	171,000	161,500
West	narrow	150,000	138,000	135,000	127,500

Note the above planting rates are for optimum yield. Economic yield must also be considered based on seed costs.

Partial funding for this project was provided by the North Dakota Soybean Council.

Jump Starting Mycorrhizal Colonization in Corn Following Non-host Crop – First Trial Year

Szilvia Yuja, Mike Ostlie, and Jasper M. Teboh

Introduction

Corn is dependent on root association by vesicular arbuscular mycorrhizal (VAM) fungi to maximize its nutrient uptake from the soil. These fungi take up residence within the root tissue and extend their hyphae out into the soil. Through their hyphae, the fungi supply the plant with additional minerals and water as if they were an extension of the plant's own root hair system. In return, the plant supplies the fungi with carbohydrates built through photosynthesis. The majority of plant species are known to form such associations and the level of dependence varies. However, some crops like canola and beets are not hosts to mycorrhizal fungi. The active population of these beneficial organisms decreases when there is not a host crop present for an extended period of time. It has been observed that corn performance may decrease if the soil is left fallow (Kabir et al 1999). Some producers also observed decreased yields after non-host crops like sugar beets (Field Facts 2005). Though the spores of the mycorrhizal fungi can be found even after a decade of the absence of a host crop, in such circumstances it takes longer for the association between host plant and fungi to form, during which time the crop may not produce its full yield potential. It is hypothesized that by growing a mycorrhizal winter cover crop after the non-host crop, the population of active VAM fungi can be increased by the time of corn planting. There are also commercially available mycorrhizal inoculants that can be applied with the seed. Currently, the cover crop option is by far the cheaper method, however the timeframe in which a cover crop can be grown after a cash crop is relatively short in our climate and may not be enough to substantially increase the population of mycorrhizal fungi. For this reason it's also worth looking at inoculants as a means of boosting yield, in the hope that they might be cheaper in the future. This research aims to answer questions regarding these two options.

Table1. Treatment structure

Trt no.	Previous Crop	Inoculant	Cover Crop	Trt Name
1	Soybean	no	no	soy
2	Soybean	yes	no	soy+I
3	Soybean	no	yes	soy+C
4	Soybean	yes	yes	Soy+I+C
5	Canola	no	no	canola
6	Canola	yes	no	canola+I
7	Canola	no	yes	canola+C
8	Canola	yes	yes	canola+I+C
9	Beet	no	no	Beet
10	Beet	yes	no	Beet+I
11	Beet	no	yes	Beet+C
12	Beet	yes	yes	Beet+I+C

Trial description

In this study corn was planted after canola or sugarbeet, which are both non-mycorrhizal crops that are commonly grown in North Dakota. As a comparison, corn was planted after soybeans as well. Soybean has a strong association with VAM fungi. For each of these crop histories, there were four treatments meant to impact the corn roots' mycorrhizal associations: 1) a rye cover crop planted in the fall after harvest of the previous crop and terminated two weeks prior to corn planting 2.) a mycorrhizal inoculant planted with the seed, 3.) a combination of the rye cover crop and the inoculant 4.) no mycorrhizal treatment as a control. The complete treatment structure is displayed in Table 1. At the 6-leaf stage corn roots were collected from each plot for mycorrhizal quantification using the grid intersect method

(Giovannetti and Mosse 1980). Above-ground plants were also collected at this time for tissue nutrient analysis. Plant heights and NDVI readings were taken at the 6-leaf stage as well.

Results

Data collected at the 6-leaf stage of corn showed that corn planted after soybeans was taller, more vigorous and contained more phosphorus, zinc and copper in its tissue than corn grown after the two non-mycorrhizal crops (Fig. 1-4). The roots of those plants were also colonized by VAM fungi at a higher rate (Fig. 5). There was a strong correlation between the level of mycorrhizal root colonization and phosphorous content in the above-ground biomass of corn at this stage (Fig. 6). It was expected that the greener and more robust plants at this stage would translate into increases in yield as well. However, this was not the case (Fig. 7). In fact, the yields from the soybean plots were slightly lower than those from the other plots, albeit not significantly. Within each previous crop treatment, the ones with the rye cover crop and no-inoculant had the highest yield numerically, but the difference was very small. Grain phosphorus content also did not show a significant response to treatments, but numerically the P content of grain from the soybean plots was higher for each of the respective mycorrhizal management treatments than for the other two crops. There was no obvious effect of the commercial inoculant on either mid-season growth or yield.

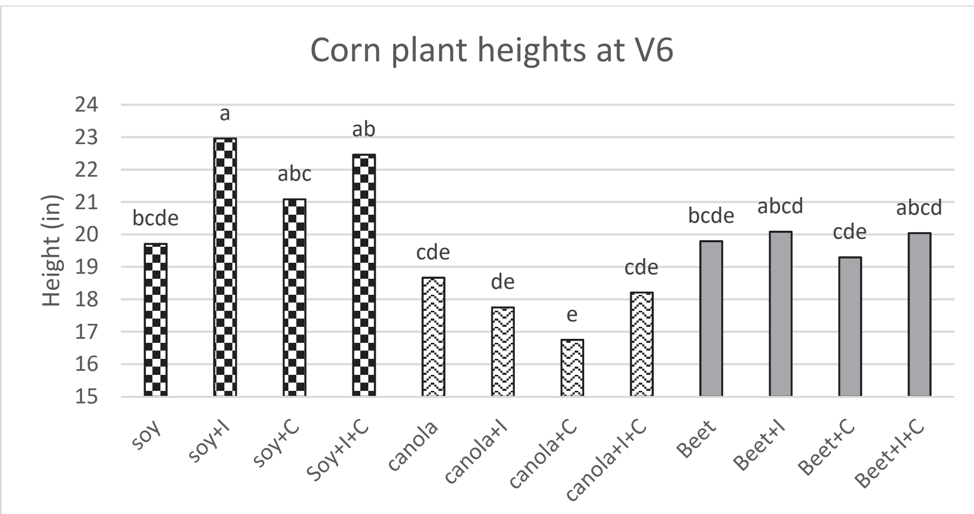


Figure 1. Corn plant heights taken at the 6-leaf stage.

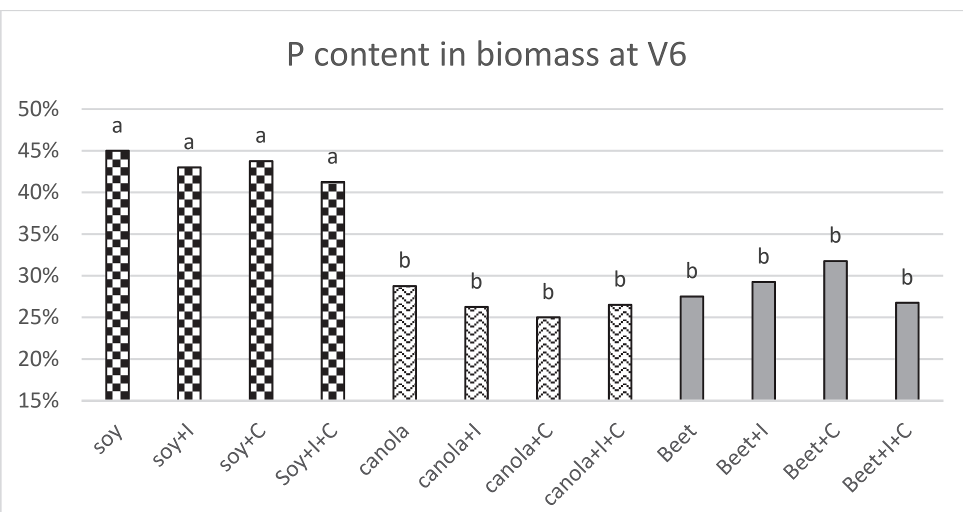


Figure 2. Corn biomass phosphorus content at the 6-leaf stage.

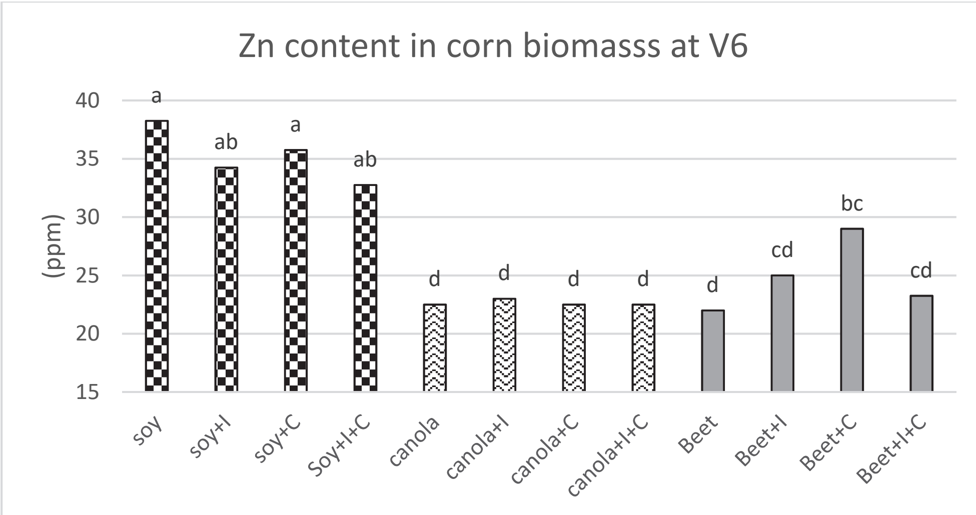


Figure 3. Corn biomass zinc content at the 6-leaf stage.

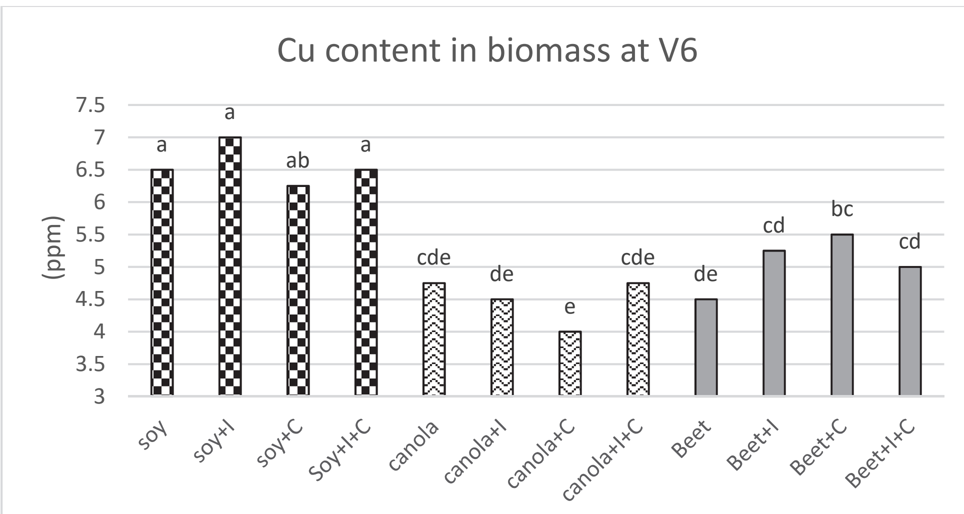


Figure 4. Corn biomass copper content at the 6-leaf stage.

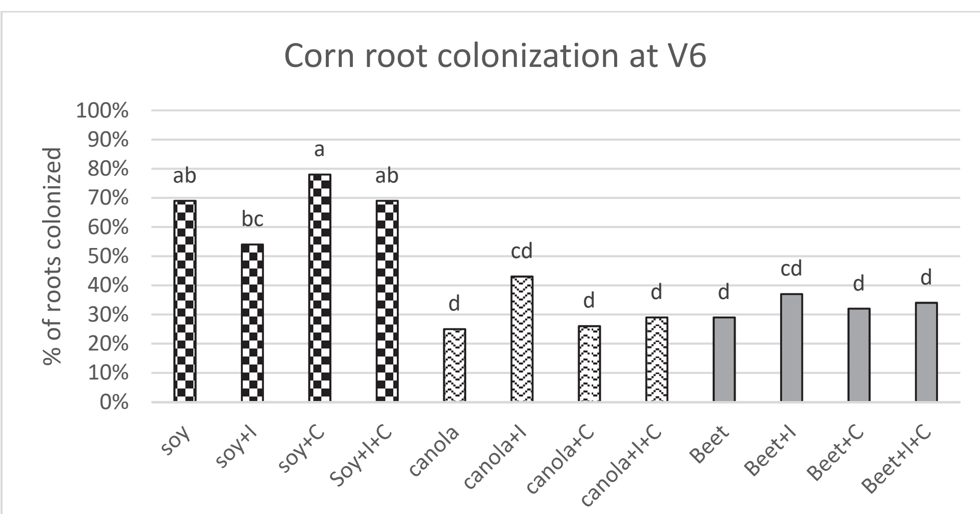


Figure 5. Rate of corn root colonization by VAM fungi at the 6-leaf stage of corn.

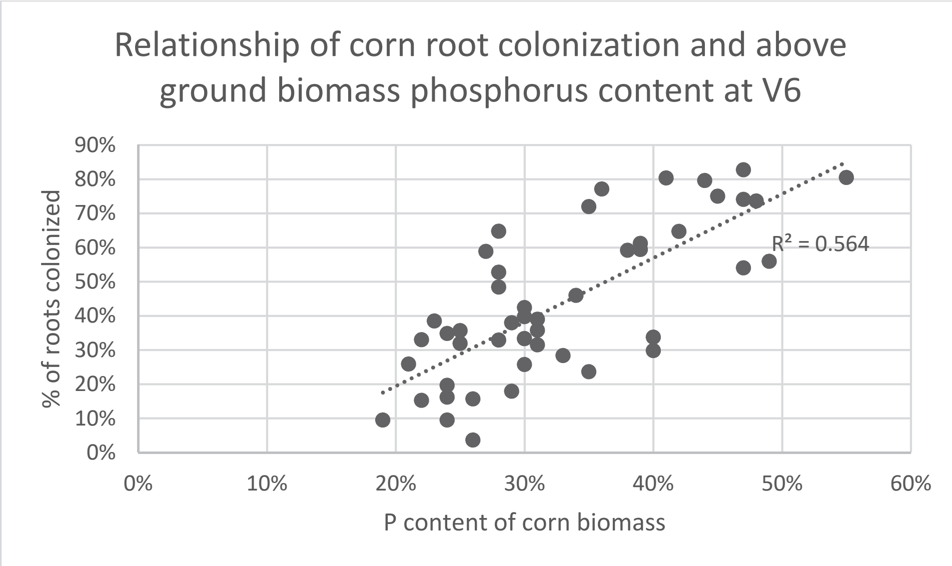


Figure 6. Relationship of the observed VAM fungi colonization of corn roots to the phosphorus content of the above-ground biomass at the 6-leaf stage of corn.

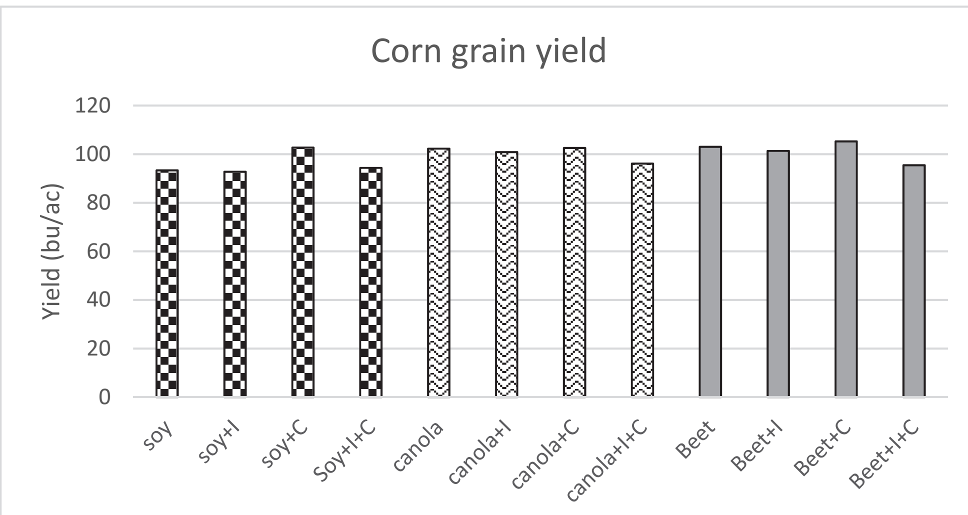


Figure 7. Corn grain yield.

Mycorrhizal symbiosis is a two-way street between the fungi and the plants. The plant has to support the fungi in exchange for the extra nutrients they provide. Corn roots from all the treatments and all the plots were colonized. The root colonization difference was not in the presence or absence of the symbiosis, but in the magnitude. It is possible that the level of colonization to maximize corn yield was achieved by even the least colonized corn plants and there was no added yield benefit to a higher density of VAM fungi in the roots, despite the boost in growth they gave the plants early in the season.

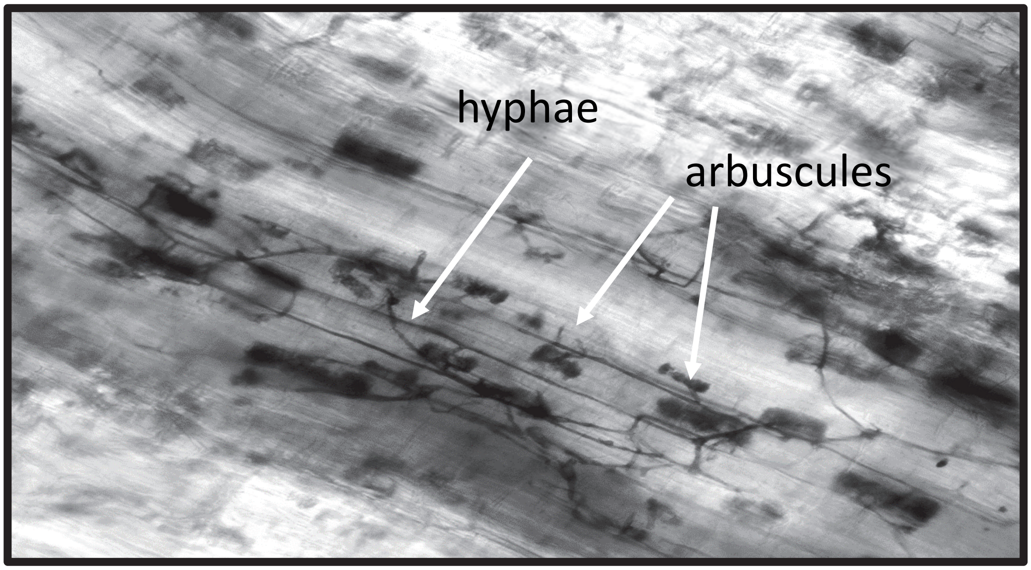


Figure 8. Ink staining reveals mycorrhizal structures in corn root colonized by VAM fungi.

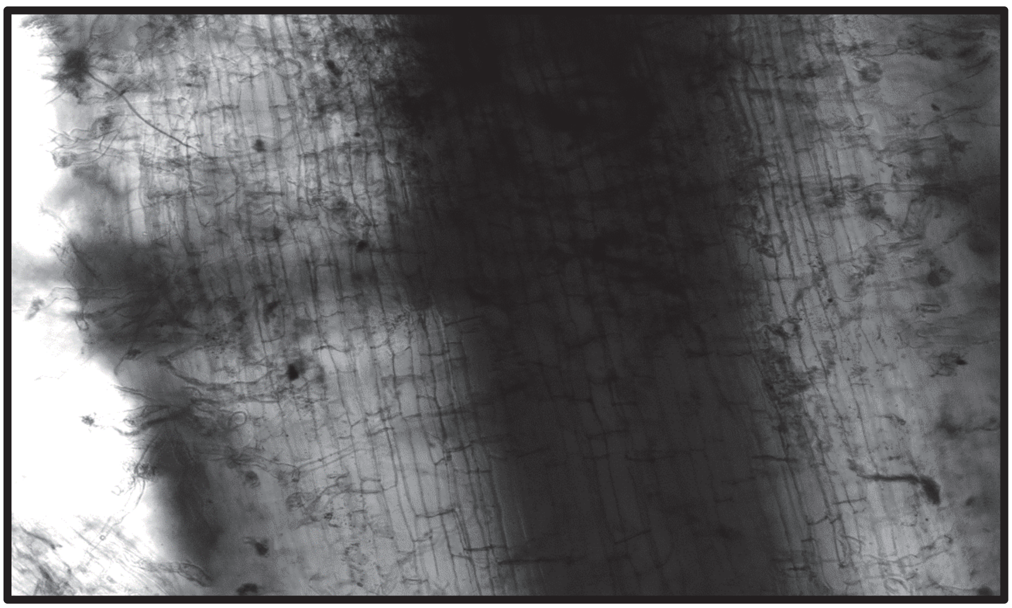


Figure 9. Ink-stained corn root showing no colonization.

This was the first year of this trial and the results are not conclusive. It is likely that the effects of mycorrhizal colonization on corn vary with environmental conditions related to soil and climatic factors. For this reason, the trial will be repeated in the 2021 growing season.

References

Kabir Z, O'Halloran I.P, Hamel C.1999. Combined effects of soil disturbance and fallowing on plant and fungal components of mycorrhizal corn (Zea mays L.). Soil Biology and Biochemistry, Vol.31, No. 2, 307-314

Field Facts 2005: Managing corn grown after sugar beets. Vol.5, No.3, 1-2; https://www.crystalsugar.com/media/19686/ffacts.pdf

Giovannetti M, Mosse B. 1980. An evaluation of techniques for measuring vesicular arbuscular mycorrhizal infection in roots. New Phytol. 1980;84:489–500.

Partial funding for this project was provided by the North Dakota Corn Utilization Council.

Organic Evaluation and Increase of a Determinate Buckwheat Variety

Steve Zwinger, Steve Schaubert, Owen Trangsrud, Theresa Podoll, and Verna Kragnes

Buckwheat is a late planted, short-season, broadleaf crop that is adapted to the North Dakota environment. Buckwheat also has a positive impact on a number of ecosystem services including weed suppression, nutrient addition, erosion control, and tilth improvement. Buckwheat, with its long flowering periods and abundant flowers, provides habitat for pollinators. The majority of buckwheat varieties are indeterminate, meaning they will continue to flower and set seed throughout the season until the crop is terminated. This report will focus on the determinate variety, Devyatka, which has an earlier, shorter flowering period and earlier maturity.

In the summer of 2012, the Northern Plains Sustainable Agriculture Society Farm Breeding Club (FBC) members met with agricultural representatives from Ukraine who came to North Dakota to study crop management and to attend trade shows. They provided the FBC with one kilogram each of two of their favorite buckwheat varieties, which are large seeded and determinate in their growth. Results from the initial project "New Buckwheat varieties for Greater Sustainability" can be found in the North Central SARE final report, https://projects.sare.org/project-reports/fnc13-924/.

Only small amounts of seed remained after the initial work was completed in 2014. In 2019, the CREC, in collaboration with NPSAS, increased the remaining seed on the Research Center's certified organic plot ground. The increase was planted May 31, swathed August 19, harvested August 29 and resulted in 99.6 pounds (1179 lbs/ac) of clean seed to be furthered increased in 2020 along with evaluations to compare the line to currently planted indeterminate varieties.

An organic variety trial was planted at the CREC on May 25 on ground that was previously cover crop. Six currently available buckwheat varieties with the indeterminate growth habit were planted to compare their performance to Devyatka. Conditions were good at seeding with fast uniform emergence that aided in weed control. Devyatka was earlier to flower and mature, it was swathed on August 20 and harvested on September 1. The other varieties were swathed on August 27 and harvested on September 4. Data gathered on flowering (Table 1), illustrate that most of the varieties started to flower 35 to 36 days after planting with Devyatka starting to flower in 30 days. Data also show that this variety is shorter when compared to the other varieties. This reduced height did result in less plant lodging compared to other varieties. Test weight was significantly lower for Devyatka compared to other varieties. Growing conditions and seed yields in the 2020 organic variety trial were excellent, the highest ever recorded in the organic tests at the CREC. Seed yield of Devyatka was good, 1459 lbs/ac, although it was significantly lower than all other varieties tested, with a trial mean of 2066 lbs/ac. Koto was the highest yielding entry at 2362 lbs/ac. Koto also had one of the highest test weights in the trial.

Organic buckwheat variety trial, August 27.

Table 1. Organic Buckwheat Variety Trial, 2020

Variety	Days to Bloom	Plant Height	Plant Lodge	Test Weight	Seed Yield
		inch	0-9	lb/bu	lb/ac
Springfield	36.0	46.7	1.3	47.7	2211
Horizon	35.8	48.6	1.3	47.8	2291
Koma	35.8	42.8	1.8	49.3	1952
Koto	35.0	46.0	1.0	49.3	2362
Manor	34.8	49.2	1.5	48.0	1907
Devyatka	30.0	32.0	0.0	44.9	1459
Green Testa	35.8	46.0	2.0	48.2	1970
Mean	34.7	45.1	1.3	47.8	2066
C.V. (%)	1.5	6.1	60.0	2.2	10.5
LSD 0.05	0.7	4.1	1.2	1.6	320

Seed was increased this year at two locations to insure against severe weather conditions. The main increase was a 1.8 acre planting managed by Owen Trangsrud on a certified organic farm in north central Ransom County, near Enderlin, ND. Plant heights were greater at this location at 49 inches tall with some plants reaching heights of 64 inches. Plant lodging occurred near the end of the growing season due to the tall plant height. The crop was swathed on September 2 and harvested September 12. The field yielded 3740 lbs. of seed or 2077 lbs/ac. This site received more rainfall than the CREC site with 15.76” compared to 9.04” at the CREC. A small backup increase was planted at the CREC that yielded 71 lbs. clean seed or 1085 lbs/ac. Yield at this site was reduced due to deer predation.

The 2020 growing season provided conditions that resulted in higher buckwheat yields. This environment appears to favor the traditional indeterminate varieties. Plans are to continue testing this variety to determine its performance across a range of growing season environments.

Partial funding for this project was provided by Northern Plains Sustainable Agriculture Society through the Organic Crop Improvement Association R&E Micro Grant program.

Enhanced Efficiency Nitrogen Fertilizer Impact on Soil Available N, Corn and Wheat

Jasper M. Teboh, Szilvia Yuja, Ihor Tarnavchyk, Deep Kalita, and Mike Ostlie

Introduction

Numerous nitrogen (N) fertilizers are advertised and sold to farmers annually as enhanced efficiency N fertilizers (EENFs), protecting N from loss by controlling or delaying N release from the fertilizer. Only a few of them are effective, and because EENFs cost a lot more than conventional fertilizers, the amount of N prevented from loss compared to a conventional N fertilizer must be high enough to enhance grain yield and quality to justify the cost. Field trials were conducted with newly developed and established EENFs in 2020 at Carrington with the following objectives.

Objectives

1. Assess the effectiveness of eNhance™ as a relatively stable liquid N fertilizer that minimizes N loss.
2. Assess crop response to three newly-developed polymer-coated biodegradable EENF formulations.

3. Determine if ANVOL is an effective EENF by assessing its impact on wheat grain yield and protein.

Methods

Objective 1: Fertilizer treatments were applied on bare soil surface at the 150 lb N rate with eNhance a UAN based liquid fertilizer (AgroLiquid™), UAN (28%), and a control 0 lbs N/ac. Soil samples were taken periodically from 0-6, and 6 -12 inches and analyzed for total available N (NO_3-N + NH_4-N).

Objective 2: Wheat and corn response to four polymer-coated urea fertilizer formulations, RVix1, RVix2, RVix3, RVix4 (Renuvix, LLC) was compared to that of urea, ESN® and Agrotain® at different N rates.

Objective 3: Surface application of N as plain urea, Agrotain®, and ANVOL® at 60, 90, 120, and 160 lbs N/ac.

Results

Objective 1: Starting at week one after application (wk1), soil available N was consistently greater for all plots that received eNhance fertilizer compared to conventional UAN and the control at 0-6 inches (Fig. 1A), and 6 -12 inches (Fig. 1B). This suggests that the N in eNhance was protected from loss to the environment.

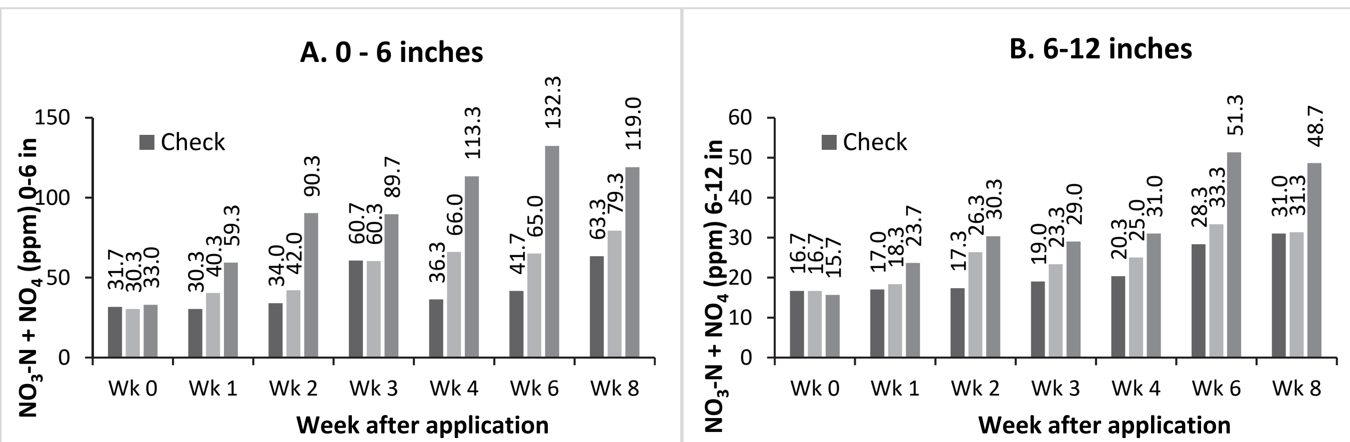


Figure 1. Available soil N at 0-6 (A) and 6-12 inches (B) over time after application of UAN and eNhance.

Objective 2: Results from Renuvix polymer-coated urea showed that corn and wheat yield and grain protein were not significantly different between EENFs and urea. However, the control yield for corn and wheat was significantly less than corn yields at RVix1, RVix2, and SuperU, and wheat yields from all EENF treatments. Meanwhile, yields were not different between control and urea (at the same N rate as EENFs) (Fig. 2).

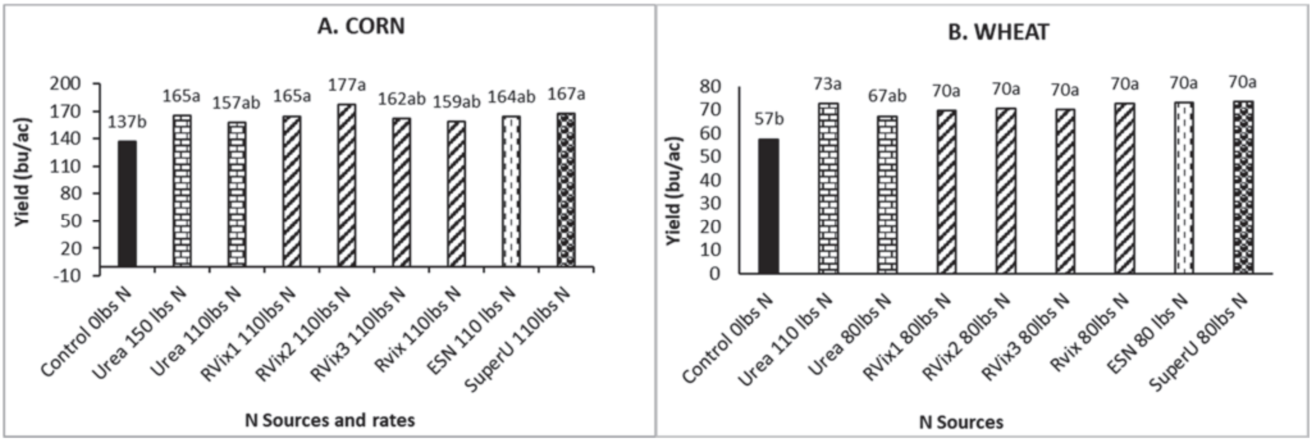


Figure 2. Effects of Renuvix polymer-coated urea formulations on corn (A) and wheat (B) yield.
[ab] different letters depict significant differences ($P < 0.05$).

Objective 3: Due to an interaction effect of N sources and rates on grain protein, ANVOL and Agrotain significantly improved grain protein (Fig. 3) at 60 lbs N compared to urea on dryland. It was evident that, at 90 lbs N or above, yields were not significantly different among N sources. Treatments did not impact yields, and grain protein under irrigation. In 2019, under irrigation, ANVOL significantly enhanced grain protein compared to urea in the order ANVOL[a] > Agrotain[ab] > Urea[b] (identical letters in superscript are not different).

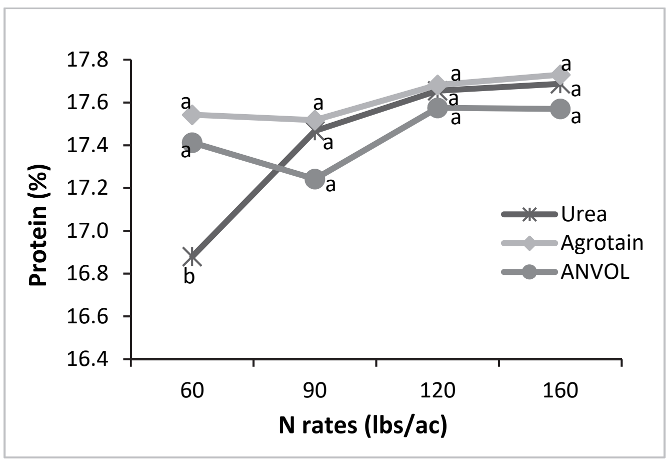


Figure 3: Grain protein of wheat in response to N sources and rates.
(% grain protein with identical letters on the graphs are not significantly different from each other).

Conclusion

ANVOL, eNhance, and Renuvix showed prospects of N stabilizing effects in soil. Due to the high cost of EENFs and inconsistent and often marginal impact on yields, they should only be used in situations where plain urea would result in significant N losses such as in the fall, on wet soils, or as surface top-dress N application.

Partial funding for these projects was provided by AgroLiquid, Renuvix, LLC, and by Koch Agronomic Services

Influence of Oat Variety and Harvest Timing on Alfalfa Establishment in an Organic System

Steve Zwinger, Steve Schaubert, Tom Rabaey, and Paul Richter

Companion crops are commonly used for establishment of alfalfa in an organic crop production system. Small grains, including oats, are used as companion crops and are recommended for establishment of organic alfalfa.

A three-year field trial was established at the CREC in 2018 to evaluate organic alfalfa establishment methods using an oat companion crop and harvest timing of the companion crop. Treatments included four oat varieties that differed in maturity, plant height, and yield potential. Harvest timings were represented by oats harvested as either a forage or grain crop. Among the oat varieties was Sumo, an early, short variety developed at SDSU for use in organic production for companion cropping with alfalfa. The other three varieties are releases from the NDSU oat breeding program including Souris, a shorter variety that is competitive with early row closure; Rockford, a high yielding grain variety that is upright and tall with good straw strength; and Newberg, a tall, earlier, high yielding grain variety. The alfalfa variety used for these trials was Charger.

The oat-alfalfa companion crops were sown on May 3, 2018 on ground previously cropped to field pea. Oat seeding rate was 600,000 PLS/ac while alfalfa was seeded at 15 lbs/ac PLS. Both crops were sown at the same time with a plot drill in 7-inch rows at a 1-inch depth. Stand counts were taken 20 days after planting to determine established densities. Stands did not differ significantly among treatments with established stands for oats and alfalfa averaging 14 and 13 plants per square foot respectively. Days to heading for Souris, Rockford and Newberg averaged 55-56 days after planting while Sumo was 10 days earlier to heading.

The timing for forage harvest was based on when the varieties reached the early milk stage with Sumo harvested on June 28 and the other varieties July 5 (Table 1). Forage yield of the early variety Sumo was significantly lower than the other three varieties. The highest yield of 2.33 DM ton/acre was achieved with Newberg which was also the tallest variety.

Table 1. Performance of oat varieties harvested as forage during alfalfa establishment in 2018.

Variety	Harvest Date	Oat Stand	Alfalfa Stand	Days to Heading	Plant Height	Harvest Moisture	Forage DM Yield
		plts ft^{-2}	plts ft^{-2}		inch	%	ton/ac
Sumo	28-Jun	14.4	12.0	45.8	31.5	72.3	1.84
Souris	5-Jul	14.6	13.4	55.0	33.0	73.6	2.20
Rockford	5-Jul	13.5	13.2	55.3	35.7	75.5	2.09
Newberg	5-Jul	12.5	11.6	55.3	38.8	72.5	2.33
Mean		13.7	12.6	52.8	34.7	73.5	2.11
C.V. (%)		13.9	22.2	1.2	3.1	2.9	7.0
LSD 0.05		NS	NS	1.0	1.7	NS	0.24

Harvest timing for the oat grain treatments occurred on August 23 with all varieties straight cut as high as possible. Agronomic traits including oat grain yield and quality are reported in table 2. Newberg and Rockford were the highest yielding varieties with Rockford having the highest test weight and Sumo the highest grain protein content. The height of the alfalfa plants in the understory were similar across all varieties. No plant lodging occurred among the varieties in either harvest timing.

Table 2. Performance of oat varieties harvested as a grain crop during alfalfa establishment in 2018.

Variety	Days to Heading	Oat Height	Alfalfa Height	Grain Protein	Test Weight	Grain Yield
		inch	inch	%	lb/bu	bu/ac
Sumo	46.5	29.2	16.6	11.6	35.1	48.1
Souris	55.8	31.5	16.7	9.0	33.8	63.3
Rockford	56.0	36.6	16.3	8.9	36.4	71.9
Newberg	55.0	38.2	16.7	9.1	33.8	76.9
Mean	53.3	33.9	16.6	9.6	34.8	65.1
C.V. (%)	0.8	5.6	11.7	2.4	1.5	7.4
LSD 0.05	0.7	3.0	NS	0.4	0.8	7.7

Alfalfa was harvested in 2019 and 2020 to determine if harvest timing management in the establishment year had an impact on subsequent alfalfa performance. Two harvest cuttings were taken in 2019 and three in 2020. Data gathered from each harvest included plant height, harvest moisture and forage yield. Alfalfa plant height and harvest moisture was similar among treatments across harvest timings in both years with limited variations (data not shown). Mean forage yields in 2019 were 3.55 and 3.40 DM ton/ac for the forage and grain management treatments respectively (Table 3). Mean forage yields in 2020 were higher at 5.45 DM ton/ac for each management treatment (Table 4).

Table 3. 2019 alfalfa forage yields compared across oat harvest management treatments.

	** Oat harvested for Forage **			** Oat harvested for Grain **		
Variety	June 18	July 23	Total Yield	June 18	July 23	Total Yield
	----- tons DM/acre -----			----- tons DM/acre -----		
Sumo	1.68	1.87	3.55	1.65	1.81	3.46
Souris	1.73	1.73	3.46	1.54	1.83	3.37
Rockford	1.73	1.90	3.64	1.65	1.82	3.47
Newberg	1.69	1.88	3.57	1.64	1.64	3.28
Mean	1.70	1.85	3.55	1.62	1.77	3.40
C.V. (%)	11.6	3.2	5.3	13.0	7.0	8.6
LSD 0.05	NS	0.10	NS	NS	NS	NS

Third cutting organic alfalfa on September 1.

Table 4. 2020 alfalfa forage yields compared across oat harvest management treatments.

Variety	** Oat harvested for Forage **				** Oat harvested for Grain **			
	June 17	July 23	Sept. 2	Total Yield	June 17	July 23	Sept. 2	Total Yield
	----- tons DM/acre -----				----- tons DM/acre -----			
Sumo	1.95	1.94	1.54	5.43	2.18	1.86	1.42	5.46
Souris	1.96	1.86	1.52	5.34	2.12	1.97	1.45	5.55
Rockford	2.17	1.89	1.51	5.58	2.22	1.85	1.43	5.51
Newberg	2.08	1.83	1.57	5.47	2.08	1.90	1.30	5.29
Mean	2.04	1.88	1.53	5.45	2.15	1.90	1.40	5.45
C.V. (%)	6.1	7.8	6.7	4.1	5.9	4.1	9.3	3.3
LSD 0.05	0.20	NS	NS	NS	NS	NS	NS	NS

Data gathered after two years of alfalfa harvest following establishment shows that neither oat variety choice nor companion crop harvest management had any effect on alfalfa yield. Results gathered suggest that the choice of oat variety is more important to either maximize return in grain or forage yield during the year of alfalfa establishment.

Field Pea and Canola Intercropping Production Management

Mike Ostlie, Justin Jacobs, Steve Zwinger, and Ezra Aberle

Intercropping is a revamped old-fashioned concept. The premise is that two (or more) crops are planted and harvested together. Due to the complexity of growing two crops simultaneously, there have been many historical barriers to adopting this practice. These barriers come in the form of mechanical limitations, pest management options, post-harvest management, insurance or program restrictions, and identifying appropriate species and varieties to pair. These barriers are the least substantive they have ever been due to mechanization. The benefits of intercropping vary, but often include better resource utilization (fertility/water), better erosion management through mixed residue types, a more competitive crop for weed management, and more productivity per acre. It is accepted that yields of either crop will be reduced when intercropping, compared to monocropping. The benefit is that the total yield of both crops will surpass what a single crop can produce. This is measured by the land-equivalency ratio (LER). LER is the term used to describe performance of each component of a cropping system compared to growing a single crop. Each component will be comparatively less than a monocrop, but when the components are added together, a successful intercropping pair will equal greater than either monocrop (>1).

From 2018 to 2020, a field pea and canola intercropping study was conducted with some shared treatments across years. The goal of the study was primarily to test the different seeding ratios of the two crops to establish baseline agronomic strategies for intercropping. The seeding ratios were based off standard seeding rates for each crop and were reduced to a set percentage of that total. For field pea the standard seeding rate was 330,000 PLS/ac and 5 lbs/ac for canola. Field pea were divided to 66, 50, or 33% of that standard, or 220K, 165K, or 110K PLS/ac. For canola those same ratios equaled 3.3, 2.5, 1.65 lb/ac. The goal was to find the ratio that produced the highest total yield per acre. In 2019 and 2020, fertility was added as a component so that each ratio was fertilized with 0, 60, or 120 lbs of extra nitrogen. Potassium sulfate was added to these trials to ensure adequate sulfur nutrition for the canola. Each treatment was replicated four times for each year of the study within a split-plot randomized complete block design. Following production analysis, a price of $9 per acre for field peas and $520/ton for canola was used to calculate the cost/benefit of different intercropping combinations in terms of gross return.

The good and bad news is that the results varied by year. In 2018 and 2019 canola production was very good and drove the success of the treatments. In 2020, the canola was very poor which caused the field peas to drive the success of the system. Overall, field pea yields were stable across years, with canola yield varying widely year to year. In each year of the study, there were substantial yield gains through intercropping (Table 1). In general terms, this system functioned best when at least one of the seeding rates remained at 66% of the standard rate. Field pea yields were reduced to a greater degree than canola yields as a result of intercropping. With canola, yield loss from intercropping usually ranged from 10-20% when seeding ratios were 50% or greater. With field peas, yield losses were often 40% or greater, even in the most favorable ratios. The exception was in 2020, when canola performance was poor, the field pea yield loss was much lower when the seeding percent was at least double that of canola. LER values indicate the best performing treatments were when seeding ratios were 66/66% of standard, followed by 33% canola and 66% field pea. The treatment of 33% canola and 66% field pea performed poorly in 2018 and 2019, but did considerably better in 2020. Lower fertility treatment generally performed poorer with intercropping. The middle and higher fertility treatments did not differentiate.

Table 1. Land Equivilency Ratio (LER) comparing monocropping and intercropping field pea and canola at different seeding ratios and nitrogen rates. Values greater than 1 indicate higher productivity than a monocrop per area, and values less than one indicate a reduction in land utilization.

		2020			2019			2018		
Canola Seeding Rate	Nitrogen Rate	Field Pea	Canola	Combined	Field Pea	Canola	Combined	Field Pea	Canola	Combined
% of standard rate	lb/ac	LER	LER	LER	LER	LER	LER	LER	LER	LER
0/100 (FP mono)		1	.	1	1	.	1			
100/0 (canola mono)		.	1	1	.	1	1			
66/66		0.67	0.64	1.31	0.39	0.87	1.26			
33/66	120	0.81	0.40	1.21	0.57	0.79	1.36			
50/50		0.62	0.50	1.11	0.37	0.85	1.22			
66/33		0.43	0.88	1.31	0.22	0.93	1.15			
33/100		0.90	0.28	1.18						
0/100 (FP mono)		1	.	1	1	.	1	1	.	1
100/0 (canola mono)		.	1	1	.	1	1	.	1	1
66/66		0.67	0.69	1.37	0.25	0.98	1.23	0.50	0.65	1.15
33/66	60	0.72	0.47	1.20	0.44	0.72	1.16	0.63	0.68	1.28
50/50		0.75	0.61	1.36	0.32	0.85	1.17	0.58	0.55	1.13
66/33		0.49	0.78	1.27	0.21	0.89	1.10	0.38	0.65	1.03
33/100		0.89	0.30	1.19						
0/100 (FP mono)		1	.	1	1	.	1			
100/0 (canola mono)		.	1	1	.	1	1			
66/66		0.50	0.56	1.06	0.35	0.79	1.14			
33/66	0	0.65	0.38	1.03	0.48	0.68	1.16			
50/50		0.62	0.53	1.14	0.27	0.83	1.10			
66/33		0.44	0.72	1.16	0.19	0.85	1.04			
33/100		0.83	0.37	1.19						
Mean yield (bu/ac or lb/ac)		56.4	1002		53.6	3420		46.6	2107	
LSD (0.05)		0.20	0.17	0.23	0.13	0.13	0.14	0.23	0.3	0.17

The problem with using LER as the primary indicator of success is that it takes raw yield out of the equation. This can make a poor crop seem like it is adding a lot of value to the system. Since the starting monocrop yield is low, the intercropping yield reduction is often also less since it is based on percent of the monocrop yield. This is the case in the dataset in Table 1. In 2020, when canola yields were not good, it disproportionately made the system appear more successful than it actually was. As a result, it is best to take this one step further and look at the economics behind the yields.

The economics of intercropping can be confusing. While looking at gross return on its own can be helpful, Table 2 is a decision support tool that compares monocropping to the different intercropping treatments based on dollar gains or losses. The best way to read this table is to view the monocrop as the baseline (within each nitrogen rate) and each treatment below it is the gain or loss of adding a second crop. For instance, in the poor performing 2020 canola, it was always advantageous to add field peas. The opposite is true for 2019 when it was always advantageous (to a large degree) to add canola as an intercrop compared to field peas alone. The conundrum is whether it is better to add a second crop to a good performing monocrop. In 2020, many treatments lost money when adding canola to field peas. The higher the percent of canola, the greater the profit loss. In 2020, the decision to add canola could either lose up to $130/ac or gain up to $70/ac. The best decisions resided in the medium fertility treatments in 2020. In 2019, where canola yields were exceptional, strategies that benefited canola naturally produced the best returns (high fertility, high canola seeding rates). Adding field peas to 2019 canola was sometimes a detriment, but was always a positive with high fertility treatments. With low fertility (0 nitrogen) gross returns were the poorest, with the largest negative values and the smallest positive values for most combinations.

Table 2. Change in gross return based on crop seeding ratios and nitrogen rates over three years. Returns are a comparison of monocropping field pea or canola versus any other treatment within a nitrogen rate.

		2020		2019		2018	
Canola Seeding Rate	Nitrogen Rate	Field Pea	Canola	Field Pea	Canola	Field Pea	Canola
% of standard rate	lb/ac	$/ac	$/ac	$/ac	$/ac	$/ac	$/ac
0/100 (FP mono)	120		.		.		
100/0 (canola mono)		.		.			
66/66		-9.0	281.5	499.0	55.0		
33/66		2.1	292.6	507.3	63.3		
50/50		-80.5	210.0	477.9	33.9		
66/33		-78.0	212.5	476.7	32.7		
33/100		18.5	309.0				
0/100 (FP mono)	60		.		.		.
100/0 (canola mono)		.		.		.	
66/66		59.8	220.7	491.7	104.2	150.7	22.5
33/66		15.9	176.8	356.1	-31.4	84.5	-43.7
50/50		68.0	228.8	414.6	27.1	114.2	-14.0
66/33		-0.9	159.9	393.9	6.4	187.1	58.9
33/100		41.1	202.0				
0/100 (FP mono)	0		.		.		
100/0 (canola mono)		.		.			
66/66		-132.9	157.3	381.3	-7.2		
33/66		-94.7	195.5	349.4	-39.1		
50/50		-81.9	208.3	373.9	-14.6		
66/33		-131.2	159.0	349.8	-38.7		
33/100		-12.0	278.2				
Mean yield (bu/ac or lb/ac)		56.4	1002	53.6	3420	46.6	2107

Navigating the nuances of intercropping will be an ongoing learning curve for everyone involved. With a growing body of farmer and researcher data about intercropping, it is clear that there are some winning and losing combinations. Like all of agriculture, it will come down to the individual year. The biggest takeaway from this trial is that intercropping can help manage risk. Each treatment had an equal chance to succeed at the start of the year. Due to differences in rainfall or location there was always a dominant crop in this system that couldn't be predicted ahead of time. Mother nature is the most important driver of crop success, by having both crops present, you can hedge your bets about which crops will be the winners in a particular year. This is one intercropping system where both components can be successful.

Assessment of a New Scalable Non-near Infrared Vegetation Index for Crop Assessment

David Kramar

Introduction
Monitoring and mapping of agricultural systems and land cover/land use is not new. The use of aerial imagery to quantify land cover and land use change is a widely applied and accepted remote sensing process that has been in practice for decades. In recent years there has been an increase in the use of small unmanned aerial systems (UAS). The ability to capture high resolution imagery from small UAS platforms provides a low cost alternative to traditional aerial surveys and has been widely used in recent years for agricultural monitoring (Lelong et al. 2008), weed mapping (Pflanz, Nordmeyer, and Schirrmann 2018), and grass monitoring (Barbosa et al. 2019). As the use of UAS has increased, so has the interest in applying vegetation indices that do not rely on the near-infrared (NIR) portion of the electromagnetic spectrum (EMS). Whereas the normalized difference vegetation index (NDVI) is a well-known index based on the ratio of red and NIR radiation, the application of this metric is limited to UAS platforms that are outfitted to collect information in the NIR portion of the EMS. Furthermore, the NDVI is subject to atmospheric, anisotropic, and spectral error. Typical "off-the-shelf" UAS such as the DJI Phantom 4 Pro require aftermarket modification in order to collect NIR information. Notwithstanding, several indices have been developed that use only the red, green, and blue (RGB) components of the EMS, with varied levels of success. These indices include the Green-Red Vegetation Index (GRVI) (Motohka et al. 2010), the Green Leaf Index (GLI) (Louhaichi, M., Borman, M.M., Johnson 2001), a scalable Visible Vegetation Index (VVI) from the Planetary Habitability Laboratory at the University of Puerto Rico (PHL-UPR 2017), and the triangular greenness index (TGI) (Hunt et al. 2012)) (Table 1).

Index	Formula
Green-Red Vegetation Index	GRVI=(Green-Red)/(Green+Red)
Green Leaf Index	GLI=(2*Green-Red-Blue)/(2*Green+Red+Blue)
Visible Vegetation Index	VVI=$[(1-\|(Red-R_0)/(Red+R_0)\|)(1-\|(Green-G_0)/(Green+G_0)\|)(1-\|(Blue-B_0)/(Blue=B_0)\|)]^{(1/w)}$ where R_0, G_0, and B_0 represent a vector of the reference green color; and w is a weight exponent
Visible Atmospherically Resistant Index	VARIGreen=(Green-Red)/(Green+Red+Blue)

Methods
The study was conducted using a Phantom 4 Pro (P4P) and the 20-megapixel RGB sensor that is standard on the P4P platform. Secondary analysis used information derived from an AgBOT UAS with a 5-band MicaSense Multispectral sensor. Imagery was typically collected at either 150' or 250' on both airframes. The selection of the P4P was to gain insight as to how useful an inexpensive UAS could be to precision agriculture applications, and the ease at which vegetation indexes that do not rely on the near infrared portion of the spectrum could be calculated. Data were collected across numerous trials at the CREC, however, this project focuses on one area of soybean. Qualitatively, visual inspection of the VVI, GLI, and GRVI, and TGI was performed in conjunction with the true color imagery collected from the UAS platform and NDVI collected from a MicaSense 5-band sensor mounted on a secondary platform (AgBOT). Given the exceptionally high resolution, it was adequate for preliminary evaluation of the performance of each of the indices. Implementation of the vegetation indices was completed using ArcGIS 10.6 and the raster calculator.

Results
There was variation in how the different indices performed. Not surprisingly, the more commonly known GRVI and the GLI performed adequately. The VVI also performed adequately, and in some cases resulted in a more granular representation (e.g. GRVI and GLI were more "washed out") of the vegetative health. That said, both GRVI and GLI tend to classify healthy vegetation adequately (Figure

1). The TGI appeared to most closely resemble the output of the NDVI index, with less overall variability in "greenness". In terms of overall applicability, any one of the other three (GRVI, GLI, VVI) indexes would suffice for approximating plant health. Note that the scalability of the VVI is particularly useful when "fine-tuning" the index, and offers some flexibility when imagery is collected in sub-par conditions.

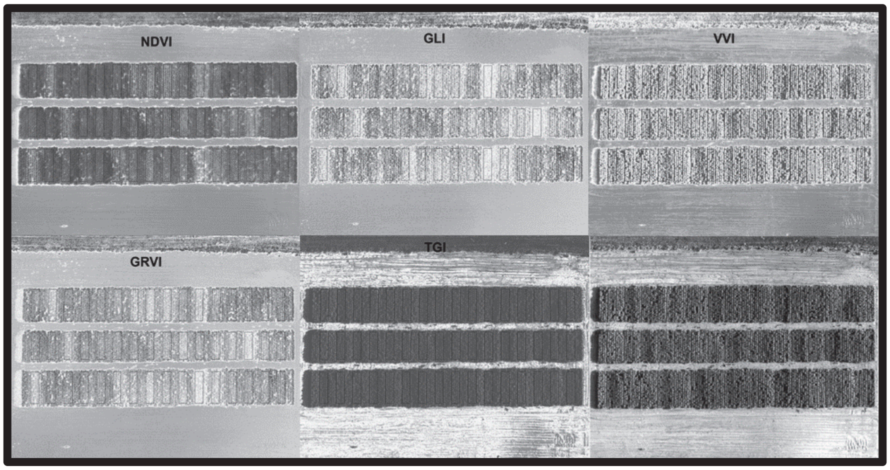


Figure 1: Comparison of the GRVI, GLI, VVI and TGI against the standard NDVI Index. While there is variability among the different indexes, overall patterns can still be determined upon visual inspection. Zoomed in, we lose some granularity among the more common indexes.

Discussion

The application of non-NIR vegetation indices, as well as classification of ultra-high resolution imagery presents significant challenges, particularly in ecosystems characterized by homogenous vegetation types, such as agricultural fields. A number of techniques were evaluated to identify and classify healthy vegetation using a mix of non-NIR vegetation indices. Using GRVI, GLI, or VVI resulted in adequate representation of vegetative health, with the VVI resulting in a more granular result that was less "washed out" than either GRVI or GLI. These results are not surprising given that GRVI and GLI are relatively well-established, and GLI was designed for low-altitude applications. We are enthusiastic about the VVI, particularly due to the scalability of the vectors. Future work will focus on further identifying the most suitable vector values for each portion of the EMS. Given the ultra-high resolution, many areas had an abundance of shadows that proved difficult to manage. It is likely that many of these areas were vegetation however; future work needs to include a field component to verify the percentages that are, or are not, vegetation.

References

Barbosa, B D S, G A S Ferraz, L M Gonçalves, D B Marin, D T Maciel, P F P Ferraz, and G Rossi. 2019. "RGB Vegetation Indices Applied to Grass Monitoring: A Qualitative Analysis." *Agronomy Research* 17 (2): 349–57. https://doi.org/10.15159/AR.19.119.

Hunt, E Raymond, Paul C Doraiswamy, James E McMurtrey, Craig S T Daughtry, Eileen M Perry, and Bakhyt Akhmedov. 2012. "A Visible Band Index for Remote Sensing Leaf Chlorophyll Content at the Canopy Scale." *International Journal of Applied Earth Observation and Geoinformation* 21 (1): 103–12. https://doi.org/10.1016/j.jag.2012.07.020.

Lelong, Camille C D, Philippe Burger, Guillaume Jubelin, Bruno Roux, Sylvain Labbé, and Frédéric Baret. 2008. "Assessment of Unmanned Aerial Vehicles Imagery for Quantitative Monitoring of Wheat Crop in Small Plots." *Sensors* 8 (5): 3557–85. https://doi.org/10.3390/s8053557.

Louhaichi, M., Borman, M.M., Johnson, D E. 2001. "Spatially Located Platform and Aerial Photography for Documentation of Grazing Impacts on Wheat." *Geocarto International* 16: 65–70.

Motohka, Takeshi, Kenlo Nishida Nasahara, Hiroyuki Oguma, and Satoshi Tsuchida. 2010. "Applicability of Green-Red Vegetation Index for Remote Sensing of Vegetation Phenology." *Remote Sensing* 2 (10): 2369–87. https://doi.org/10.3390/rs2102369.

Pflanz, Michael, Henning Nordmeyer, and Michael Schirrmann. 2018. "Weed Mapping with UAS Imagery and a Bag of Visualwords Based Image Classifier." *Remote Sensing* 10 (10): 1–17. https://doi.org/10.3390/rs10101530.

PHL-UPR. 2017. "Visible Vegetation Index (VVI)." http://phl.upr.edu/projects/visible-vegetation-index-vvi.

Long-Term Cropping Systems Study – 2019 Yield Results

Ezra Aberle

The following information provides performance data of the main treatments within the long-term cropping systems study at the CREC during the 2019 growing season. Performance of treatments is represented by crop yield data. As background, the study was initiated in 1987 with three distinct crop rotations, three tillage systems and multiple nitrogen fertility levels. Over the years the crop rotations are modified slightly to reflect changes in crops of interest in the region, however consistency of plant type biology is generally maintained. All system treatments are established each growing season and specific components of treatments may be modified after completing a 4-year cycle.

The 2019 growing season started out with generally dry conditions as surface moisture was limited and subsoil moisture was below average. The beginning of the season was characterized by below normal precipitation from April through June, starting out 2.32 inches below normal. July, August and September had above average precipitation ending the season with 5.05 inches above normal. The end result was a growing season with above-average total precipitation, but with abnormal distribution. Temperatures were significantly lower in April and May and slightly above normal for June and July with the rest of the growing season near normal.

Grain yields from each crop within the three rotations during the 2019 season are shown in table 1. The yields listed represent the crop performance when averaged across nitrogen fertility treatments. Results show that crop performance was not influenced by tillage system that season. Spring wheat and soybean also yielded in a similar manner in each of the rotations they were included.

Table 1. Grain yield of crops among rotations across tillage systems, 2019.

	Rotation 1				Rotation 2				Rotation 3			
Tillage System	Spring Wheat	Sunflower	Barley	Soybean	Spring Wheat	Field Pea	Corn	Soybean	Winter Wheat	Corn	Soybean	Spring Wheat
	bu/ac	lb/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac
Minimum	42.8	1679	65.8	64.8	35.3	NA	113.4	62.1	28.5	135.0	62.0	37.5
No-Till	39.5	1846	60.9	62.2	32.8	NA	122.3	65.1	28.1	125.7	61.6	38.8
Conventional	40.9	1933	61.8	62.6	38.3	NA	135.1	65.7	27.1	133.8	61.2	38.7
Average	41.1	1819.5	62.9	63.2	35.5	NA	123.6	64.3	27.9	131.5	61.6	38.4
LSD 0.05	NS	NS	NS	NS	NS	NA	NS	NS	NS	NS	NS	NS

Rotation 1 = Spring Wheat-Sunflower-Barley-Soybean
Rotation 2 = Spring Wheat-Field Pea-Corn-Soybean
Rotation 3 = Winter Wheat-Corn-Soybean-Spring Wheat
NA: Field pea not reported due to herbicide injury.

The influence of N fertilizer treatments on grain yields from 2019 are listed as crop averages across the three tillage systems in table 2. As might be expected, the crop yields generally responded to additions of N as different levels of fertilizer were applied. Only with corn did the 150-pound application result in a trend for yield greater than the 100-pound N fertilizer application. Crop performance across the composted manure N fertility treatments typically resulted in high yields across crops. The 2019 season represents the first year of a new 4-year cycle and manure is only applied at the onset of a cycle. Yield does tend to decline in the manure treatments as the years progress in the 4-year cycle. The significance of soybean as a legume preceding spring wheat in rotation is reflected in relatively minor response to higher levels of additional N fertilizer.

Table 2. Grain yield of crops among rotations across nitroge fertility treatments, 2019.

	Rotation 1				Rotation 2				Rotation 3			
Nitrogen Fertility	Spring Wheat	Sunflower	Barley	Soybean	Spring Wheat	Field Pea	Corn	Soybean	Winter Wheat	Corn	Soybean	Spring Wheat
lbs/ac	bu/ac	lb/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac	bu/ac
0	35.6	1385	24.4	65.7	31.8	NA	80.1	57.5	21.3	76.8	63.1	36.6
50	36.1	1862	71.7	66.1	33.4	NA	103.9	54.4	28.4	114.7	56.4	34.6
100	43.0	1898	72.0	62.2	35.2	NA	119.8	80.7	22.3	126.3	62.5	38.0
150	45.6	1610	64.9	59.0	34.4	NA	135.8	74.7	31.7	158.5	59.6	39.9
Manure	45.2	2343	81.4	63.0	42.6	NA	178.3	54.1	35.7	181.4	66.4	42.7
Average	41.1	1819.5	62.9	63.2	35.5	NA	123.6	64.3	27.9	131.5	61.6	38.4
LSD 0.05	6.2	398	14.3	NS	6.2	NA	21.2	12.6	5.7	21.2	NS	6.2

** Soybean and field pea as legumes do not receive any N fertilizer application.
NA: Field pea not reported due to herbicide injury.

Optimizing Fungicide Droplet Size for Improved Management of White Mold in Soybeans

Michael Wunsch, Jesse Hafner, Thomas Miorini, Suanne Kallis; Kelly Cooper, Heidi Eslinger and Seth Nelson

Results from a 4-year research project conducted in Carrington and Oakes indicate that fungicide droplet size is a critical determinant of fungicide performance for the management of white mold in soybeans and that the optimal droplet size is dependent on canopy characteristics.

In research conducted with TeeJet extended-range (XR) flat-fan nozzles (Spraying Systems Company, Glendale Heights, IL), nozzles emitting fine to medium droplets optimized fungicide performance against white mold when the soybean canopy was open and nozzles emitting coarse droplets optimized fungicide performance against white mold when the soybean canopy was at or near closure. When the soybean canopy averaged less than 80% closure at fungicide application, nozzles emitting fine to medium droplets optimized white mold management (Figure 1). When the soybean averaged 80-89% closure when fungicides were applied, nozzles emitting medium droplets optimized white mold management (Figure 2). When the soybean canopy averaged 92 to 100% closure when fungicides were applied, nozzles emitting coarse droplets optimized white mold management (Figures 3 and 4).

Parallel research was also conducted with Wilger Combo-Jet flat-fan nozzles (Wilger Corp.; Lexington, TN). As this report went to press, yield data from the 2020 studies conducted with Wilger nozzles were still being assessed and data were still being analyzed. Preliminary results with Wilger nozzles from the 2019 season suggest that a similar relationship between optimal droplet size and canopy closure exists, except that the droplet spectrum may differ with Wilger nozzles. In 2019, very coarse droplets optimized fungicide performance with Wilger nozzles when the soybean canopy was at or near closure.

Testing was conducted with a tractor-mounted sprayer equipped with a pulse-width modulation system (Capstan AG; Topeka, KS). A single application of the fungicide Endura (5.5 or 8.0 oz/ac) was made at the R2 growth stage. Spray volume was 15 gal/ac, and pulse width was modified to maintain a constant driving speed and constant spray volume across nozzles differing in output. Driving speed and the nozzles and application pressures utilized to achieve the target droplet size spectrum differed across studies (Table 1).

Table 1. Driving speed, fungicide application rate, nozzles, and application pressures utilized in the studies evaluating the impact of fungicide droplet size on management of white mold in soybeans.

	2017 Carrington	2018 Carrington and Oakes	2019 Carrington and Oakes	2020 Carrington	2020 Oakes
			Fungicide applied:		
	Endura at 5.5 oz/ac	Endura at 5.5 oz/ac	Endura at 5.5 oz/ac	Endura at 8.0 oz/ac	Endura at 5.5 oz/ac
			Driving speed:		
	4.0 mph	6.7 mph	8.9 mph	10.5 mph	6.0 mph
	Nozzles and application pressures utilized to achieve the target droplet size spectrum				
Fine droplets	XR8004, 60 psi	XR8003, 50 psi	XR11004, 50 psi	XR11005, 60 psi	XR11004, 60 psi
Medium-fine	XR8004, 40 psi	XR8004, 40 psi	XR11005, 40 psi	XR11006, 50 psi	XR11005, 40 psi
Medium droplets	XR8006, 60 psi	XR8006, 40 psi	XR11006, 35 psi	XR11006, 35 psi	XR11006, 35 psi
Medium-coarse	not tested	XR8008, 35 psi	XR11008, 40 psi	XR11008, 40 psi	XR11008, 40 psi
Coarse droplets	XR8010, 40 psi	XR8010, 30 psi	XR11010, 30 psi	XR11010, 30 psi	XR11010, 30 psi

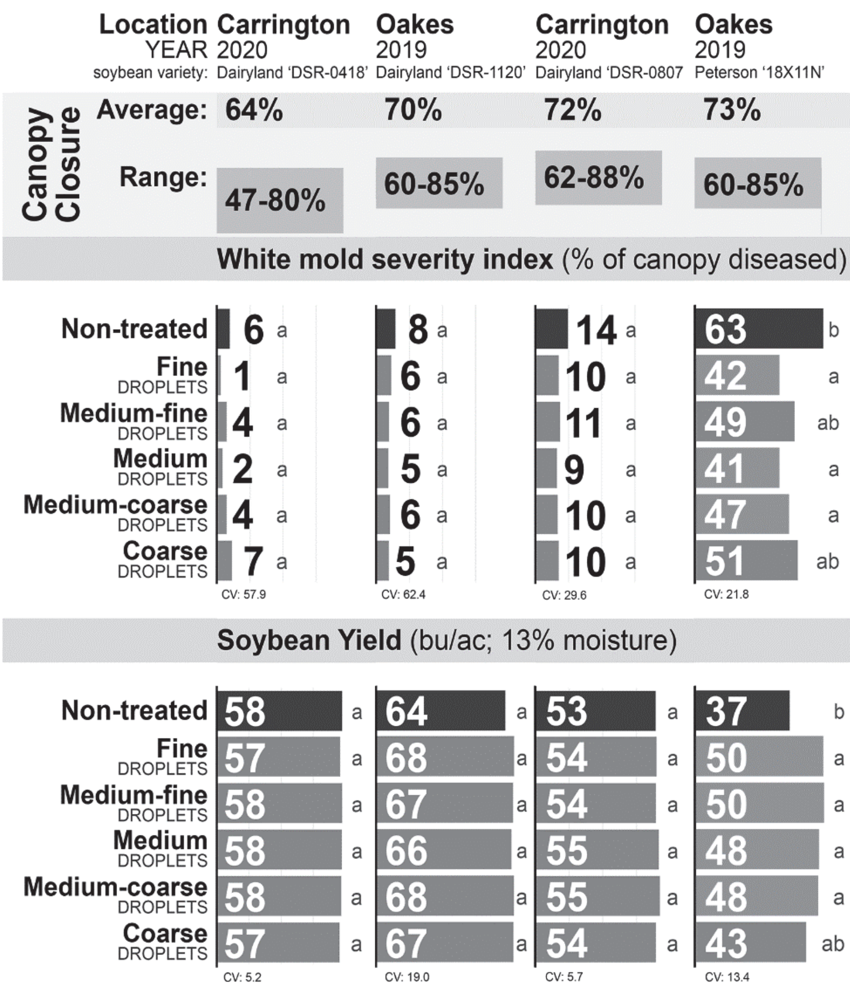


Figure 1: When the soybean canopy closure averaged less than 75% at fungicide application at the R2 growth stage, fine to medium-fine droplets optimized fungicide performance in the only study in which statistical separation of treatments was observed. Within-column means followed by different letters are significantly different (*P* < 0.05).

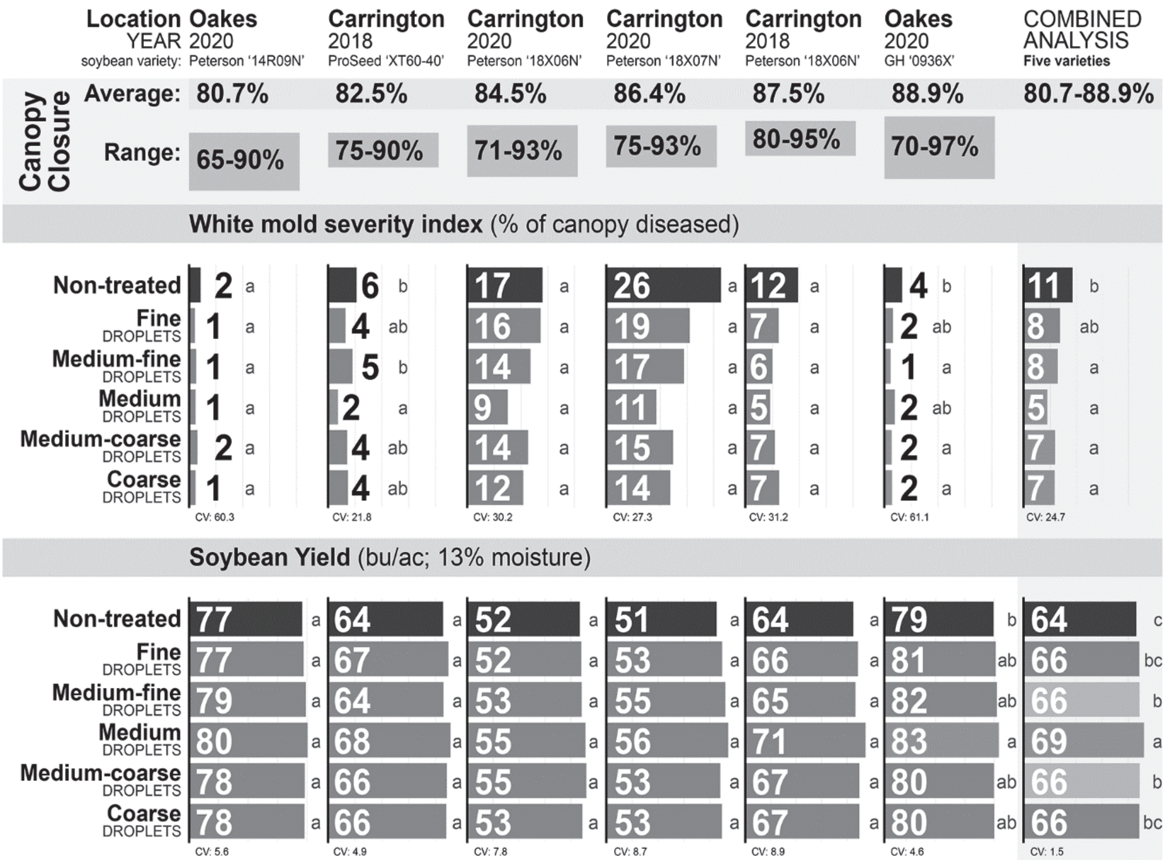


Figure 2: When the soybean canopy closure averaged 80-89% at fungicide application at the R2 growth stage, medium droplets optimized fungicide performance against white mold in soybeans. Within-column means followed by different letters are significantly different (*P* < 0.05).

Making applications with the tractor-mounted sprayer to the droplet size studies in Carrington in 2019. Flags mark the start and end of the treatment plots. To prevent edge effects, alleys were not cut between plots until harvest.

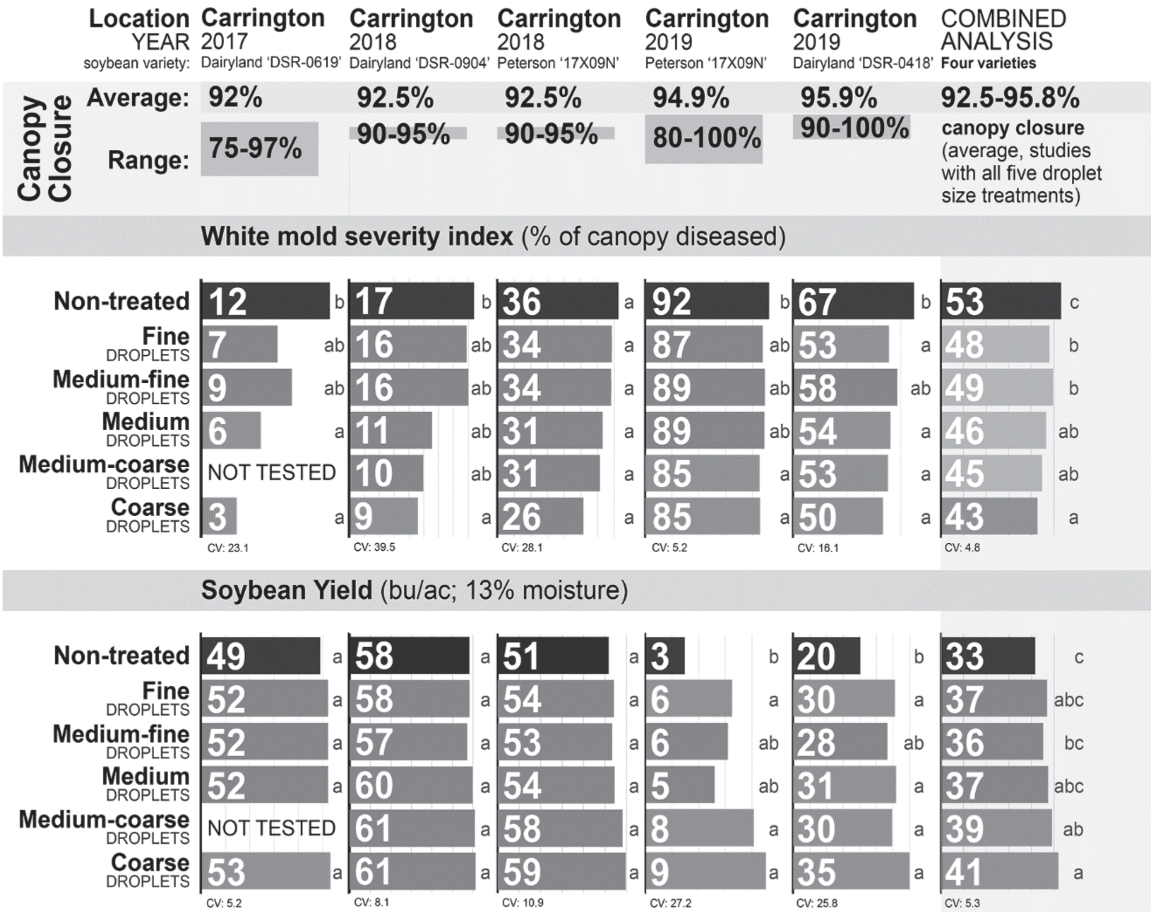


Figure 3: When the soybean canopy closure averaged 92-96% at fungicide application at the R2 growth stage, coarse droplets optimized fungicide performance against white mold in soybeans. Within-column means followed by different letters are significantly different (*P* < 0.05).

To ensure a constant spray volume of precisely 15 gal/ac across droplet size treatments, sprayer output was measured, and pulse width was manually calibrated immediately before fungicides were applied.

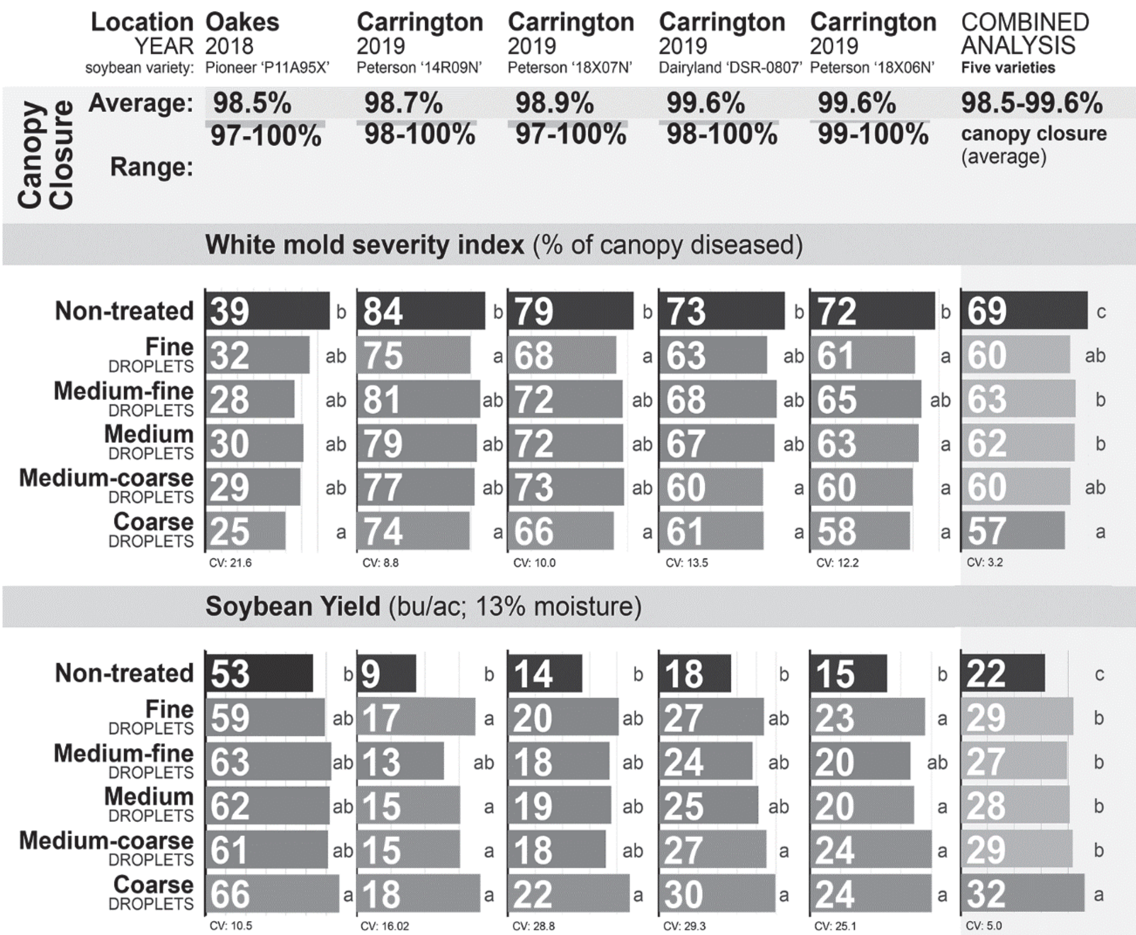


Figure 4: When the soybean canopy closure averaged 98-100% at fungicide application at the R2 growth stage, coarse droplets optimized fungicide performance against white mold in soybeans. Within-column means followed by different letters are significantly different ($P < 0.05$).

Soybean *Sclerotinia* infection.

Partial funding for this projects was provided by the North Dakota Soybean Council.

Pollinator Communities in Annual Pollinator Plantings and Adjacent Dry Bean Crops

Savannah Adams, Jason Harmon, Torre Hovick, Katherine Kral-O'Brien, and Mike Ostlie

Introduction

Supplemental pollinator plantings are a common practice used to support pollinators by increasing floral resources in agroecosystems (Wratten et al., 2012). These pollinator plantings are often composed of perennial plants. However, since most crops grown globally are annuals, annual pollinator plantings could be more effective in agroecosystems for both the pollinators and producers. One main benefit is the ability to be moved yearly depending on the land allocation or crop rotation (Mallinger et al., 2019). Another advantage of an annual planting is the quick floral expression and, therefore, quick pollinator response (Carreck and Williams, 2002). Additionally, annual plantings can include prevalent annual cover crop species, which can benefit the soil and land productivity while also serving as an extra floral resource for pollinators (Mallinger et al., 2019).

Many crops planted across the United States today directly and indirectly rely on insect pollinators (Klein et al., 2007). However, the leading food crops do not rely on insect pollinators. These include predominant crops such as corn, soybeans, and dry beans. Dry beans, which are self-pollinated, are planted on 1.5 to 2 million acres annually within the United States (UDSA-NASS, 2019), and in 2017 about 705,000 acres were planted in North Dakota alone (USDA-NASS, 2019). Pinto beans are the most abundant dry bean produced in North Dakota, making up about 66% of the total state dry bean production in 2017, accounting for around 468,000 acres (USDA-NASS, 2019). However, there have been little to no studies conducted on the pollinator community within these dry beans, or whether visiting pollinators may have an effect on bean yield.

Figure 1. Pollinator planting at the CREC showing plains coreopsis, buckwheat, and flax.

Objectives:

1. Identify plant-pollinator interactions within annual pollinator plantings.
2. Assess the potential pollinator community and visitation in dry bean crops.

Materials and Methods

An annual seed mix was planted directly adjacent to plots of Palomino pinto beans. Four research plots in each of the last two years were established at the Carrington Research Extension Center (CREC). Similar research was conducted at the Hettinger Research Extension Center (HREC), but this report focuses on CREC results. The seed mix included 17 different annual forbs including cover crops like buckwheat and flax and wildflowers such as phacelia and plains coreopsis. Timed, 15-minute bee surveys in both beans and annual plantings were conducted throughout the growing season to sample the pollinator community. For the 15-minute bee survey, a 20-meter x 2-meter transect collected any bee visiting a flower. All collected specimens were identified in the lab. These specimens helped determine the network of plant-pollinator interactions within the pollinator planting and determined the insect community that visited the adjacent pinto beans.

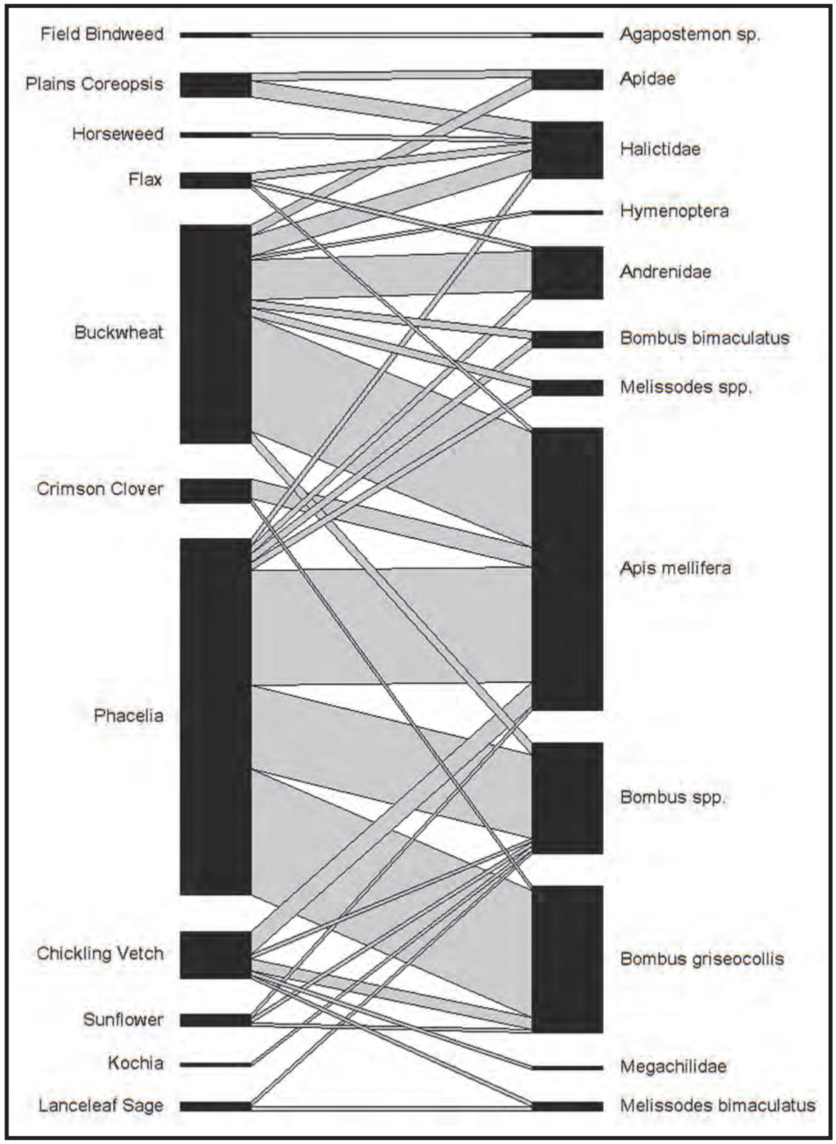


Figure 2. Plant pollinator network from CREC pollinator plantings in 2019 and 2020.

Results and Discussion

Pollinator Plantings

A plant-pollinator interaction network (Figure 2) shows the collected species of bees and which plants they were visiting within the pollinator planting. The bars on the left side of the network represent the different plant species the bees visited. The bars on the right side of the network show the different groups of bees (down to the lowest taxonomic level possible). The thicker the bars are, the more observations of that specific group and thicker connecting lines indicate more common interactions.

The network shows all observed interactions from 2019 and 2020 in the CREC pollinator plantings. One hundred eighty-one bees were collected on 11 different plants. Phacelia, which is an attractive purple forb, was the most visited flower with 90 out of the 181 interactions. Buckwheat was the next most visited planted forb with 55 out of the 181 interactions. Following these forbs, the most visited planted forbs were chickling vetch, crimson clover, and plains coreopsis. However, breaking down the interactions by year, the buckwheat had more interactions (39 out of 91) in 2020 despite phacelia having higher observed interactions overall. The most frequently observed bee family within the pollinator plantings at CREC was Apidae. The family Apidae is composed of genera such as Apis (honey bees) and Bombus (bumblebees). The most commonly observed bees were honey bees (*Apis mellifera*), brown-belted bumblebees (*Bombus griseocollis*), and other bumblebee species (*Bombus spp.*). Both these genera made up a large proportion of the phacelia interactions and were the only species collected on crimson clover.

Dry Bean Pollinators

For both 2019 and 2020, 49 insect visitors were observed on pinto bean flowers (Figure 3). The most common insect visitor belonged to the order Diptera, which is the order of flies. These flies were 38 out of the 49 total visitations. Following flies, four bees visited bean flowers in 2020. A few other insects such as butterflies, true bugs, and a wasp also visited the pinto bean flowers.

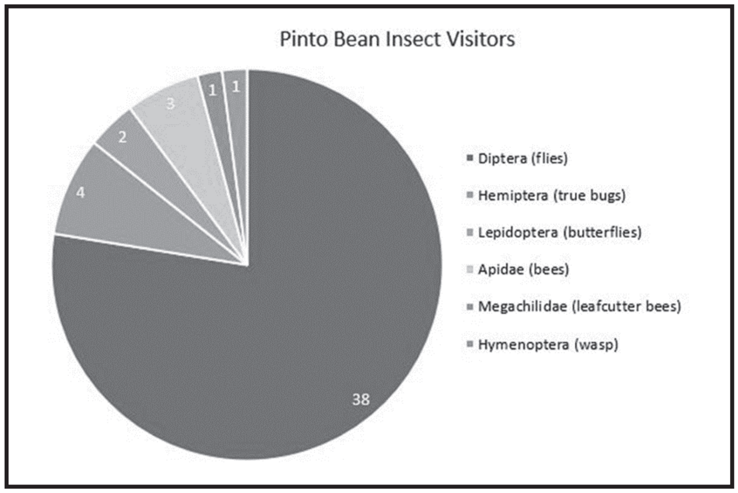


Figure 3. Pie chart of all pinto bean visitors from 2019 and 2020.

Conclusions

Annual pollinator plantings provided extra non-crop floral resources and many insect pollinators utilized and visited the planted forbs. Despite their classification of being self-pollinating, pinto bean flowers do have insect visitors (Figure 3 and Figure 4). Additionally, pinto bean data is being analyzed to see if cross-pollination or insect visitation influence bean yield.

Figure 4. Bumblebee visiting a pinto bean flower.

References

Carreck, N. L., & Williams, I. H. (2002). Food for insect pollinators on farmland: insect visits to flowers of annual seed mixtures. *Journal of Insect Conservation*, *6*, 13–23.

Klein, A. M., Vaissière, B. E., Cane, J. H., Steffan-Dewenter, I., Cunningham, S. A., Kremen, C., & Tscharntke, T. (2007). Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences*, *274*(1608), 303–313.

Mallinger, R. E., Franco, J. G., Prischmann-voldseth, D. A., & Prasifka, J. R. (2019). Annual cover crops for managed and wild bees : Optimal plant mixtures depend on pollinator enhancement goals. *Agriculture, Ecosystems and Environment*, *273*(December 2018), 107–116.

USDA-NASS. (2019). *North Dakota State and County Data*. *1*(34), 1-614.

Wratten, S. D., Gillespie, M., Decourtye, A., Mader, E., & Desneux, N. (2012). Pollinator habitat enhancement: Benefits to other ecosystem services. *Agriculture, Ecosystems and Environment*, *159*, 112–122. https://doi.org/10.1016/j.agee.2012.06.020

Utilization of Soybean Hulls in Drylot Beef Cow-calf Rations

Rebecca L. Moore and Bryan W. Neville

The objective of this study was to evaluate the use of soybean hulls as a partial forage replacement in drylot cow-calf rations during an entire calving cycle. Specific objectives included: 1) To evaluate drylot beef cow-calf performance when fed rations including soybean hulls or not as a partial forage replacement, 2) To evaluate milk production and quality during lactation while beef cows were fed rations including soybean hulls or not as a partial forage replacement, 3) To evaluate beef calf performance based on dams being fed either soybean hulls or not as a partial forage replacement under drylot management.

Summary

One hundred and twenty beef cows were assigned to one of eight pens at the Carrington Research Extension Center. Prior to breeding during the summer of 2019, cow-calf pairs were sorted based on age, body weight, body condition score and calving date to create pen groups. Pens were provided one of two treatment diets: 1) the control ration (**CON**) consisted of silage, straw and modified distillers grains with solubles (**mDGS**), and 2) the soybean hull ration (**SBH**) replaced portions of corn silage, straw, and mDGS with pelleted soybean hulls (DM basis). Rations were formulated to meet the nutritional requirements of beef cows for lactation/early gestation, mid-gestation, and late gestation. During the four study segments evaluated (two lactation periods, mid-gestation, and late-gestation) there were no differences in body weight, body condition score, or average daily gain between cows on either treatment ($P \geq 0.12$). Colostrum quality was largely unaffected by inclusion of soybean hulls in beef cow rations. Milk production appeared to be greater during early lactation in cows fed diets containing soybean hulls, however this did not translate into any differences in calf weights at weaning. The data indicate that soybean hulls can be used to as a partial forage replacement, up to 27% of dietary DM, in beef cow rations when provided in a feedlot. Further data on potential effects of inclusion rate of soybean hulls is still needed.

Introduction

Research on feeding soybean hulls to beef cows under drylot conditions is limited. Soybean hulls have been studied more extensively in beef feedlot rations and under grazing conditions (Anderson et al., 1988; Hibberd 1986). Cows supplemented soybean hulls while grazing pasture have been shown to lose less weight than those supplemented corn (Hibberd, 1986); these authors hypothesized that digestible fiber feeds, like soybean hulls, may be more effective range supplements than starch-based feeds. This was further supported by more recent research where the high digestible fiber content of soybean hulls improved fiber digestibility in steers (Smith et al., 2017a). One of the few published beef cow studies evaluating soybean hulls demonstrated that feeding hay and soybean hulls during late gestation had no impact on cow or calf performance (Smith et al., 2017b). The study objective was to evaluate the use of soybean hulls as a partial forage replacement on a long-term basis.

Experimental Procedures

All animals involved in this study were handled in conformity with the protocols approved by the North Dakota State University Institutional Animal Care and Use Committee. Prior to breeding in summer of 2019, 121 cow-calf pairs were stratified by age (4.52 ± 0.85 years), body condition score (5.40 ± 0.10), and body weight (1433.4 ± 67.5 lbs.). Pairs were divided into one of eight pens (n = four pens per treatment; six groups of multiparous cows and two groups of primiparous cows). Replacement of open cows with replacement heifers was completed at weaning following culling of open cows. Treatments were control (**CON**; rations included corn silage, straw and mDGS), and a treatment (**SBH**; rations included soybean hulls at 26-27% of dietary DM replacing portions of corn silage, cereal straw and mDGS). Rations were developed to meet the nutritional requirements of the cow during lactation, mid-gestation, and late-gestation (NASEM, 2016). In addition, beginning in mid-gestation cows were given *ad libitum* access to straw. Weights and body condition scores were collected on two consecutive days at the initiation and conclusion of each study segment (Lactation 2019, Mid-gestation, Late-gestation, Lactation 2020). Additionally, body weight and body condition scores were collected approximately every 28d to monitor cow performance. Colostrum samples were collected from a subset of cows from each pen (61 head total) within 24 hours to analyze milk quality. Weigh-suckle-weigh was used to further evaluate milk production in beef cows fed **CON** or **SBH**-based rations. Milk production was measured at approximately day 60±1 and 120±1 postpartum by a modified procedure described by Radunz et al (2010), Williams et al (1979) and Benson et al (1999). Calf performance was determined during birth to weaning. At birth, body weights were collected from all calves. A two-day body weight was collected from calves at weaning to allow for determination of calf weight gain. Data were analyzed with the mixed procedures of SAS (SAS Inc.). Cow performance data were analyzed by period within the study. All data was analyzed with pen serving as the experimental unit.

Results and Discussion

During four study segments evaluated (two lactation periods, mid-gestation, and late-gestation) there were no differences in body weight, body condition score, or average daily gain between cows on either treatment ($P \geq 0.12$; Table 1). Colostrum quality was analyzed for fat, somatic cell count, milk urea nitrogen, and other solids in milk samples between the two treatments and found no difference ($P \geq 0.06$; Table 2). However, protein content within colostrum samples was greater ($P = 0.02$) for cows fed control rations compared to those fed soybean hull rations (11.9 vs. 9.5 ± 0.54%, respectively). Weigh suckle weigh data indicated that milk production at d 60 of lactation was greater ($P = 0.03$) in cows fed SBH compared to those on CON, 16.0 vs. 11.8kg/d respectively. However, no differences were present at day 120 of lactation ($P = 0.55$). There were no differences in calf birth, initial, and final body weights, or average daily gain between the control and soybean hull treatments ($P \geq 0.11$; Table 3).

Cow-calf pairs in drylot.

Table 1. Effects of soybean hull inclusion on performance of beef cows fed in confinement during an entire production cycle.

	Treatment[1]			
	CON	SBH	SEM[2]	*P* -value[3]
Lactation[4]				
Initial BW, kg[5]	649.5	652	31.52	0.96
Initial BCS[5]	5.4	5.4	0.109	0.98
Final BW, kg[6]	609.8	613.1	28.17	0.94
Final BCS[6]	5.3	5.2	0.149	0.84
ADG, kg	-0.35	-0.35	0.041	0.9
Mid-Gestation				
Initial BW, kg	574.6	581.8	23.18	0.83
Initial BCS	5.3	5.2	0.149	0.84
Final BW, kg	633.3	646.2	27.22	0.75
Final BCS	5.9	6.1	0.15	0.15
ADG, kg	0.64	0.71	0.062	0.5
Late-Gestation				
Initial BW, kg	633.3	646.2	27.22	0.75
Initial BCS	5.9	6.1	0.105	0.15
Final BW, kg	673.19	696.4	25.81	0.55
Final BCS	5.6	5.6	0.091	0.9
ADG, kg	0.47	0.6	0.048	0.12
Lactation[7]				
Initial BW, kg	605.4	620.1	21.36	0.64
Initial BCS	5.3	5.4	0.081	0.3
Final BW, kg	618.1	628.3	22.68	0.76
Final BCS	5.3	5.4	0.063	0.31
ADG, kg	0.13	0.08	0.054	0.56

[1]Treatment: CON, control diet; SBH, soybean hull diet; [2] n = 4 pens per treatment; [3]*P* -value less than 0.05 considered significantly different; [4]Lactation 2019; [5]Initial body weights and body condition scores were collected at the beginning of study; [6]Final body weights and body condition scores were collected at the conclusion of study; [7]Lactation 2020.

Table 2. Effects of soybean hull inclusion on colostrum quality and milk production of beef cows fed in confinement during an entire production cycle.

	Treatment[1]			
	CON	SBH	SEM[2]	*P*-value[3]
Colostrum Analysis[4]				
Fat, %	4.1	4.9	0.33	0.14
Protein, %	11.9	9.5	0.54	0.02
SCC	2405	5319	871.1	0.06
MUN	2.7	6.6	1.54	0.12
Other	4.8	4.6	0.08	0.19
Milk Production, kg[5]				
60 days post-calving	11.8	16	1.34	0.03
120 days post-calving	8.81	9.76	1.12	0.55

[1]Treatments: CON, control diet; SBH, soybean hull diet; [2] n = 54 cows for colostrum collection and n = 48 pairs used for weigh-suckle-weigh ; [3]*P*-value less than 0.05 considered significantly different.; [4]Colostrum samples were collected within 24 hours of birth for milk analysis; [5]To determine milk production during lactation 2020, the weigh-suckle-weigh technique was used.

Table 3. Effects of soybean hull inclusion on performance of beef calves resulting from dams fed in confinement during an entire production cycle.

	Treatment[1]			
	CON	SBH	SEM[2]	*P*-value[3]
Calf Performance				
Birth Weight, kg	35.74	36.88	2.69	0.54
Initial BW, kg[4]	78.5	83.9	2.063	0.11
Final BW, kg[5]	170.65	180.2	5.989	0.3
ADG, kg[6]	0.95	0.99	0.052	0.58

[1]Treatment: CON, control diet; SBH, soybean hull diet; [2] n = 4 pens per treatment; [3]*P*-value less than 0.05 considered significantly different; [4]Initial body weight is considered the average 30-day weight post-calving; [5]Final body weight is considered the average weight at end of study (weaning); [6]ADG calculated for 95 days (initial to weaning).

The data indicate that soybean hulls can be used to as a partial forage replacement, up to 27% of dietary DM, in beef cow rations when provided in a feedlot. Previous research has also demonstrated that soybean hulls can be utilized in mid- to late-gestation as a partial forage replacement without impacting cow or calf performance (Smith et al., 2017b). Supplementing soybean hulls and DDGS have also shown to provide similar effects on body weight and condition scores in heifers provided a limit-fed diet (Engel et al., 2008). Jointly, the present and previous data indicate that soybean hulls can be used effectively as a partial forage replacement in beef cow rations. Further data on potential effects of inclusion rate of soybean hulls is still needed.

Literature Cited

Anderson, S.J., J.K. Merill, and T.J. Klopfenstein. 1988. Soybean hulls as an energy supplement for the grazing ruminant. J. Anim. Sci. 66: 2959-2964.

Benson, M.E., M.J. Henry, R.A. Cardellino. 1999. Comparison of weigh-suckle-weigh and machine milking for measuring ewe milk production. J. Anim. Sci. 77: 2230-2335.

Engel, C.L., Patterson, H.H., Perry, G.A. 2008. Effects of dried corn distillers' grains plus solubles compared with soybean hulls, in late gestation heifer diets, on animal and reproductive performance. J. Anim. Sci. 86: 1697-1708.2008.

Hibberd, C.A., and C.C. Chase Jr. 1986. Corn vs soybean hull supplements for fall-calving beef cows in winter. J. Anim. Sci. 63:311. (Abstr.).

Radunz, A.E., F.L. Fluharty, M.L. Day, H.N. Zerby, S.C. Loerch. 2010. Prepartum dietary energy source fed to beef cows: I. Effects on pre- and postpartum cow performance. J. Anim. Sci. 88: 2717-2728.

Smith, W.B., K.P. Coffey, R.T. Rhein, E.B. Kegley, D. Philipp, J.G. Powell, J.D. Caldwell, and A.N. Young. 2017a. Feeding distillers' grains, soybean hulls, or a mixture of both to cows as a forage replacement: Effects on intake, digestibility, and ruminal fermentation characteristics. J. Anim. Sci. 95:33666-3675.

Smith, W.B., K.P. Coffey, J.D. Tucker, D.S. Hubbell, E.B. Kegley, D. Philipp, J.D. Caldwell, and A.N. Young. 2017b. Using soybean hulls to meet dietary energy requirements of gestating cows having restricted access to poor-quality hay. Prof. Anim. Sci. 33:101-107.

Williams, J.H., D.C. Anderson, D.D. Kress. 1979. Milk production in Hereford cattle. I. Effects of separation interval on weigh-suckle-weigh milk production estimates. J. Anim. Sci. 49: 1438-1442.

Discovering Value in North Dakota Calves: 20 Years of the Dakota Feeder Calf Show Feedout

Karl Hoppe and Dakota Feeder Calf Show Livestock Committee

North Dakota cattle producers are identifying cattle with superior growth and carcass characteristics by participating in the Dakota Feeder Calf Show. Average profitability between consignments from the top five herds and the bottom five herds was $99.56 per head for the 2019-2020 feeding period. Average profit per steer was $88.74 over the 19 year period from 2001 to 2020.

Summary

The Dakota Feeder Calf Show feedout project helps North Dakota cattle producers discover the actual value of their spring-born beef steer calves, provides comparisons among herds, and benchmark feeding and carcass performance. For the 2019-2020 feedout project, cattle consigned to the feedout project were delivered to the Carrington Research Extension Center Livestock Unit on October 19, 2019. After a 213-day feeding period with 2.56 percent death loss, cattle averaged 1344.7 pounds (shrunk harvest weight). Feed required per pound of gain was 6.4 (dry-matter basis). Overall pen average daily gain was 3.35 pounds. Feed cost per pound of gain was $0.464 and total cost per pound of gain was $0.728. Profit ranged from $165.95 per head for pen-of-three cattle with superior growth and carcass traits to $41.52 per head (no death loss). For the 19 year period, 2001 – 2020, the average feeding profit was $88.74 per steer per year and the range in profit was ($137.17) to $582.99 per head. Substantial variability in the feeding and carcass value of spring-born calves continues to be discovered through participation in the feedout project.

Introduction

Cow calf produces need to remain competitive with other livestock and poultry in the meat industry. By determining calf value in a feedout program, cow-calf producers can identify superior genetics under common feedlot management. Marketplace premiums are provided for calves that have exceptional feedlot performance and produce a high-quality carcass.

Cost-effective feeding performance is needed to justify the expense of feeding cattle past weaning. Since North Dakota has low-cost feeds and a favorable climate, low cost per pound of gain can be accomplished.

Combining the low cost of gains with the identification of superior cattle, this ongoing feedlot project provides cattle producers with an understanding of cattle feeding and cattle selection in North Dakota.

Experimental Procedures
The Dakota Feeder Calf Show was developed for cattle producers willing to consign steer calves to a show and feedout project. The first feedout was started in October 2001 with finished cattle sold in May 2002. The project has been continued yearly since 2001.

For the 2019-2020 feedout period, the calves were received in groups of three or four on Oct. 19, 2019, at the Turtle Lake Weighing Station, Turtle Lake, N.D., for weighing, tagging, veterinary processing and showing. The calves were evaluated for conformation and uniformity, with the judges providing a discussion to the owners at the beginning of the feedout. The number of cattle consigned was 117, of which 100 competed in the pen-of-three contest.

The calves were shipped to the Carrington Research Extension Center, Carrington, N.D., for feeding. Prior to shipment, calves were vaccinated, implanted with Synovex-S, dewormed and injected with a prophylactic long-acting antibiotic.

Calves were sorted and placed on corn-based receiving diets. After an eight-week backgrounding period, the calves were transitioned to a 0.62 megacalorie of net energy for gain (Mcal NEg) per pound finishing diet. Cattle were weighed every 28 days, and updated performance reports were provided to the owners. Cattle were re-implanted with Synovex-choice.

An open house was held on February 7, 2020, at the Carrington Research Extension Center Livestock Unit, where the owners reviewed the calves and discussed marketing conditions.

The cattle were harvested on May 20, 2020 (114 head). The cattle were sold to Greater Omaha Packing Co., Omaha, Neb., on a flat bid carcass basis, with no premiums and discounts based on carcass quality. Carcass data was not collected after harvest due to packing plant restraints resulting from the COVID 19 pandemic.

Results and Discussion
For the 2019-2020 feeding period, cattle consigned to the Dakota Feeder Calf Show feedout project averaged 596.2 pounds upon delivery to the Carrington Research Extension Center Livestock Unit on October 19, 2019. After an average 213-day feeding period, cattle averaged 1,344.7 pounds (at plant, shrunk weight). Death loss was 2.56 percent (three head) during the feeding period.

Average daily feed intake per head was 32.7 pounds on an as-fed basis and 21.6 pounds on a dry-matter basis. Pounds of feed required per pound of gain were 9.7 on an as-fed basis and 6.4 pounds on a dry-matter basis.

The overall feed cost per pound of gain was $0.464. The overall yardage cost per pound of gain was $0.102. The combined cost per pound of gain, including feed, yardage, veterinary, trucking and other expenses except interest, was $0.728.

Calves were priced by weight upon delivery to the feedlot. The pricing equation ($ per 100 pounds = (-0.008990915* initial calf weight, pounds) + 151.2910293) was determined by regression analysis on local livestock auction prices reported for the weeks before and after delivery.

The top-profit pen-of-three calves with superior genetics returned $165.95 per head, while the bottom pen-of-three calves returned $41.52 per head. The average of the five top-scoring pens of steers averaged $152.66 per head, while the average of the bottom five scoring pens of steers averaged $53.10 per head.

For the 19-year feeding period, 2001-2020, the average per consigned steer profitability was $88.74. The range of profitability was $-137.17 to 582.99 per head. Average daily gain was fairly similar over the years. Feed costs per pound of gain averaged $0.48 over 19 years. Feed cost per pound of gain was affected more by feed price changes than cattle gain. The percent USDA Choice carcasses has increased from 2001 to 2019 while ribeye area and back fat thickness at slaughter have remained similar. Cattle weight (average 614 pounds) upon entry into the feedout has been similar over the years while final weight at slaughter has increased (1207 and 1344 for years 2002 and 2020 respectively).

Prices for feeder cattle and finished cattle have changed over the past 19 years. Steer calf prices per hundred weight have doubled and even tripled for certain years. Finished steer prices per hundred weight have also doubled. Cattle prices, feed prices and profitably were quite variable during the 19-year feeding period. However, average cattle performance and carcass characters have been similar during the 19-year feeding period.

Implications
Exceptional average daily gains, weight per day of age, and harvest weights can be found in calves produced from North Dakota beef herds. Feedout projects provide a source of information for cattle producers to learn about feedlot performance and individual animal differences, and discover cattle value.

Dakota Feeder Calf Show Feedout steers.

Table 1. Selected performance parameters for the Daktoa Feeder Calf Show Feedout 2019 - 2020.

Year	Profit per head	Feed cost per pound Gain	Average Daily Gain	Choice	Rib Eye Area	Backfat	In Weight	In Price	Out Weight	Out Price
	$	$	lb.	%	sq. in.	in.	lb.	$/cwt	lb.	$/cwt
2001-02	-19.26	0.252	3.04	49.6	13.1	0.42	602.4	95.68	1207.9	67.42
2002-03	112.27	0.326	3.36	48.0	13.3	0.42	589.0	84.06	1240.3	73.21
2003-04	116.76	0.317	3.25	57.1	13.3	0.44	577.5	114.17	1257.8	87.1
2004-05	94.08	0.307	3.09	68.1	14.2	0.43	613.5	123.53	1308.6	91.82
2005-06	-86.28	0.280	3.18	57.5	12.9	0.53	607.6	128.53	1249.5	79.33
2006-07	107.89	0.471	3.02	60.3	13.7	0.49	639.7	116.85	1298.2	99.24
2007-08	-24.51	0.571	3.34	43.6	13.7	0.42	639.2	115.24	1308.7	94.02
2008-09	-0.46	0.553	2.98	67.1	13.5	0.42	648.5	98.82	1260.1	87.49
2009-10	296.59	0.378	3.28	56.3	13.7	0.56	625.0	97.05	1277.5	99.01
2010-11	167.28	0.737	3.29	72.3	14.0	0.46	615.9	116.64	1272.5	117.87
2011-12	85.72	0.710	3.63	76.0	15.6	0.36	596.4	150.06	1353.6	123.62
2012-13	-50.15	0.865	2.77	84.2	13.6	0.51	608.9	157.23	1224.2	128.7
2013-14	324.28	0.575	3.53	75.8	14.0	0.49	600.3	176.88	1313.6	151.36
2014-15	-37.39	0.431	3.36	79.8	13.4	0.53	629.3	272.79	1353.6	161.38
2015-16	-137.17	0.519	3.21	72.2	14.0	0.46	621.1	215.36	1325.0	132.23
2016-17	582.99	0.494	3.15	76.8	13.7	0.47	623.8	123.38	1334.9	142.92
2017-18	37.17	0.474	3.13	81.3	13.6	0.53	634.2	168.73	1311.1	124.11
2018-19	32.49	0.487	3.25	68.8	13.3	0.46	604.9	162.94	1325.4	118.38
2019-20	83.71	0.464	3.35	*	*	*	596.2	145.93	1344.7	112.46
Average	88.74	0.48	3.22	66.38	13.70	0.47	614.39	140.20	1293.01	110.09
Standard Deviation	167.67	0.16	0.20	12.20	0.58	0.05	18.93	46.03	43.93	26.63

* No carcass data was collected in May 2020 due to Covid 19 pandemic

Northern-Hardy Fruit Evaluation Project: Drought Returns, SWD Persists

Kathy Wiederholt

In 2020, the Northern-Hardy Fruit Evaluation Project provided distance learning for approximately 950 people through videos and video conference programs. We served over 100 people and educators in-state as well as from Iowa, Michigan, Minnesota, Montana and Tennessee through calls and email. Current research is concentrating on selecting better haskap cultivars for North Dakota's growing conditions through collaboration with the only North American breeder of Japanese haskaps.

In fall 2019, we received 13.1" of rain which included a deluge of 3.6" of rain September 20-21. A blizzard, October 10-12, dropped 20" of snow which melted over the next weeks when temperatures returned to normal. The CREC orchard went into winter 2019-20 with an abundance of moisture. On November 11, the temperature plunged and for three days, lows were 0 to -4.5°F. Red currant and some apple production were affected.

Winter high temperatures were about normal, but low temperatures were 2.5 degrees warmer. Typical snowfall began in November and was enough to blanket the orchard plants. Spring high temperatures were over 5°F cooler than average, leading to later blossoming and delayed development of most orchard fruit for a second year in a row. Rainfall was extremely short this year. Irrigation efforts began in June and continued through October. At 9.4", the April through October rainfall left us 7.6" below average and in "severe drought" conditions.

Spotted wing Drosophila (SWD) fruit flies were detected June 25 in fallen haskap fruit. Our spray program began on June 29 and continued weekly until early August. Infestation of haskap, Juneberry and early cherry was reduced but not completely eliminated. Black currants were heavily affected. The spray program will begin earlier in 2021.

Notable events in the fruit orchard:

- Fruit harvests were limited to reduce exposure of staff to the novel coronavirus.
- Data was collected for 21 new Japanese haskap plants. Older plants were pruned by one-third and were not netted or harvested.
- 'Juliet' cherry was harvested July 13 in good condition. Evans cherry was almost ripe July 30 but was a complete loss to SWD. 'Romeo' and our single unnamed plant lost most of their few fruits to birds and SWD affected these varieties.
- Juneberry fruit was ready for harvest July 6. The crop was heavy despite removal of older branches by spring pruning. Volunteers and students harvested the crop until SWD and desiccation of 'Smoky' fruit caused us to discard the last of the fruit.
- Two of three red currant varieties did not have a crop in 2020 due to the sudden cold temperatures in November 2019.
- Black currant fruit was again affected by SWD ovipositioning. The egg does not seem to be able to develop into larvae, but the loss of skin integrity causes the berry to shrivel and fall.
- 'Zestar!' and 'Sweet 16' apple had very small crops while 'Honeycrisp' apples were abundant. The November 2019 freeze is the suspected cause.
- The aronia crop faded as drought conditions persisted. A large crop in spring was reduced to a small harvest in fall despite irrigation.

Haskap flowering.

Northern Hardy Fruit Project - Yearly Production Records										
		No. of plants	2017		2018		2019		2020	
			Date	pounds	Date	pounds	Date	pounds	Date	pounds
Apples	Haralred	4	5-Oct	x	3-Oct	x	9-Oct	181.0	13-Oct	83.7
	Hazen	3	31-Aug	x	28-Aug	262.0	18-Sep	218.4	10-Sep	200.3
	Sweet Sixteen	4	3-Oct	x	3-Oct	119.1	9-Oct	157.0	13-Oct	14.8
	Honey Crisp	6	28-Sep	x	28-Sep	431.3	9-Oct	209.5	12-Oct	418.0
	Zestar	4	9-Jan	x	28-Aug	146.0	18-Sep	199.9	11-Sep	24.0
*** All apples are thinned to apx.*						**958.4**		**965.7**		**740.8**
one fruit per cluster.			*Weight not recorded*		*HR- not recorded*		*Forced harvest. Snow 10/10*			
Aronia	Nero	4	12-Sep	12.6	10-Sep	105.8	17-Sep	19.4	19-Sep	26.3
	Raintree Seedling	4	x	x	12-Sep	70.3	18-Sep	11.8	10-Sep	15.1
	Raintree Select	4	13-Sep	7.4	31-Aug	94.2	13-Sep	23.0	11-Sep	14.4
	Viking	4	12-Sep	4.5	22-Aug	105.7	16-Sep	27.8	14-Sep	NA
	McKenzie	4	11-Sep	5.1	28-Aug	78.0	16-Sep	37.0	14-Sep	NA
	Galicjanka	4	5-Sep	1.0	27-Aug	29.0	13-Sep	23.9	12-Sep	4.3
				30.6		**483.0**		**142.9**		**(60.1)**
			Crop aborted		*Overcropped*		*Hail, SWD loss*		*Drought, fruit dropped*	
									NA= samples removed	
Hardy Cherries	SK Romeo	3					31-Jul	11.5	26-Jul	*Birds*
	SK Not Romeo	1					19-Jul	8.2	21-Jul	*Birds*
	SK Juliet	5					17-Jul	46.2	13-Jul	41.0
								65.9		**41.0**
							SWD loss			
	Evans / Bali	2	8/1-2	x	7/20	x	30-Jul	**53.5**	30-Jul	*SWD loss*
			SWD infested (all)		*SWD infested (all)*		*Heavy pruning + SWD loss*		*Still SWD loss in all*	
Black Currant	*Blackcomb*	15	31-Jul	67.2	7-Aug	60.9	14-Aug	61.7	13-Aug	48.2
New	*Cheakamus*	15	28-Jul	79.7	31-Jul	79.8	7-Aug	63.9	5-Aug	19.2
Variety Trial	*Stikine*	15	26-Jul	115.4	7/18-24	52.2	7/31-8/5	58.1	8-5	12.4
	Tahsis	15	26-Jul	77.6	26-Jul	83.5	7/31-8/6	76.9	30-Jul	47.6
	Tiben	15	8-Aug	88.0	6-Aug	82.2	16-Aug	79.2	14-Aug	64.0
	Tofino	14	1-Aug	45.9	8-Aug	14.3	*Removed*	*Removed*	*Removed*	*Removed*
	Nechako - 2 ft space	7	11-Aug	21.5	9-Aug	12.7	20-Aug	14.4	13-Aug	6.8
	Nechako - 3 ft space	7	11-Aug	26.6	9-Aug	18.6	20-Aug	25.4	13-Aug	9.4
				521.9		**404.2**		**379.6**		**207.6**
			some SWD		*Borer prune, some SWD*		*Pruning Spring +Summer*		*SWD, summer pruning*	
Black Currant	Ben Lomand	4	x	x	25-Jul	4.9	30-Jul	7.2	27-Jul	3.4
	Blackcomb	4	x	x	1-Aug	17.6	15-Aug	38.3	12-Aug	19.8
	Champion	4	x	x	25-Jul	11.5	30-Jul	9.6	30-Jul	6.4
	Minaj Smyriou	4	x	x	18-Jul	5.5	x	*SWD loss*	27-Jul	6.6
				0.0		**39.5**		**55.1**		**36.2**
Japanese	20-04	3	7-Jul	12.8	26-Jun	3.2	*Fruit fell early*	x	*did not pick*	x
Haskap	21-20	3	12-Jul	4.3	2-Jul	5.9	12-Jul	NA	*did not pick*	x
2012	22-14	3	7-Jul	8.2	28-Jun	6.5	10-Jul	4.8	*did not pick*	x
	22-26	3	7-Jul	12.0	26-Jun	8.9	12-Jul	NA	*did not pick*	x
	41-75	3	4-Jul	15.7	27-Jun	15.8	8-Jul	10.3	*did not pick*	x
	44-19	3	12-Jul	9.4	2-Jul	7.1	12-Jul	NA	*did not pick*	x
	57-49	3	11-Jul	13.0	2-Jul	10.1	10-Jul	21.8	*did not pick*	x
	88-92	3	4-Jul	6.3	27-Jun	6.2	8-Jul	5.8	*did not pick*	x
	88-102	2	4-Jul	5.8	26-Jun	4.7	5-Jul	12.9	*did not pick*	x
	108-23	3	6-Jul	17.0	26-Jun	8.9	5-Jul	18.0	*did not pick*	x
	131-08	3	12-Jul	10.8	5-Jul	8.7	12-Jul	NA	*did not pick*	x
	142-30	3	10-Jul	6.8	28-Jun	5.7	10-Jul	9.5	*did not pick*	x
	78-89	2	7-Jul	0.8	5-Jul	3.5	10-Jul	4.7	*did not pick*	x
				122.9		**95.2**		**(87.8)**	*Covid +*	
			Excellent Bbee popl.				*NA= qwk pick bc of SWD*		*Heavy prune; left to birds*	

Northern Hardy Fruit Project - Yearly Production Records (cont.)										
		No. of plants	**2017**		**2018**		**2019**		**2020**	
			Date	pounds	Date	pounds	Date	pounds	Date	pounds
Japanese	21-17	2							13-Jul	0.5
Haskap	67-95	1							13-Jul	1.7
2017	100-22	1							29-Jun	1.3
	108-42	2							2-Jul	3.3
	110-26	2							2-Jul	1.4
	120-10	2							2-Jul	1.0
	120-14	2							29-Jun	1.6
	120-16	2							5-Jul	2.7
	122-03	2							11-Jul	0.9
	122-12	2							7-Jul	1.4
	122-16	1							29-Jun	0.2
	123-05	2							7-Jul	2.3
	125-04	1							NA	x
	132-09	2							29-Jun	0.2
	132-10	1							6-Jul	x
	132-13	1							29-Jun	0.5
	132-14	2							29-Jun	1.2
	139-24	2							5-Jul	3.2
	142-31	2							13-Jul	0.5
	144-04	1							2-Jul	0.5
	145-10	2							7-Jul	x
										24.4
									1st year of production	
Rus. Honeyberry	Berry Blue	4	28-Jun	23.6	*did not pick*	x	*did not pick*	x	*did not pick*	x
	Blue Belle	4	19-Jun	21.8	*did not pick*	x	*2-Jul*	28.0	*did not pick*	x
	Blue Moon	4/ **2** 2016	*did not pick*	x	*removed*	removed	*removed*	removed	*removed*	removed
	Blue Velvet	4/ **2** 2016	*did not pick*	x	*removed*	removed	*removed*	removed	*removed*	removed
	Kamchatka	4	*did not pick*	x	*did not pick*	x	*did not pick*	x	*did not pick*	x
	Cinderella	4	*did not pick*	x	*removed*	removed	*removed*	removed	*removed*	removed
				45.4		**0.0**		**28.0**		
			Excellent Bbee popl.				*Left for birds*		*Left for birds*	
Haskaps	Borealis	4/ **2** 2016	26-Jun	9.6	22-Jun	0.2	*did not pick*	x	*did not pick*	x
- Canadian	Tundra	5/ **3** 2016	27-Jun	17.7	21-Jun	4.8	*did not pick*	x	*did not pick*	x
	Indigo Gem (9-15)	5/ **4** 2016	27-Jun	20.9	21-Jun	3.6	*did not pick*	x	*did not pick*	x
	Indigo Treat (9-91)	5/ **2** 2016	29-Jun	6.9	21-Jun	3.7	*did not pick*	x	*did not pick*	x
	Aurora	1			2-Jul	0.3	*did not pick*	x	*did not pick*	x
				55.1		**12.6**		**0.0**		
			Excellent Bbee popl.				*Left for birds*		*Left for birds*	

Haskap/honeyberry.

Weather Summary

Monthly Temperatures (°F) and Normals

	Max Temp				Min Temp				Monthly Avg. Temp			
Month	2020	Norm*	2019	2018	2020	Norm*	2019	2018	2020	Norm*	2019	2018
Apr	48	55	51	44	26	31	31	23	37	37	41	33
May	63	68	63	75	41	43	38	46	52	54	50	61
June	81	76	77	79	55	53	53	57	68	63	65	68
July	81	82	80	81	60	58	58	56	71	65	69	68
Aug	79	81	75	81	56	55	53	52	67	65	64	67
Sept	70	71	68	67	44	45	48	42	57	58	58	55
Avgs:	70	72	69	71	47	47	47	48	59	57	58	59

*Normals = 1981-2010 averages

Monthly Precipitation (in) and Normals

	2020 Monthly Precipitation*				
Month	NDAWN	NOAA	Normal[1]	2019	2018
Apr	0.45	0.95	1.17	0.92	0.06
May	1.18	1.48	2.76	1.46	1.28
June	1.23	0.71	3.77	3.00	4.63
July	5.00	5.97	3.39	3.64	2.65
Aug	1.06	1.23	2.31	3.08	0.24
Sept	0.13	0.17	1.91	8.26	0.75
Totals:	9.04	10.51	15.31	20.36	9.61

[1] Normals = 1981-2010 averages * NDAWN and NOAA are two different weather stations at the CREC.

Monthly Growing Degree Days and Normals

	Wheat GDD				Sunflower GDD				Corn GDD			
Month	2020	Norm*	2019	2018	2020	Norm*	2019	2018	2020	Norm*	2019	2018
Apr	274	357	308	225	---	---	---	---	---	---	---	---
May	641	736	593	872	333	386	303	575	222	282	202	431
June	1081	982	986	1085	721	626	630	725	536	448	458	544
July	1193	1182	1141	1130	821	810	769	758	625	624	585	573
Aug	1097	1119	980	1070	725	747	610	704	539	561	444	515
Sept	762	775	788	685	434	437	441	383	312	320	298	273
Totals	5048	5155	4796	5026	3034	3006	2753	2914	2234	2235	1987	2336

*Normals = 1981-2010 averages

Growing season GDD Totals, Normals, and Killing Frost Dates

Year	Frost Date	Corn Temp (°F)	Total GDD	Frost Date	Sunflower Temp (°F)	Total GDD
2018	Sept 28	27	2336	Sept 28	27	3142
2019	*Oct 2	32	1987	**Oct 10	29	2637
2020	*Sept 8	29	2002	**Sept 9	27	2496
*Normal Corn GDD for date =			2020	**Normal Sunflower GDD for date =		2513
Total corn GDD = May 1 to frost date				Total sunflower GDD = May 20 to frost date		

Normals=1981-2010 averages Source: NDAWN

Agronomic Research Trials

The following information is a listing of agronomic research conducted at the Carrington Research Extension Center. CREC and other NDSU research staff provide this list to illustrate specific research issues that are being addressed. The listing briefly describes the trial and indicates project collaborators who are working in cooperation with CREC agronomy team leaders. Results of this work may be made available at a later date by contacting the CREC.

Cover Crop

Corn: Corn cover crop grazing experiment; *North Central Region Sustainable Agriculture Research and Education*
Dry bean: Pinto bean with rye cover/companion; *Northarvest Bean Growers Assoc.*
Greenhouse: Rye cover crop establishment from aerial seeding with varying levels of precipitation
Greenhouse: Turnip cover crop establishment from aerial seeding with varying levels of precipitation
Soybean: Evaluation of rye seeding rate by planting date; *North Dakota Soybean Council*
Soybean: Winter rye cover crop management techniques for soybean - Tri-County (Wishek); *North Dakota Soybean Council*
Wheat: Wheat cover crop grazing experiment; *North Central Region Sustainable Agriculture Research and Education*
Wheat: Legume interseeding – year 2 test crop

Crop Fertility

Canola: Optimizing nitrogen and sulfur application strategies to improve canola production
Corn: Jump starting corn mycorrhizal colonization
Corn: Phosphorus in corn/soybean rotation
Corn: Potassium effect on corn performance (3); *North Dakota Corn Utilization Council*
Corn: Sensor-based fertility management for corn
Corn: Sensor-based fertility management for corn - Fingal
Corn: Sensor-based fertility management for corn on dryland – Oakes
Corn: Sensor-based fertility management for corn under irrigation - Oakes
Corn: Starter fertilizer evaluation; *North Dakota Corn Utilization Council*
Corn: Sulfur and nitrogen fertilization effect on corn – dryland
Corn: Sulfur and nitrogen fertilization effect on corn – irrigated
Corn: Sulfur and nitrogen fertilization effect on corn – Oakes
Corn: Yield response of dryland corn to split N application at V8 and tasseling; *North Dakota Corn Utilization Council*
Corn: Yield response of dryland corn to split N application at V8 and tasseling on dryland at Oakes; *North Dakota Corn Utilization Council*
Corn: Yield response of irrigated corn to split N application at V8 and tasseling; *North Dakota Corn Utilization Council*
Corn: Yield response of irrigated corn to split N application at V8 and tasseling – Oakes; *North Dakota Corn Utilization Council*
Dry bean: Pinto bean starter and foliar fertilizer; *Northarvest Bean Growers Assoc.*
Greenhouse: Phosphorus fertilization of wheat under different soil moisture conditions
Soybean: Phosphorus fertilization of soybean at different planting dates - dryland
Soybean: Phosphorus fertilization of soybean at different planting dates - irrigated
Wheat: Phosphorous by zinc antagonism
Wheat: Predicting protein content of irrigated wheat using remote sensors
Wheat: Predicting protein content of wheat using sensors - dryland
Wheat: Sensor based fertility management for wheat - Oakes
Wheat: Sensor based fertility management for wheat - Eddy County
Wheat: Sensor based fertility management for wheat - Wishek
Wheat: Dryland zinc fortification
Wheat: Irrigated zinc fortification

Crop Management
Alfalfa: Organic alfalfa establishment with oats as nurse crop/genetics and harvest timing; *General Mills*
Barley: Cropping systems experiment - rotation, tillage, and fertility
Corn: Cropping systems experiment - rotation, tillage, and fertility
Corn: Evaluation of the 60-inch row strategy in North Dakota corn; *North Dakota Corn Utilization Council*
Corn: SHARE farm - tillage and soil health; *Wick (Soil Science)*
Dry Bean: Dry bean performance adjacent to native pollinator habitat (4); *Adams (School of Natural Resource Sciences)*
Dry bean: Pinto bean row spacing and population; *Northarvest Bean Growers Assoc./Hanson (Langdon REC)*
Field Pea: Cropping systems experiment - rotation, tillage, and fertility
Field Pea: Organic seeding rate trial
Field Pea: Timing of POST nitrogen application for protein; USDA *Specialty Crop Block Grant*
Flax: Organic perennial flax crop management trial; *Hulke (USDA)/Johnson/Gramig (Plant Sciences)*
Intercropping: Chickpea and flax intercropping seeding rate x fungicide; *Jacobs (Williston REC)*
Intercropping: Field pea and canola intercropping seeding rate x N; *Jacobs (Williston REC)*
Intercropping: Field pea intercropping variety trial; *Valesco Genetics*
Intercropping: Soybean and canola intercropping trial
Misc: Field pea and lentil tolerance to water logging - dryland; *SBARE New and Emerging Crops*
Misc: Field pea and lentil tolerance to water logging - irrigated; *SBARE New and Emerging Crops*
Misc: Hail insurance demonstration plots; *Natl. Assoc. of Underwriting Agents*
Oats: Organic intercropping with pea types and rates; *General Mills*
Oats: Organic oat phenotype cart evaluations; *General Mills/Google X*
Rye: Organic seeding rate
Soybean: Cropping systems experiment - rotation, tillage, and fertility
Soybean: Soybean and winter rye water use; *North Dakota Soybean Council*
Soybean: Soybean early planting date demonstration; *BASF*
Sunflower: Cropping systems experiment - rotation, tillage, and fertility
Wheat: Cropping systems experiment - rotation, tillage, and fertility
Wheat/Flax: Organic wheat/flax intercropping trial
Winter Wheat: Cropping systems experiment - rotation, tillage, and fertility

Entomology
Wheat: Wireworm management through seed treatments; *BASF*

Forage Production
Forages: Cereal forage trial - cool season; *Industry/McMullen (Plant Sciences)*
Forages: Cereal/pea forage trial; *Pulse USA*
Forages: Forage/cover crop pea variety trial; *Industry*
Forages: Winter triticale forage trial; *Northern Seed*
Misc: Annual forage evaluation - Wishek; *Sedivec (Central Grasslands REC)*

Product Evaluation
Barley: Foliar Badge for early season use in barley; *Gowan*
Canola: Evaluation of foliar applied products in canola; *Lallemand*
Canola: Evaluation of SymTRX as a multinutrient fertilizer in canola; *Anuvia*
Corn: Biological in-furrow products in corn; *Ag Concepts*
Corn: Formulation screening for biologicals; *Ag Concepts*
Corn: Aquayield product evaluation in corn; *Aquayield*
Corn: Product evaluation in corn; *Heliae*
Corn: Plant nutrient and growth stimulator product evaluation in corn; *IQ2grow*
Corn: Polymer-coated urea evaluation in corn; *Renuvix LLC*
Corn: Broadcast product comparison in corn; *West Central*

Corn: Corn infurrow biostimulants (2); *West Central*
Field Pea: Field pea inoculant treatment screening; *Loveland Products*
Field Pea: Plant nutrient and growth stimulator product evaluation in field pea; *IQ2grow*
Hemp: Effect of seed coating on stand establishment; *Germains*
Lentil: Lentil inoculant formulations; *Loveland Products*
Lentil: Lentil seed treatment evaluation; *USDA/Miller (Montana State Univ.)*
Lentil: Lentil special input trial; *USDA/Miller (Montana State Univ.)*
Misc: Evaluation of nitrogen efficiency enhancer product (eNhance) on bare ground; *AgroLiquid*
Soybean: Evaluation of inoculants on soybean; *Lallemand*
Soybean: Product evaluation in soybean; *Heliae*
Soybean: Phosphorus fertilization of soybean using distillers by-products – dryland; *North Dakota Soybean Council*
Soybean: Phosphorus fertilization of soybean using distillers by-products – irrigated; *North Dakota Soybean Council*
Soybean: Plant nutrient and growth stimulator product evaluation in soybean; *IQ2grow*
Soybean: Soybean infurrow biostimulants evaluation; *West Central*
Soybean: Soybean seed treatment biostimulants evaluation; *West Central*
Sunflower: Effect of seed coating on stand establishment and yield in confection hyrbids; *Germains*
Sunflower: Effect of seed coating on stand establishment and yield in oil hybrids; *Germains*
Wheat: Effects of N extenders (ANVOL, Agrotain Advanced1.0) on wheat performance - dryland; *Koch Agronomic Services*
Wheat: Effects of N extenders (ANVOL, Agrotain Advanced1.0) on wheat performance - irrigated; *Koch Agronomic Services*
Wheat: Evaluation of fertility products on wheat; *Invictis*
Wheat: Evaluation of SymTRX as a multinutrient fertilizer in wheat; *Anuvia*
Wheat: Foliar application of phosphorus products; *Yara*
Wheat: Plant nutrient and growth stimulator product (IQ2grow) evaluation in wheat; *IQ2grow*
Wheat: Polymer coated slow release urea product evaluation; *Pursell*
Wheat: Polymer coated urea evaluation in wheat; *Renuvix*

Plant Pathology
Barley: Fungicide applications for disease control in barley
Canola: Evaluation of biological seed treatments in canola; *BASF*
Canola: Evaluation of foliar fungicides for management of white mold in canola; *Gowan*
Canola: Evaluation of foliar fungicides for management of white mold in canola; *Syngenta*
Canola: Evaluation of fungicide seed treatments for management of Fusarium root rot in canola; *BASF*
Canola: Evaluation of fungicide seed treatments for management of Rhizoctonia root rot in canola; *BASF*
Chickpea: Evaluation of foliar fungicides for management of Ascochyta blight in chickpeas; *BASF*
Chickpea: Evaluation of foliar fungicides for management of Ascochyta blight in chickpeas; *Nichino*
Chickpea: Evaluation of foliar fungicides for management of Ascochyta blight in chickpeas - tank-mix strategies with chlorothalonil, Carrington; *Northern Pulse Growers Assoc./ND Crop Protection Product Harmonization and Registration Board*
Chickpea: Evaluation of foliar fungicides for management of Ascochyta blight in chickpeas - tank-mix strategies with chlorothalonil, Hofflund; *Northern Pulse Growers Assoc./ND Crop Protection Product Harmonization and Registration Board*
Chickpea: Evaluation of seed treatments for management of seed-borne Ascochyta in chickpeas; *Valent USA*
Chickpea: Evaluation of the impact of spray droplet size on the efficacy of foliar fungicides for management of Ascochyta blight in chickpeas, TeeJet nozzles; *Northern Pulse Growers Assoc./ND Crop Protection Product Harmonization and Registration Board*
Chickpea: Evaluation of the impact of spray droplet size on the efficacy of foliar fungicides for management of Ascochyta blight in chickpeas, Wilger nozzles; *Northern Pulse Growers Assoc./ND Crop Protection Product Harmonization and Registration Board*

Chickpea: Evaluation of the impact of spray volume on the efficacy of foliar fungicides for management of Ascochyta blight in chickpeas; *Northern Pulse Growers Assoc./ND Crop Protection Product Harmonization and Registration Board*
Dry Bean: Evaluation of foliar fungicides for management of white mold in dry beans; *BASF/Gowan*
Dry Bean: Evaluation of foliar fungicides for management of white mold in dry beans; *Bayer CropScience*
Dry Bean: Evaluation of foliar fungicides for management of white mold in dry beans; *Nichino*
Dry Bean: Evaluation of fungicide seed treatments for management of Rhizoctonia root rot in dry beans; *McGregor and Company*
Dry Bean: Evaluation of fungicide seed treatments for management of Rhizoctonia root rot in kidney beans; *Albaugh*
Dry Bean: Evaluation of fungicide seed treatments for management of white mold in dry beans; *McGregor and Company*
Dry Bean: Evaluation of in-furrow fungicides and seed treatments for management of Rhizoctonia root rot in pinto beans; *Bayer CropScience*
Dry Bean: Evaluation of seed treatments for management of seed-borne anthracnose in pinto beans; *Valent USA*
Dry Bean: Evaluation of seed treatments on pinto bean seed carrying seed-borne Sclerotinia; *Syngenta*
Dry Bean: Evaluation of seed treatments on pinto bean seed carrying seed-borne Sclerotinia; *Valent USA*
Dry Bean: Evaluation of the impact of spray droplet size on the efficacy of foliar fungicides for management of white mold in dry beans, TeeJet nozzles; *Northarvest Bean Growers Assoc./ND Crop Protection Product Harmonization and Registration Board*
Dry Bean: Evaluation of the impact of spray droplet size on the efficacy of foliar fungicides for management of white mold in dry beans, Wilger nozzles; *Northarvest Bean Growers Assoc./ND Crop Protection Product Harmonization and Registration Board*
Dry Bean: Evaluation of the impact of spray volume on the efficacy of foliar fungicides for management of white mold in dry beans; *Northarvest Bean Growers Assoc./ND Crop Protection Product Harmonization and Registration Board*
Dry Bean: Impact of rye cover crop, row spacing and seeding rate on pinto and kidney bean agronomic performance under white mold pressure - Carrington; *USDA Specialty Crop Block Grant Program*
Dry Bean: Impact of rye cover crop, row spacing and seeding rate on pinto and kidney bean agronomic performance under white mold pressure - Oakes; *USDA Specialty Crop Block Grant Program*
Dry Bean: Optimizing fungicide application timing for improved manangement of white mold in black beans; *USDA Specialty Crop Block Grant Program*
Dry Bean: Optimizing fungicide application timing for improved manangement of white mold in kidney beans; *USDA Specialty Crop Block Grant Program*
Dry Bean: Optimizing fungicide application timing for improved manangement of white mold in navy beans; *USDA Specialty Crop Block Grant Program*
Dry Bean: Optimizing fungicide application timing for improved manangement of white mold in pinto beans; *USDA Specialty Crop Block Grant Program*
Dry Bean: Optimizing fungicide application timing for improved manangement of white mold in pinto beans - Oakes; *USDA Specialty Crop Block Grant Program*
Dry Bean: Optimizing row spacing and seeding rate for improved agronomic performance of black beans under white mold pressure; *USDA Specialty Crop Block Grant Program*
Dry Bean: Optimizing row spacing and seeding rate for improved agronomic performance of kidney beans under white mold pressure; *USDA Specialty Crop Block Grant Program*
Dry Bean: Optimizing row spacing and seeding rate for improved agronomic performance of navy beans under white mold pressure; *USDA Specialty Crop Block Grant Program*
Dry Bean: Optimizing row spacing and seeding rate for improved agronomic performance of pinto beans under white mold pressure; *USDA Specialty Crop Block Grant Program*
Dry Bean: Screening of dry bean breeding lines for resistance to white mold; *USDA National Sclerotinia Initiative/Everhart (Univ. of Nebraska-Lincoln)*
Durum: Management of leaf and head diseases with fungicides; *Bayer CropScience*

Durum: USWBSI uniform fungicide efficacy trial; *Friskop (Plant Pathology)*
Faba Bean: Evaluation of seed treatments for management of seed-borne Botrytis in faba beans *Syngenta*
Faba Bean: Evaluation of seed treatments for management of seed-borne Botrytis in faba beans; *Valent USA*
Field Pea: Evaluation of fungicide seed treatments for management of Fusarium root rot in field peas; *Albaugh*
Field Pea: Evaluation of foliar fungicides for management of Ascochyta blight in field peas; *BASF*
Field Pea: Evaluation of foliar fungicides for management of Ascochyta blight in field peas; *Syngenta*
Field Pea: Evaluation of planting date and seed treatments for management of Fusarium and Aphanomyces root rot in field peas - Carrington, no-till production; *Northern Pulse Growers Assoc./ND Crop Protection Product Harmonization Board and Registration Board*
Field Pea: Evaluation of planting date and seed treatments for management of Fusarium and Aphanomyces root rot in field peas - on-farm site in McLean County; *USDA Specialty Crop Block Grant Program*
Field Pea: Evaluation of planting date and seed treatments for management of Fusarium and Aphanomyces root rot in field peas - on-farm site in Mountrail County; *USDA Specialty Crop Block Grant Program*
Field Pea: Evaluation of planting date and seed treatments for management of Fusarium and Aphanomyces root rot in field peas - on-farm site in Williams County; *USDA Specialty Crop Block Grant Program*
Field Pea: Evaluation of Rhizoctonia inoculants in field peas; *BASF*
Field Pea: Evaluation of seed treatments for management of Fusarium and Aphanomyces root rot in field peas; *Bayer*
Field Pea: Evaluation of seed treatments for management of Fusarium and Aphanomyces root rot in field peas - on-farm site in McLean County; *Syngenta*
Field Pea: Evaluation of seed treatments for management of Fusarium and Aphanomyces root rot in field peas - on-farm site in Mountrail County; *Syngenta*
Field Pea: Evaluation of seed treatments for management of Fusarium and Aphanomyces root rot in field peas; *Syngenta*
Field Pea: Impact of crop rotation and fungicide seed treatment on management of Fusarium and Aphanomyces root rots in field peas; *Northern Pulse Growers Assoc./ND Crop Protection Product Harmonization and Registration Board*
Lentil: Evaluation of foliar fungicides for management of anthracnose in lentils; *Corteva*
Lentil: Evaluation of planting date and seed treatments for management of Fusarium and Aphanomyces root rot in lentils - Carrington, conventional tillage; *USDA Specialty Crop Block Grant Program*
Lentil: Evaluation of planting date and seed treatments for management of Fusarium and Aphanomyces root rot in lentils - Carrington, no-till production; *USDA Specialty Crop Block Grant Program*
Lentil: Evaluation of planting date and seed treatments for management of Fusarium and Aphanomyces root rot in lentils - on-farm site in McLean County; *USDA Specialty Crop Block Grant Program*
Lentil: Evaluation of planting date and seed treatments for management of Fusarium and Aphanomyces root rot in lentils - on-farm site in Mountrail County; *USDA Specialty Crop Block Grant Program*
Lentil: Evaluation of planting date and seed treatments for management of Fusarium and Aphanomyces root rot in lentils - on-farm site in Williams County; *USDA Specialty Crop Block Grant Program*
Lentil: Evaluation of planting date and seed treatments for management of Fusarium root rot in lentils - Carrington; *USDA Specialty Crop Block Grant Program*
Lentil: Evaluation of planting date and seed treatments for management of Fusarium root rot in lentils - Oakes; *USDA Specialty Crop Block Grant Program*
Lentil: Evaluation of Rhizoctonia inoculants in lentils; *BASF*
Lentil: Evaluation of seed treatments for management of Rhizoctonia root rot in lentils; *Syngenta*
Lentil: Lentil anthracnose foliar fungicide evaluation; *BASF*
Soybean: Evaluation of foliar fungicides for management of white mold in soybeans; *ADAMA Ltd.*
Soybean: Evaluation of foliar fungicides for management of white mold in soybeans; *BASF*
Soybean: Evaluation of foliar fungicides for management of white mold in soybeans; *Bayer*

Soybean: Evaluation of foliar fungicides for management of white mold in soybeans; *Gowan*
Soybean: Evaluation of foliar fungicides for management of white mold in soybeans; *Syngenta*
Soybean: Evaluation of fungicide seed treatments on early-planted soybeans; *Valent USA*
Soybean: Evaluation of the impact of fungicide application interval on the management of white mold in soybeans; *North Dakota Soybean Council*
Soybean: Evaluation of the impact of spray droplet size on the efficacy of foliar fungicides for management of white mold in soybeans, TeeJet nozzles - Carrington; *North Dakota Soybean Council*
Soybean: Evaluation of the impact of spray droplet size on the efficacy of foliar fungicides for management of white mold in soybeans, TeeJet nozzles - Oakes; *North Dakota Soybean Council*
Soybean: Evaluation of the impact of spray droplet size on the efficacy of foliar fungicides for management of white mold in soybeans, Wilger nozzles - Carrington; *North Dakota Soybean Council*
Soybean: Evaluation of the impact of spray droplet size on the efficacy of foliar fungicides for management of white mold in soybeans, Wilger nozzles - Oakes; *North Dakota Soybean Council*
Soybean: Impact of application method and application frequency on the efficacy of foliar fungicides for the management of white mold in soybeans; *North Dakota Soybean Council*
Soybean: Impact of application method and application frequency on the efficacy of foliar fungicides for the management of white mold in soybeans - Oakes; *North Dakota Soybean Council*
Sunflower: Efficacy of bee-vectored Clonostachys roseae for management of Sclerotinia head rot in sunflowers - Carrington; *USDA Specialty Crop Block Grant Program*
Sunflower: Efficacy of bee-vectored Clonostachys roseae for management of Sclerotinia head rot in sunflowers - Langdon; *USDA Specialty Crop Block Grant Program/Chapara (Langdon REC)*
Sunflower: Efficacy of bee-vectored Clonostachys roseae for management of Sclerotinia head rot in sunflowers - on-farm; *USDA Specialty Crop Block Grant Program*
Sunflower: Evaluation of foliar fungicides for management of Sclerotinia head rot in sunflowers; *Syngenta*
Sunflower: Screening of sunflower germplasm and breeding lines for resistance to Sclerotinia head rot; *Underwood (USDA)*
Sunflower: USDA stalkrot nursery; *Miser (USDA)*
Wheat: Wheat biological seed treatment evaluation - hybrid wheat; *BASF*
Wheat: Evaluation of fungicides application timing for scab control; *BASF*
Wheat: Evaluation of fungicide standards in a systems approach; *BASF*
Wheat: Management of bacterial leaf streak in wheat; *Bayer CropScience*
Wheat: Management of leaf and head diseases with fungicides; *Bayer CropScience*
Wheat: CREC scab fungicide evaluation; *BASF*
Wheat: Evaluation of biological seed treatments in spring wheat; *BASF*
Wheat: Evaluation of fungicide seed treatments and seeding rate in hybrid wheat; *BASF*
Wheat: Evaluation of fungicide seed treatments for management of common root rot in spring wheat; *BASF*
Wheat: Evaluation of fungicide seed treatments for management of common root rot in spring wheat; *Bayer CropScience*
Wheat: Evaluation of fungicide seed treatments for management of common root rot in spring wheat; *Syngenta*
Wheat: Evaluation of fungicide seed treatments for management of common root rot in spring wheat; *Valent USA*
Wheat: Evaluation of fungicide seed treatments for management of Fusarium root rot in spring wheat; *BASF*
Wheat: Evaluation of fungicide seed treatments for management of Rhizoctonia root rot in spring wheat; *BASF*
Wheat: Foliar fungicide for scab and leafspot disease management - Wishek
Wheat: Integrated scab fungicide management trial; *U.S. Wheat and Barley Scab Initiative/Friskop (Plant Pathology)*

Seed Increase
Buckwheat: Increase of Devyatka a determinate variety; *Northern Plains Sustainable Agriculture Society FBC*
Buckwheat: Increase of an experimental buckwheat line
Field Pea: Seed increase; *Valesco Genetics*
Field Pea: Small-seeded green pea seed increase
Field Pea: Winter pea breeder nursery; *Kissing Kucek(USDA)*

Salinity
Barley: Barley variety tolerance to saline soils

Germplasm Evaluation/Cultivar Development
Barley: Barley breeder nurseries (3); *Horsley (Plant Sciences)*
Barley: Barnes County (Dazey) variety trial
Barley: Drill strip demonstration plots
Barley: Dryland variety trial
Barley: Irrigated variety trial
Barley: No-till variety trial
Barley: Organic variety trial
Barley: Tri-County (Wishek) variety trial
Buckwheat: Conventional variety trial
Buckwheat: Organic variety trial; *Northern Plains Sustainable Agriculture Society FBC/Organic Crop Improvement Assoc.*
Canola: Canola breeder nursery; *Rahman (Plant Sciences)*
Canola: Clearfield and Liberty Link performance test; *Industry*
Canola: Conventional canola performance test; *Industry*
Canola: Roundup Ready performance test; *Industry*
Chickpea: Chickpea variety trial; *Bandillo (Plant Sciences)/Worral (North Central REC)*
Corn: Dryland hybrid performance test; *Industry*
Corn: Dryland hybrid performance test - conventional lines; *Industry*
Corn: Evaluation of organic N-fixing hybrids; *Northern Plains Sustainable Agriculture Society FBC/Mandaamin Institute*
Corn: Fingal hybrid performance test; *Industry*
Corn: Irrigated hybrid performance test; *Industry*
Corn: Oakes dryland hybrid performance test; *Industry*
Corn: Oakes irrigated hybrid performance test; *Industry*
Corn: Organic hybrid performance test; *Alber Lea Seed*
Dry Bean: Dry bean breeder nursery; *Osorno (Plant Sciences)*
Dry Bean: Dryland variety trial
Dry Bean: Irrigated variety trial
Dry Bean: Tri-County (Wishek) variety trial; *CREC*
Durum: Drill strip demonstration plots
Durum: Dryland variety trial
Durum: No-till variety trial
Durum: Organic Variety Trial
Durum: Uniform Regional Durum Nursery - dryland; *Elias (Plant Sciences)*
Durum: Uniform Regional Durum Nursery - irrigated; *Elias (Plant Sciences)*
Einkorn: Organic variety trial
Emmer: Organic variety trial
Fababean: Dryland variety trial; *Industry*
Fababean: Evaluation of yield components of fababean; *AGRALYTICA/*Risk Management Admin.
Fababean: Variety trial
Field Pea: Breeder nursery - advanced yield trial; *Bandillo (Plant Sciences)/Worral (North Central REC)*
Field Pea: Field pea nursery; *Pulse USA*

Field Pea: Field pea primary yield trial nursery; *Bandillo (Plant Sciences)*
Field Pea: Organic variety trial and nursery; *Industry*
Field Pea: Variety trial - primary evaluation; *Bandillo (Plant Sciences)/Worral (North Central REC)*
Flax: Variety trial
Flax: Breeder nursery; *Rahman (Plant Sciences)*
Flax: Organic flax variety trial; *Ameriflax/Rickertsen (Hettinger REC)*
Forages: Winter rye forage variety trial
Hemp: Dryland variety trial; *Hanson (Langdon REC)*
Lentil: Breeder nursery - advanced yield trial; *Bandillo (Plant Sciences)/Worral (North Central REC)*
Lentil: Organic variety trial
Lentil: Variety trial; *Bandillo (Plant Sciences)/Worral (North Central REC)*
Lentil: Lentil germplasm screening; *Specialty Crop Research Initiative/Miller (Montana State Univ.)*
Lupin: Evaluation of advanced lupin selections
Lupin: Lupin multi-species variety evaluation
Mustard: Organic variety trial
Oats: Drill strip demonstration plots
Oats: Dryland variety trial
Oats: Midseason Oat Nursery; *McMullen (Plant Sciences)*
Oats: Oat breeder nursery; *McMullen (Plant Sciences)*
Oats: Organic breeder nursery; *Mitchell Fetch/Nilsen (Agri Food Canada)*
Oats: Organic early advanced yield trial nursery; *McMullen (Plant Sciences)*
Oats: Organic hexaploid yield trial; *Richter (General Mills)*
Oats: Organic rust sentinel evaluation; *Richter (General Mills)*
Oats: Organic SDSU Variety Trial; *Caffe-Treml (South Dakota State Univ.)*
Oats: Organic variety trial
Potatoes: Organic specialty type variety trial; *Carter Farms*
Rye: Organic winter rye variety trial
Rye: Winter rye variety trial
Safflower: Variety trial; *Miller/Bergman (Williston REC)*
Sorghum: Forage sorghum evaluation
Soybean: Barnes County (Dazey) conventional variety performance test and 20D19 breeder nursery; *Industry/Helms (Plant Sciences)*
Soybean: Barnes County (Dazey) Roundup Ready variety performance test; *Industry*
Soybean: Breeder Nursery: Expt. 20C14 glyphosate tolerant; *Helms (Plant Sciences)*
Soybean: Breeder Nursery: Expt. 20C15 glyphosate tolerant; *Helms (Plant Sciences)*
Soybean: Breeder Nursery: Expt. 20C16 advanced glyphosate - dryland; *Helms (Plant Sciences)*
Soybean: Breeder Nursery: Expt. 20C17 advanced conventional - dryland; *Helms (Plant Sciences)*
Soybean: Breeder Nursery: Expt. 20C18 tofu conventional; *Helms (Plant Sciences)*
Soybean: Breeder Nursery: Expt. 20D16 advanced glyphosate tolerant - Barnes County (Dazey); *Helms (Plant Sciences)*
Soybean: Breeder Nursery: Expt. 20D18 tofu conventional - Barnes County (Dazey); *Helms (Plant Sciences)*
Soybean: Breeder Nursery: Expt. 20I16 advanced glyphosate - irrigated; *Helms (Plant Sciences)*
Soybean: Breeder Nursery: Expt. 20I17 advanced conventional - irrigated; *Helms (Plant Sciences)*
Soybean: Breeder Nursery: Expt. 20I19 advanced donventional - 4th year - irrigated; *Helms (Plant Sciences)*
Soybean: Breeder Nursery: Expt. 20W16 advanded glyphosate tolerant - Tri-County (Wishek); *Helms (Plant Sciences)*
Soybean: Dryland conventional performance test and 20D19 breeder nursery; *Industry/Helms (Plant Sciences)*
Soybean: Dryland Roundup Ready variety performance test; *Industry*
Soybean: Dryland soybean agronomic performance trial - Carrington; *BASF*
Soybean: Dryland soybean agronomic performance trial - Oakes; *BASF*
Soybean: Irrigated conventional variety performance test; *Industry*

Soybean: Irrigated Roundup Ready variety performance test; *Industry*
Soybean: Irrigated soybean agronomic performance trial - Carrington; *BASF*
Soybean: Irrigated soybean agronomic performance trial - Oakes; *BASF*
Soybean: LaMoure conventional variety performance test; *Helms (Plant Sciences)*
Soybean: LaMoure Roundup Ready variety performance test; *Helms (Plant Sciences)*
Soybean: Oakes conventional variety performance test
Soybean: Oakes irrigated Roundup Ready variety performance test;
Soybean: Soybean agronomic performance trial - Barnes County (Dazey); BASF; *BASF*
Soybean: Soybean agronomic performance trial - Fingal; BASF; *BASF*
Soybean: Soybean agronomic performance trial - Tri-County (Wishek); *BASF*
Soybean: Tri-County (Wishek) Roundup Ready variety performance test; *Industry*
Soybean: Tri-County (Wishek) conventional variety performance test; *Industry*
Soybeans: Organic variety trial; *Albert Lea Seed*
Spelt: Organic variety trial
Sunflower: Non-oil sunflower hybrid performance test; *Industry*
Sunflower: Oil sunflower hybrid performance test; *Industry*
Sunflower: Sunflower hybrid nursery; *SunOpta*
Wheat: Barnes County (Dazey) variety trial
Wheat: Drill strip demonstration plots
Wheat: Dryland variety trial
Wheat: Irrigated variety trial
Wheat: No-till variety trial
Wheat: Organic variety trial
Wheat: Spring wheat breeder nursery; *Green (Plant Sciences)*
Wheat: Tri-County (Wishek) variety trial
Wheat: Uniform Regional Spring Wheat Nursery; *Garvin (USDA)*
Winter Wheat: Winter wheat elite breeder nursery; *Marais (Plant Sciences)*
Winter Wheat: Winter Wheat Variety Trial; *Marais (Plant Sciences)*

Weed Science
Barley: Weed Control with Luxxur herbicide; *Bayer CropScience*
Canola: Canola weed management systems with Warrant; *Baye CropSciencer*
Flax: Flax tolerance to POST herbicides; *Ameriflax/Jenks (North Central REC)*
Flax: Flax tolerance to PRE herbicides; *Ameriflax/Jenks (North Central REC)*
Flax: Organic perennial flax weed management trial; *Hulke (USDA)/Johnson/Gramig (Plant Sciences)*
Hemp: Hemp herbicide tolerance evaluation; *Gowan*
Misc: Broadleaf crop tolerance to preplant dicamba
Misc: Burndown options with Vida; *Gowan*
Misc: Glyphosate + glufosinate and Enlist antagonism screening
Misc: Herbicide site of action demonstration
Misc: Herbicide trait demonstration plots - corn; *BASF*
Misc: Herbicide trait demonstration plots - DT soybean; *BASF*
Misc: Herbicide trait demonstration plots - E3 soybean; *BASF*
Soybean: Residual herbicide impact on cover crops; *North Dakota Soybean Council/Howatt (Plant Sciences)*
Soybean: Soybean simulated herbicide drift; *Flores (Ag and Biosystems Engineering)*
Soybean: UAV weed resistance screening; *Sun (Ag and Biosystems Engineering)*
Wheat: Kochia management in wheat; *Bayer CropScience*

NDSU Carrington Research Extension Center Staff

Experiment Station

Blaine Schatz	Director/Agronomist
Mike Ostlie	Agronomist
Michael Wunsch	Plant Pathologist
Jasper Teboh	Soil Scientist
Bryan Neville	Animal Scientist
David Kramar	Precision Ag Specialist
Steve Zwinger	Research Specialist/Agronomy
Dave Copenhaver	Research Specialist/Seedstocks
Ezra Aberle	Research Specialist/Agronomy
Szilvia Yuja	Research Specialist/Soils
Suanne Kallis	Research Specialist/Pathology
Wayde Rodehorst	Research Specialist/Livestock
Jesse Hafner	Research Specialist/Pathology
Thomas Miorini	Post-Doctoral Research Assoc.
Tim Indergaard	Research Technician/Agronomy
Todd Ingebretson	Research Technician/Agronomy
Rick Richter	Research Technician/Seedstocks
Tim Schroeder	Research Technician/Livestock
Steve Schaubert	Research Technician/Agronomy
Scott Fetch	Research Technician/Seedstocks
Chad Richter	Research Technician/Seedstocks
Tom Smith	Research Technician/Agronomy
Dave Widmer	Research Technician/Agronomy
Jesse Nelson	Research Technician/Livestock
Billy Kraft	Research Technician/Seedstocks
Harley Burgard	Research Technician/Agronomy
Kathy Wiederholt	Fruit Project Manager
Melissa Hafner	Laboratory Manager
Mark Halvorson	Seasonal Research Assistant
Sam Richter	Seasonal Research Assistant
Rebecca Moore	Grad. Assistant/Livestock
Myrna Friedt	Administrative Assistant
Holly Cunningham	Part-time Administrative
Sabrina Cunningham	Part-time Administrative
Kalie Anderson	Part-time Program Assist.
Vern Anderson	Animal Scientist - Emeritus
Tami Snow	Part-time Custodian/Grounds

NDSU Extension

Greg Endres	Cropping Systems Specialist
Karl Hoppe	Livestock Systems Specialist
Mary Keena	Environmental Management
David Kramar	Precision Ag Specialist
Linda Schuster	Administrative Secretary

North Dakota Forest Service

Gerri Makay	Community Forestry Specialist

North Dakota Farm Business Management Education Program

Joel Lemer	Instructor/Coordinator
Steve Metzger	Instructor - Retired

Oakes Irrigation Research Site

Kelly Cooper	Research Agronomist
Seth Nelson	Research Specialist/Agronomy
Heidi Eslinger	Research Technician

Throughout the year, the Center hires individuals on a part-time basis to help in the research effort. Many of these are students and local residents. We would like to acknowledge the following who helped at some time during the year: Emma Aberle, Hunter Beumer, Kelly Bjerke, Taylor Braaten, Colton Buskness, Cayler Ellingson, Spencer Eslinger, Savanna Friedt, Sydney Friedt, Christine Halvorson, Jared Hartl, Tessa Hartl, Gabriela Henson, Peter Henson, Carsyn Hilbert, Coltyn Hilbert, Alexa Holth, Cassidy Holth, Emma Janz, Xavier Klocke, Mathias Kubal, Marlys Lange, Tristin Larson, Elizabeth Lee, Natasha Lesmann, Baylee Lura, Abby Makay, Lea Mittleider, Betty Montgomery, Jonathan Murphy, Aaron Neumiller, Austin Neumiller, Sean Nichols, Micah Nicolai, Ella Nowatzki, Travis Scanson, Tyler Scanson, Mikayla Schuldheisz, Cole Seaburg, Jacob Seaburg, Kylie Solwey, Kaitlyn Thompson, Jacie Volk, Alexis Wells, Gage Wells, and Larissa Wolff.

Advisory Board

Duane Burchill Sr.	Barnes County	Steve Metzger	Garrison Diversion
Donnie Buckmeier	Benson County	Matt Haugen	Griggs County
Tom Erdmann	Carrington	Alden Fitterer	Kidder County
	Dickey County	Lowell Berntson	LaMoure County
Dave Gehrtz	Eddy County	Tommy Gross	Logan County
Ryan Nagel	Emmons County	Barrett Herr	McIntosh County
Justin Topp	Foster County	Mike Huebner	Stutsman County
Mark Cook	Garrison Diversion	Kurt Bollingberg	Wells County

NDSU Carrington Research Extension Center

663 Hwy. 281 NE • PO Box 219
Carrington, ND 58421
701-652-2951 • fax 701-652-2055
www.ag.ndsu.edu/CarringtonREC/