MCCC-NORTH DAKOTA ANNUAL REPORT

April 2016 to February 2017

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COMPLETED RESEARCH

1) *New interseeder/side dressing drill (Breker, Oberlander, and Nowatzki)*

A cover crop interseeder (drill) was developed by Mr. Gene Breker, Amity Technology. The interseeder has 8 units, two twin rows spaced 15 cm (6 inches) apart in the center of two corn or soybean rows at 76 cm (30 inches) apart. The interseeder is a high clearance planter adapted to plant in V6 stage corn at the time of side dressing. It has a third wheel for the fertilizer (granular or liquid). The pilot planter was completed by the end of June 2016. (Fig. 1).

At Amity, engineers, Mr. Gene Breker and Jack Oberlander have been developing and marketing a single disc, direct seeding (no till) system for almost 10 years now. The original unit was designed with an average row spacing of 7 ½" for cereal crops but about 6 years ago, Joe and Gene Breker designed and built a drill with twin row 30" spacing for use on the farm, seeding soybeans in between last year's corn rows. We put residue managers on the drill that move the heavy, loose, surface residue away from the new 6" seed rows. It worked so well that we started using the drill as our strip till toolbar.

Over the past couple of years I met Mr. Breker at a meeting and brought up the subject of inter seeding cover crop in growing corn. He agreed to work with NDSU on a special project that allowed us to take the intercrop seeder project out of the normal company program and work with it on our own time. So as not to imply to the general public that Amity had a new drill we put different names on the research unit. We used all current Amity technology but redesigned the toolbar so that the openers would run "off row" in between the 30" corn rows. The inter crop seeder made for NDSU also has an opener assembly that runs between the two 6" seed rows and can side band nitrogen while seeding cover crop. This is something that is not possible with any other seeder ever made. We also made it so that it could be pulled 15" off center to allow it to go back on row so that the unit could be used to do its original job of seeding soybeans and strip tilling. The air cart has two bins and can deliver two different products to two different locations. This was done to give the seeder more value to the grower. The more it can do, the more value it has.

Because this seeder has a greater value to the grower, Amity feels that there may be a market for this with the general farming public. We have designed a drill that will do everything the NDSU research unit can do but will be up to 40' wide. Because of the early stages of the project, we cannot show any images of it but we should have a prototype for the field by late fall. We will continue to work with NDSU on operation and function of their unit during the research project.The pilot planter was used to interseed radish and rye mix in a total of approximately 100 acres at two locations, Morton and Rutland, ND (Fig. 2). Cover crops established well and provided cover in the fall after corn was harvested. No corn yield drag was observed and radish and rye established well (Fig. 3).

Fig. 1. Pilot twin row planter developed by Amity Technology International for the project. Photo Karen Hertsgaard

Fig. 2. New interseeder planting cover crops at V6 stage (Photo: Abbey Wick). Rye and radish established with the interseeeder. Photo taken August 16 (Photo: M. Berti)

Fig. 3. Radish and rye planted with new interseeder. Photo taken after corn harvest (Photo Abbey Wick).

2) Winter Rye Research at the Carrington, REC (Engel and Zwinger)

Using winter rye as a forage crop

The winter rye focus at the CREC is quite broad ranging from small plot research related to grain, forage, cover crop, weed control, and variety development to field scale seed and forage production. Winter rye has been evaluated as forage crop at the CREC demonstrating its value as reliable forage crop that provides cover and can extend the haying/grazing season. The use of winter rye as forage is a method of integrating cropland into a livestock system. In harsher northern climates like North Dakota, fall grazing of winter rye is limited although spring grazing is a possibility as rye is one of the first plants to initiate growth and accumulate biomass in the spring. Therefore advantages of using winter rye as a forage crop include the early spring growth along with an associated early harvest, providing an opportunity to sown a second crop for haying, grazing or cover cropping if adequate moisture and fertility levels are present. Average harvest dates of winter rye as a forage crop compared to other winter forages are presented in table 1. Average harvest date (10 year) compared to the past two growing season are presented illustrating differences within years.

 

Fig. 4. Spring growth of winter rye on April 14, 2008 at the CREC and winter rye at anthesis on June 7, 2010 at Carrington.

Spring stand data (not presented) illustrate that rye is the most winter hardy compared to the other winter cereals. Average harvest dates (table 1.) gathered over the years show the differences among the crop types in maturity. Forage treatment harvest dates were determined by the growth stage of the forage each year. Rye was harvested first, followed by triticale, wheat and then spelt. Harvest stage for all treatments was early to mid-anthesis or 5-10 days after heading depending on forage species. Results (table 2.) illustrate the relative yield differences among the winter cereal types trialed. Forage yields for winter rye, 2.5 ton/ac DM, are similar to winter wheat and triticale during the years of these trials. Forage yield of winter spelt is greater than the other winter cereals compared. This yield difference may in part be due to the later maturity of spelt. Rye tends to be lower in quality when compared to wheat or other crops used. Although significant quality differences exist they are minor comparing the crops. Winter wheat has the highest crude protein and TDN along with the lowest fiber values. Average protein for rye has been 11.5% with a TDN of 54. Relative Feed Value (RFV) which use multiple parameters to measure the forage quality show rye to be at 97.

Table 1. Forage harvest dates of winter cereals at the CREC.

Crop type	Average	2014	2015
Rye	6/12	6/23	6/8
Triticale	6/21	7/2	6/8
Wheat	6/24	6/26	6/16
Spelt	7/5	7/7	6/29

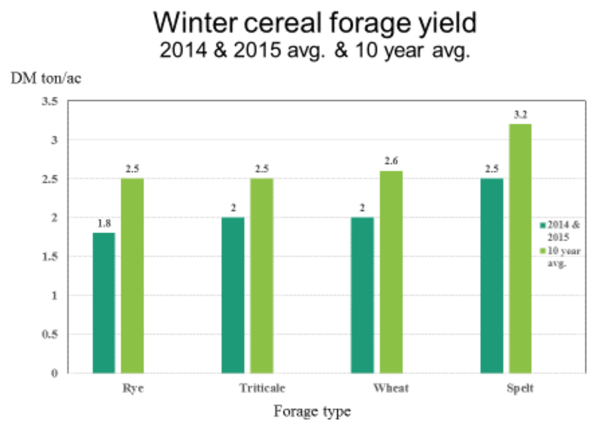

Fig. 5. Forage yields, tons/ac DM

Winter rye research at the CREC- Variety Development

Winter rye is hardiest winter cereal crop and can be planted later in the fall than other winter cereals. Winter rye germinates and grows at very low temperatures, the earliest winter cereal to grow in the spring and to reach seed maturity. Winter rye tends to require less inputs to raise, competing excellent with weeds and performing well under low fertility or moisture conditions along with providing reliable cover for erosion control. These traits are the reasons for the increasing popularity of rye being used in the rotation as a grain, forage, or cover crop.

Currently very little variety development is occurring as the crop is considered a minor crop. The majority of the varieties commercially available have been developed and released for a number of years, and in some instances have lost varietal identity or purity by not being grown in certified seed systems. The lack of certified seed production has made it difficult to source seed of a known variety.

The CREC agronomy program coordinates the NDSU state winter rye variety testing program along with a diverse research program using rye as a grain, forage and cover crop. The agronomy program has also been working on variety development focusing on winter hardiness, early season vigor, grain yield and quality, biomass production, straw strength, and early maturity. The foundation seedstocks program at the center has the capability to increase breeder and foundation seed. This collaborative effort illustrates the ability of diverse programs within a department to develop, trial, increase, and distribute seed of released varieties to the public.

ND Dylan winter rye, developed by the CREC agronomy program was released this summer by the North Dakota Agricultural Experiment Station with seed distributed by the ND County Seed Increase Program this fall.

ND Dylan is a high yielding winter rye variety that has good winter hardiness. Data gathered over multiple years indicate a yield advantage over current commercial varieties. It is a tall variety with good straw strength. ND Dylan is a medium-late Variety, one day later than Rymin and five days later than Dacold. Test weight is equal to Rymin and better than Dacold. Seed weight is average, slightly higher than Dacold. Tested across 26 locations from 2006-2016, ND Dylan had a higher yield than Dacold, Hancock, Spooner, and Rymin.

Biomass data is limited, although data gathered indicates total dry matter yields of ND Dylan to be greater than Dacold and Rymin. Winter hardiness ratings and early season vigor scores demonstrate ND Dylan's potential for use as a grain, forage or cover crop.

The renewed interest in winter rye for multiple use illustrates the need for a reliable source of adapted seed. Certified seed has not been grown in North Dakota for a number of years. The release of ND Dylan ensures seed of a known pedigree and seed source.

General Characteristics of ND Dylan:

-High Yield

-Good winter hardiness

-Medium-late maturity

-Good straw strength

-Tall

The CREC will continue to evaluate and develop winter rye varieties. Current work includes the development of a very early maturing line. Along with early maturity we are also selecting for winter hardiness, early vigor and early biomass development for use as a cover crop or double cropping.

Beef on Rye—A new twist on a Reuben

While you can't beat a good old Reuben sandwich, corned beef on rye bread; we think using rye to raise that beef is even better. Rye is an extremely hardy winter cereal crop that can handle a wide range of environmental conditions. Rye is the earliest, of the winter cereal grasses, to initiate growth and produce forage/biomass in the spring. Rye tends to require less inputs to raise and can be sown quite late in the fall; providing a wide window of opportunity to plant. These traits are the impetus for the increasing popularity of rye as a major component in cover cropping, double cropping forages, or integrated crop-livestock systems in many regions including the Midwest.

The NDSU Carrington Research extension Center (CREC) has evaluated winter cereals as forage and cover crops for a number of years and have found rye to be a reliable winter crop in south central North Dakota. Data gathered from multiple years demonstrate an average dry matter forage yield of 2.5 tons/acre (https://www.ag.ndsu.edu/carringtonrec/documents/annual-reports/2012-annual-report; p. 24). The data demonstrating the early growth habit and forage production of rye, made it apparent there is ample time to raise a second forage crop following a rye crop. These observations directed further research exploring options utilizing rye and sudangrass, as the double crop, after harvesting rye for forage. Results from this work showed, early maturity combined with the short growing season in South Central North Dakota gives rye an advantage over other winter cereals. Rye produced higher early yields and greater consistency in performance for the subsequent forage crop. (https://www.ag.ndsu.edu/carringtonrec/documents/annual-reports/2014-annual-report; p.31).

After evaluating the small plot research trials conducted with rye forage and doubling cropping we started looking at how to take the proof of concept from the plots to a field scale model.

In the fall of 2015 a 30 acre field at the NDSU Carrington Research Extension Center was seeded to "Rymin" winter rye at a rate of 70 lbs/acre, following a buckwheat crop. The fall soil test indicated 40 lbs/acre available N, an additional 80 lbs/acre N was applied. The goals were: to harvest the rye crop in the spring as silage for comparing winter rye and corn silage in feedlot finishing diets for yearling steers; followed by double cropping with an annual forage crop for use in fall grazing. Additionally one acre of the field was fenced with temporary fencing for rye grazing observations.

May 10th, ten yearling heifers and three, dry, mature beef cows, averaging 1155 lbs, were grazed for 10 days on the one acre of rye designated for grazing. The estimated average available dry matter was 1.14 tons/acre. The re-growth on June 10 was an estimated at 1.5 tons dry matter/acre and was grazed with 6 yearling steers for fifteen days. Initial observations indicate grazing sooner along with higher stocking densities, to more fully utilize the rye forage, would have been more effective; for both grazing timings.

On June 16th the remaining twenty-nine acres were cut, wilted, chopped and bagged for silage. The average yield was estimated to be 3.5 tons dry matter/acre. The forage quality measured was: 8% crude protein, 37% ADF, 61% NDF, 62% TDN. The rye was a few weeks past anthesis at the time of harvest. Quality will be higher if rye is cut at anthesis. While timing is critical for rye harvest and re-seeding of the second crop, to maximize forage quality and production from both crops, logistics and weather conditions can cause delays in both harvest and re-seeding windows. The field was re-seeded to German millet at a rate of 20 lbs/acre on June 24th. On September 15th, the German millet was swathed, allowed to dry and three windrows were combined to be used for fall and winter grazing of mature beef cows. Although not determined, estimated forage yield from this second crop is approximately 2 tons dry matter/acre.

The rye silage is currently being fed in a feedlot trial to evaluate rye silage compared to corn silage in steer finishing diets. Seventy one head of 990 lb steers are being fed diets with either corn silage (19% of the diet dry matter) or rye silage (11% of the diet dry matter) as the forage base. The steers have gained an average of 5 lbs/head/day. Animal performance, feed efficiency, and carcass data will be evaluated at the end of this feeding trial. Amazingly, we were able to harvest the rye crop in the spring and start feeding it in the feedlot within a few weeks. The corn silage used in this trial was harvested the previous fall. In addition to the feedlot research, we also have a year-round dry lot cow herd at the research center. We produced more rye silage than was needed for the feedlot trial, so have been feeding rye silage in our drylot cow rations throughout the summer. These cows will also be used to swath graze the millet crop that was re-seeded following the rye harvest. Rye can fill the gap to provide forage between corn silage harvests.

Fig. 6. Heifers grazing Rye on 1st graze and 2nd graze

Overall this demonstration project has allowed us to take research from the plots to a field scale proof of concept. Demonstrating the dual cropping role rye can play in utilizing a small number of cropland acres for harvested forage and grazing production. Additionally, demonstrating how feedlots and drylot cow/calf operations can utilize a small number of cropland acres as a forage base for silage, hay or grazing. Ultimately demonstrating the quantity and quality of forage that can be raised in a semi-arid short growing season when winter rye is a key component of the production system That is a twist to the Reuben your cattle can ruminate on!

Fig. 7. Panorama picture of German millet during swathing

Fig. 8. Millet and rye silage in ag bag

Fig. 9. Rye residue after first graze with heifers and fenceline views of grazed and ungrazed rye

Fig. 10. Chopping rye for silage and swathing rye

3) Late Season Cover Crops Effects on Soil Compaction

Chris Augustin, Area Extension Specialist/Soil Health

Soil compaction reduces plant root growth and may reduce crop yields. Producers are interested in using cover crops to reduce soil compaction. Late season cover crops (planted after a cash crop) have reduced soil compaction. However, this has been in warmer and wetter climates. This study evaluates the effects of a radish/turnip cover crop, diverse cover crop, and fall tillage on soil compaction the following spring. The site was summer fallowed during the 2015 growing season and tilled right before planting. Cover crops were planted on August 3, 2015. The fallow strips were tilled once more on October 16, 2015 for weed control. Weeds were not observed in the cover crops. Tillage treatments were completed with a tandem disc. The radish/turnip cover crop mix was planted at 2.5 lbs/ac radish and 2.5 lbs/ac turnips. The diverse cover crop planting rate was 25 Ibs/ac barley, 5 Ibs/ac sunflower, 10 lbs/ac field pea, 1 lb/ac turnips, and 1 lb/ac radish. Soil compaction was recorded with a penetrometer. This device records soil resistance pounds per square inch (PSI) and soil depth. There were four replications. Three profile readings were taken within each plot.

Results indicate that both cover crop treatments reduced soil compaction until a depth of five inches (Figure 1). The radish/turnip mix reduced soil compaction until seven inches. Radish and turnips reduce soil compaction more than the diverse cover crop mix from the three to six inch depth. After the five inch depth, the diverse cover crop and fallow treatments had similar soil penetrometer readings. Once the seven inch depth was met, all treatments had similar penetrometer readings to a depth of 18 inches. Plant root growth can be reduced when the soil resistance exceeds 200 PSI. No treatments exceeded this threshold before the eight inch depth. Below the eight inch depth all treatments had similar readings and

were within 25 PSI of 200 PSI. The 200 PSI reading at eight inches likely reflects the accumulation of clays found at this depth and a decrease in organic matter.
Late season cover crops can reduce soil compaction. However, soil compaction reduction was only observed within the top six inches of the soil and no treatments were considered compacted. Taproot cover crops mixes are more effective at reducing soil compaction than cover crop mixes composed mainly of fibrous roots.

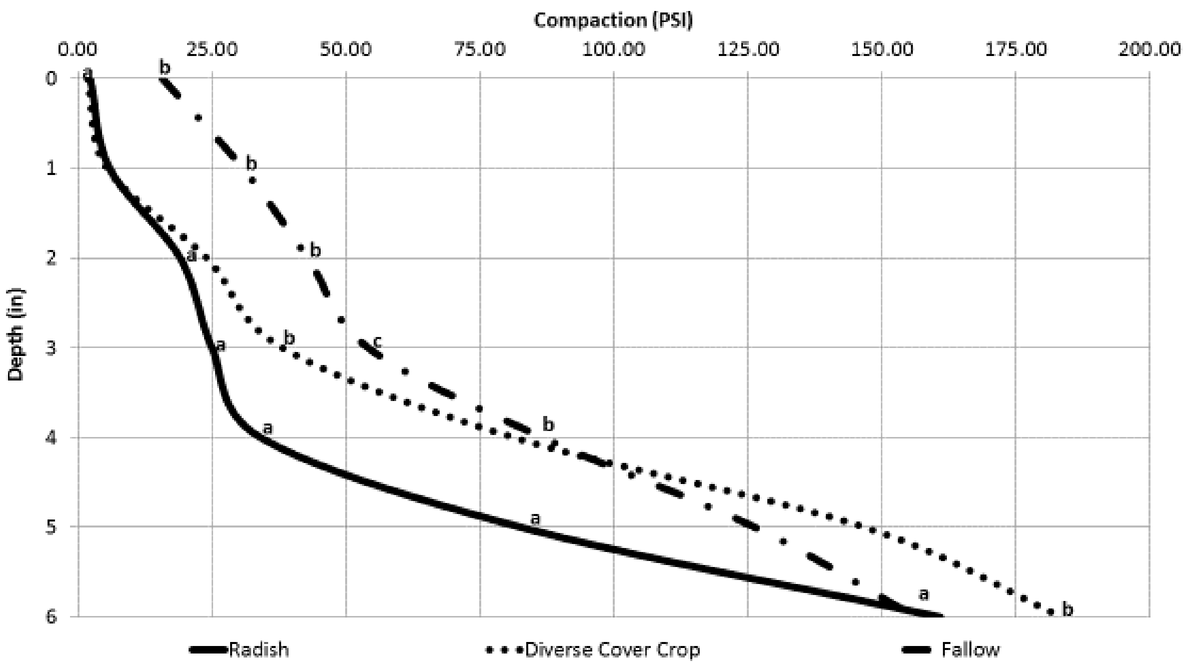

Fig. 11. Soil penetrometer readings recorded to a depth of six inches. All treatments were similar below the seven inch depth. Same letters indicate similar results.

4) **Interseeding of camelina into corn and soybean (Berti, Samarappuli)**

Camelina [*Camelina sativa* (L.) Crantz.] is an industrial oilseed crop in the Brassicaceae family with multiple uses. Currently, camelina is not used as a cover crop, but it has the potential to be used as such in corn-soybean cropping systems. The objective of this study was to determine the agronomic performance of winter camelina intersown as a cover crop into standing soybean or maize crops prior to their harvest. Experiments were conducted in Fargo, ND in 2014, Prosper, ND, in 2015, and in Morris, MN in 2014 and 2015. The experimental design was a randomized complete block design with a split-plot arrangement with three replicates. The main plot was row spacing 24 and 30 inches) in corn, 24 and 12 inches in soybean) while the sub-plot was corn or soybean growth stage at relay-sowing of camelina. Winter camelina was sown on four different dates: Date 1 (SD1), at the same sowing date as maize and soybean, Date 2 (SD2) at V4-V5 of maize and V3-V4 of soybean growth stages, Date 3 (SD3) at 'silking' of maize and R1-R2 stage of soybean, and Date 4 (SD4) after maize and soybean harvest. Camelina establishment into standing maize and soybean largely depended on rainfall after sowing. Camelina intersown on SD1 resulted in lower maize and soybean grain and biomass yield of 14 and 10%, respectively, whereas intersowing after SD2 had no significant effect (Fig. 13, 14, 15 and Table 2). Camelina N uptake varied between 24 and 59 kg N ha^{-1} and P uptake ranged between 4.3 and 9.2 kg P ha^{-1} in the spring when sown after maize and between 14 and 57 kg N ha^{-1} and 1.5 and 6.9 kg P ha^{-1} after soybean. Results indicate that camelina intersown after V4-V5 of maize or V3-V4 of soybean stages will likely avoid competition with the primary cash crop. Camelina establishment and winter survival was best when sown after maize and soybean harvest, and tended to be greater in soybean. However, there are many unanswered questions on camelina intersowing management. New research will allow optimization of intersowing management to increase yields of both crops while enhancing ecosystem services.

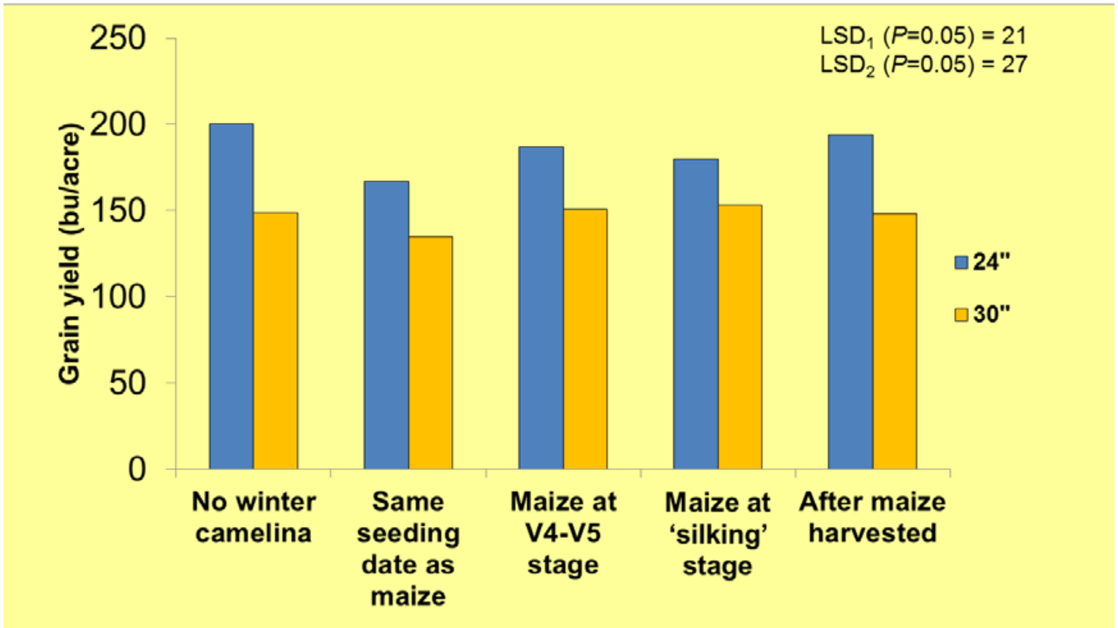

Fig. 12. Corn grain yield with winter camelina interseeded at different dates.

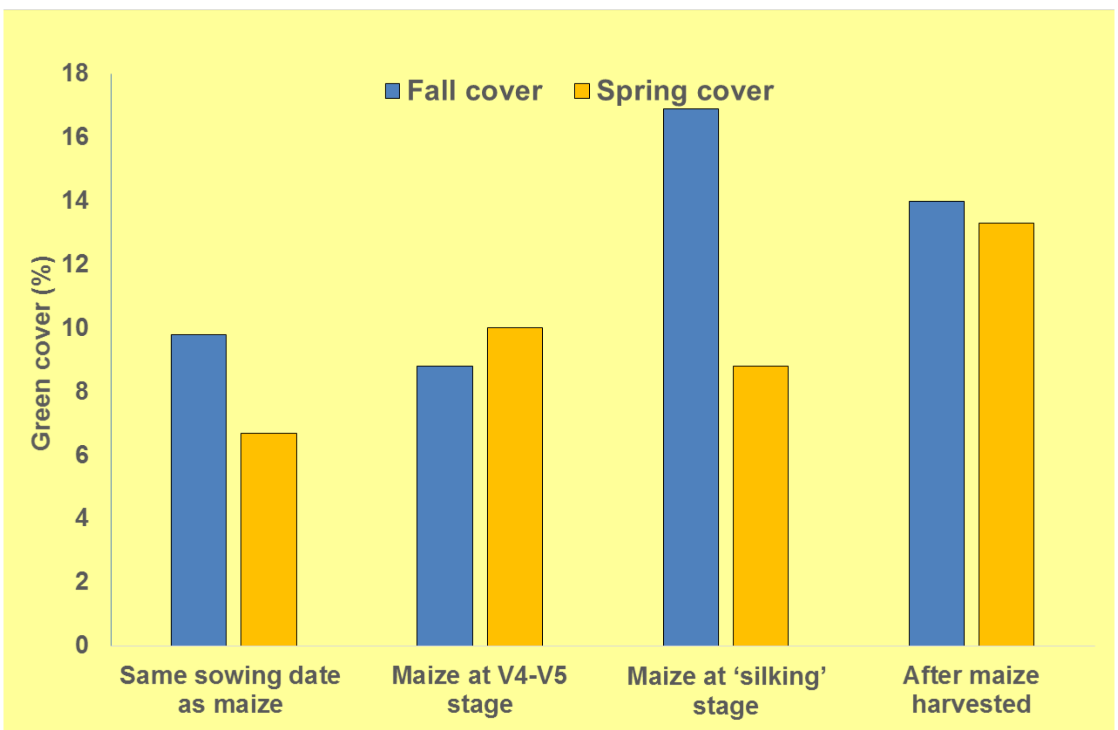

Fig. 13. Fall and spring cover of camelina interseeded into corn at different dates.

Fig. 14. Camelina interseeded in corn, 1 October 2015 and 8 May 2016.

Fig. 15. Winter camelina interseeded in soybean. 27 July, 1 October, 2015 and 8 May 2016.

Table. 2. Soybean grain yield with winter camelina interseeded in different stages.

Soybean growth stage	Grain yield
	Mg ha^{-1}
No winter camelina	4.2
Same seeding date as soybean	3.8
Soybean at V3-V4 stage	4.4
Soybean at R1-R2 stage	4.6
After soybean harvested	4.1
LSD (*P*=0.05)	0.2

5) Adaptation of cover crops to build soil health in the northern Plains (Wick)

Producers in the Northern Plains, specifically North Dakota, Minnesota and South Dakota, struggle with the incorporation of cover crops into rotations because of a short growing season and limited, regionally-specific information. To compound the issue, there is a desperate need to manage the extensive salinity issues in this region brought upon by a 20 year wet cycle and shift in management to shorter growing season crop rotations. Producers in this area estimate that 15- 35% of their cropland is impacted by salinity, drastically reducing yields and degrading soil health. The current management approach used by a majority of producers in the region is “business as usual” with excessive fall and spring tillage and planting of non-salt tolerant crops – the exact opposite of what needs to happen. A recommended management approach to combat the issue is to use water with cropping systems to drive the salts deeper into the soil profile. Using an early season, more salt-tolerant crop, such as a small grain, followed by a cover crop will increase the duration of “something growing and using water” by up to four months. Additionally, the lengthened growing season improves our ability to build soil health and develop more sustainable agronomic systems.

Objective 1: Collect regionally-specific data throughout the northern and southern Red River Valley on the effectiveness of various cover crop mixes following small grains using replicated plots.

Four replicated cover crop plots were established across the Red River Valley near De Lamere, Wahpeton, Cummings, and Thompson, ND. Sites are located in visible areas so neighboring farmers can monitor the cover crop plots throughout the seasons. After small grain (wheat or barley) harvest in 2015, three cover crop mixes were planted, each containing cereal rye to be compared to a control treatment where only volunteer grain re-growth was permitted. The three mixes seeded included: Mix 1: Cereal Rye, Radish, and Turnip. Mix 2: Cereal Rye, Radish, Turnip, Forage Pea, and Crimson Clover. Mix 3: Cereal Rye, Radish, Turnip, Forage Pea, Crimson Clover, Sorghum/Sudangrass, and Dwarf Essex Rapeseed. The mixes were designed to be additive, with the same basic species in all mixes and additional species added to investigate the potential cost or benefits associated with higher species mixes. Check plots were left as a comparison. Cover crop biomass ranged from 1.1 to 1.7 ton/ac where mixes were seeded and 0.5 to 1.3 where only volunteer small grains re-grew and additional cover crops were not seeded. There were no significant differences in biomass amongst the different cover crop mixes.

Soybeans were planted into the cereal rye cover crop strips in spring 2016. Two of the plots were hailed out or received excessive rain leading to crop failure (Wahpeton and Thompson). Soybean yield and weed pressure were measured on the remaining two plots. Soybean yields were the same or higher on the cereal rye and non-rye strips for both sites (42 bu/ac at the Delamere site; 44 bu/ac in the rye and 39 bu/ac in the non-rye at the Grand Forks site). Additionally weed biomass was 10x higher in the non-rye strips versus the cereal rye strips. This has been observed at other research plots and further highlights the benefits of a cereal rye cover crop for managing weed pressures.

Due to excessive fall rains (between 5-8”), cover crops were not planted following the soybean crop. This decision was made by the cooperating farmers to avoid rutting up fields. We applied for two additional years of funding (which was granted) to continue the project through 2019.

Objective 2: Demonstrate the use of various cover crop mixes using full-scale plots installed by partnering producers in close proximity to other established salinity demonstration locations.
Farmer cooperators were crucial in the planning and installation of the cover crop plots as well as the distribution of information from the sites. The farmers are using these sites as examples for the benefits of cover crops in managing weeds, improving trafficability at time of planting and for improving yields. They have shared these results within their communities and with the region. They have extended their knowledge past using cover crops for salinity management to using cover crops for achieving multiple goals on multiple fields. Most recently, Terry Wehlander who is our cooperator at the Delamere site, presented information from his plots at the state-level Cornvention, which drew 340 attendees. Terry will also participate on a soil health panel through the National Corn Growers Association Soil Health Partnership in San Antonio, TX on March 3 and will again be sharing information on a national stage to an anticipated 250 attendees. Doug Toussaint, cooperating farmer from Wahpeton, shared information on how he is now using cover crops at the Conservation Tillage Conference in Fargo (drawing 330 attendees), will be sharing information on his use of cover crops at the Advanced Crop Advisors workshop in Fargo (drawing 250 consultants) and also the Midwest Cover Crops Annual Meeting in Michigan. The cooperating farmers are effectively taking information generated from the plots to other farmers.

Objective 3: Increase education opportunities by demonstrating additional practices for salinity management and opportunities for improving soil health to an already existing framework of demonstration sites that have well attended annual field days.
Field days in 2015 were held at each field site during late fall, drawing a total of 284 participants. We ramped up the field days in 2016, for a total of 17 field days/workshops associated directly with this project reaching 687 participants. The group of participants included farmers, government agencies, Ag industry professionals, and Ag students from a local college. The increase in field days and attendance was a result of working a deal with cover crop seed companies to purchase seed at a lesser cost for the demo sites. This allowed us to incorporate additional sites into this project for demonstration purposes (sites in Gardner, Jamestown, Milnor). Nearly half of the soil health extension programming was devoted to these sites and almost 100% of the extension programs were focused on integrating cover crops (this would include a total of 23 field days/workshops, reaching 1,153 attendees).

RESEARCH IN PROGRESS

1) *Estimation of N credits from cover crops and increased N use efficiency by subsequent crops. (Wick and Franzen)*

In July, 2016, an inter-seeding of 40 lbs cereal rye per acre and 5 lb forage radish per acre was conducted near Rutland, ND (NE corner of experimental area 46º 12.131’ N Latitude, 97º 27.36428’ W Longitude), utilizing the prototype interseeder described in Objective 1a. The plot area was seeded 23 June, when the corn was in V6 stage. The experiment was established as a randomized complete block design with 2 cover crop treatments (no cover crop and cover crop) and 3 replications. The dimensions of each experimental unit were 60 feet wide and 60 feet long. This will enable us to add 6 N rate treatments (0, 40, 80, 120, 160, and 200 lb N/acre) in spring 2017, to make the study a split-plot with main plots cover crop history and sub-plots N rate, with 3 replications. Initial soil samples were taken in each experimental unit 23 June at the 0-6 inch and 6-24 inch depths for N, P, K, pH, organic matter, Zn, EC, and soil moisture. The rye and radish emerged 6 July, and the first plant sampling, sampling, weighing and N analysis of rye and radish separately. Cover crops were also sampled 8 and 28 September and 11 October. Follow-up soil samples were obtained on 8 and 28 September. Corn ears were harvested, 60 foot of row from center of each experimental unit, shelled, and grain yield, moisture and test weight of grain were determined.

A cover crop study following winter wheat was established August 8 about two weeks following winter wheat harvest. The winter wheat volunteers were allowed to grow and the area was seeded to field pea in 30 inch rows, with the area between rows seeded to turnip and forage radish and flax. The field will be seeded to corn in 2017, so the turnip/radish area will act as a biological 'strip-till' to seed corn into. The study was established within the field (NE corner 45º 57'55.530"N Latitude, 97º33'07.643" W Longitude) as a randomized complete block design with 2 cover crop treatments (no cover crop and cover crop) and 3 replications. The dimensions of each experimental unit were 60 feet wide and 60 feet long. This will enable us to add 6 N rate treatments (0, 40, 80, 120, 160, and 200 lb N/acre) in spring 2017, to make the study a split-plot with main plots cover crop history and sub-plots N rate, with 3 replications. On 25 August, the cover crops were emerged and the no cover crop treatments were sprayed with 22 oz/acre Roundup PowerMax with 22 oz/acre of 4 lb/gallon ammonium sulfate solution, at 10 gallon per acre using 30 psi pressure with a bicycle cart sprayer. Elimination of cover crop in these treatments was complete within 10 days. Soil samples were obtained at the 0-6 inch and 6-24 inch depths on 12 August, followed by soil samples for residual soil nitrate and soil moisture 28 September, 24 October, and 9 November.
Reduction in soil water content to 2 ft in depth was 2.89 inches due to cover crop, and the cover crop contained 142 lb N/acre in 5100 lb/acre dry-matter of the total of flax tops, winter wheat tops, radish/turnip tops field pea tops, and radish/turnip roots.

Table 3. Residual nitrate in the soil with or without a cover crop following winter wheat, Rutland, 2016.

	8/12	**9/28**	**10/24**
Treatment	**Nitrate-N, lb/acre**		
Cover crop	57	18	15
No Cover Crop	50	130	114

The rotation in these farms will be wheat-corn-soybean; corn-soybean-wheat, and soybean-wheat-corn. A site NE of Gardner, ND was also identified and a specific area was sampled for residual nitrate following spring wheat in fall, 2016. Companion sites were generally located for the soybean to wheat to corn rotation, and wheat to corn to soybean rotation, but they will not be sampled until spring, 2017.

Fig. 16 Cover crop planted into harvested winter wheat study, October, 2016.

Fig. 17. Cover crop planted into harvested winter wheat showing field peas, turnip/forage radish, flax, volunteer winter wheat, October, 2016.

2) Interseeding of camelina and pennycress into standing corn and soybean (Johnson, Gesch, Dose)

An experiment was esatablished in Prosper, ND in May 2016 to evaluate optimizing planting date for seeding winter camelina, pennycress, and winter rye into standing corn and soybean. Soil samples were taken prior to planting and after harvesting soybean and corn. These samples were analyzed for soil moisture and macronutrient (i.e., N, P, & K) content. Corn and soybean were planted according to best management practices for that site with regard to tillage and seedbed prep, cultivar maturity, fertilizer application, and pest control. Planting was in May and harvest in September for soybean and in October in corn.

Cover crops including winter camelina, pennycress, and winter rye were interseeded into standing corn at all four sites at three different planting times which corresponded to the R4, R5, and R6 growth stages of development and interseeded into soybean at R6, R7, and R8 stage of crop development. At Prosper, ND the covers were broadcast seeded between crop rows by hand and incorporated with a garden rake. In the fall just before soil freeze up, final stand counts and biomass samples of the interseeded cover crops were taken in duplicate from each plot. Biomass samples were dried to determine dry matter yield on an area basis.

At the Prosper site, pennycress populations were greatest when interseeded into standing corn at the first and second dates (R4 and R5) and lowest when seeded at the last date (R6). Winter camelina plant populations were greatest when seeded at the last date into standing corn. Winter rye plant populations when interseeded into corn and soybean at Prosper remained constant across planting dates, but tended to be lower than camelina or pennycress. Similar to interseeding into standing corn, winter camelina interseeded into standing soybean at Prosper had the greatest plant populations at the latest planting (R8) and lowest populations when seeded at the first date (R6). Pennycress plant populations remained relatively constant at Prosper when seeded across all soybean growth stages. When seeding into standing corn at the second date, winter rye had the greatest biomass accumulation (41 kg ha^{-1}), followed closely by winter camelina planted at the same time (31 kg ha^{-1}). The third planting date into standing corn at Prosper produced poor biomass, ranging from 4 to 14 kg ha^{-1} across species. Overall, greater average biomass was accumulated across all cover crop species and planting dates when interseeded into soybean (84 kg ha^{-1}) than into corn (18 kg ha^{-1}). Winter rye produced between 121 and 146 kg ha^{-1} of biomass when planted at the first and second dates into soybean. Pennycress also produced appreciable biomass when seeded during the first and second dates (93 to 133 kg ha^{-1}), but less than 22 kg ha^{-1} of biomass was produced when seeded at the last date. Winter camelina also followed a similar trend to pennycress when interseeded into soybean at Prosper (Fig. 18).

Successful cover crop establishment can reduce erosion. Therefore, estimates of percent green cover taken in the fall and spring can help make decisions on the best time to interseed these cover crops in order to maximize erosion protection. Winter camelina, when seeded into corn reached a maximum of roughly 15% cover when seeded at the second date, but was much more successful in covering the soil when seeded into soybean regardless of growth stage, as winter camelina averaged between 40 to 50% soil coverage.

Establishing a suitable soil cover using interseeded winter cover crops was more challenging in corn than soybean. Seeding during all corn growth stages resulted in a range of 2 to 15% green cover for winter rye, pennycress, and winter camelina (Fig. 6a). However, establishing soil cover when seeded into standing soybean provided better results. Winter rye averaged between 20 and 31% coverage with greater ground cover when seeded earlier. Pennycress provided 45% green cover when seeded into soybean at the first date and declined to under 20% cover when seeded at the last date. Winter camelina provided the greatest (35%) green cover when seeded at the second date in soybean, and was lower when seeded earlier or later in soybean development. There was generally not much difference among the three cover crop species with regard to amount of cover provided in both the corn and soybean systems.

Our initial (1st year) results indicate that establishing winter annual cover crops into standing corn generally is a greater challenge than establishment in soybean. This is most likely due to light interception and suitable soil moisture for germination and growth.

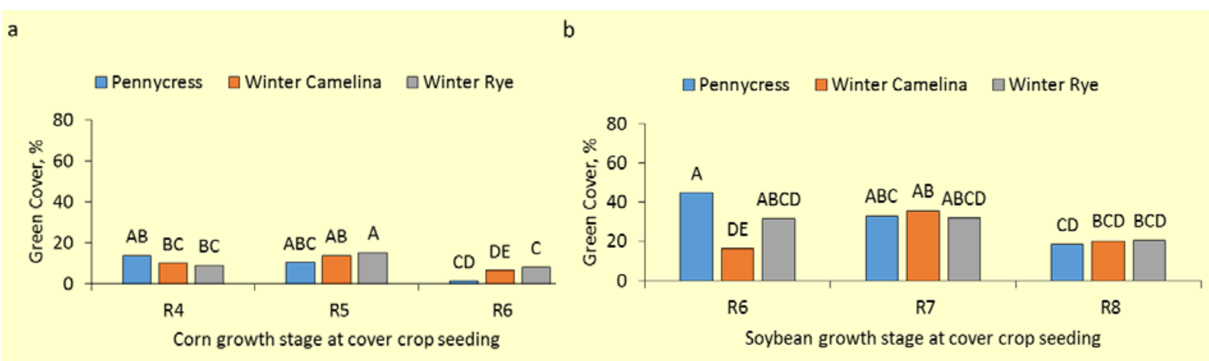

Fig. 18. Effect of establishing winter annual cover crops in the fall in a) corn and b) soybean in Prosper, ND on percent of green cover in November

3) Interseeding of cover crops in standing soybean (Berti, Peterson)

The objective of this study was to determine the effect of seeding cover crops into soybean at two late stages of development, on soybean yield, cover crop establishment, potential negatives effects to soybean quality, and soil cover. Four cover crop treatments were seeded between the soybean rows at 56 cm (22 inches) apart: Austrian winter pea (*Pisum sativum* L.), forage radish cv. Daikon (*Raphanus sativus* L.), winter camelina cv. Joelle, winter rye (*Secale cereale* L.) cv. Rymin, a mixture of all four cover crops, and a check treatment with no cover crops. Cover crops were interseeded at the R4 and R6 reproductive stages of soybean on 25 and 26 July for R4 in Fargo and Prosper, respectively and on 16 August for R6.

First year results indicate soybean grain moisture, test weight, and yield were not affected by interseeding cover crops at any of the cover crops seeding dates or locations. This indicates cover crops interseeded into soybean at R4 or R6 did not compete with soybean and provide cover in the fall (Table 4, Fig. 20).

Cover crops biomass and green cover was different among cover crops and seeding date. Austrian winter pea had the highest biomass and coverage than all other cover crops when seeded on R4 while radish coverage and biomass was greatest when seeded on R6 (Fig. 20).

Similarly, N uptake by cover crops averaged across locations and seeding dates was greater for both radish and Austrian winter pea and lowest for cereal rye. No significant differences were observed on P uptake (Fig. 21). Soil residual NO_3-N was higher in the plots with no cover crop (Fig. 22). Cover crops scavenge enough nitrate in the biomass to prevent leaching in the fall or spring.

Fig. 19. Winter Austrian peas interseeded into standing soybean at R4 stage. Photo taken after soybeans were harvested, 4 October.

Table 4. Soybean grain yield with different cover crops interseeded into standing soybeans on two seeding dates. Values averaged across seeding dates (R4 and R6) and two locations, Fargo and Prosper, ND in 2016.

Cover crop	Grain yield	
	$Mg\ ha^{-1}$	Bu/acre
Winter camelina	3.91	59
Austrian winter pea	4.23	62
Radish	4.06	58
Cereal rye	4.09	60
Mix	3.98	59
No cover crop	3.96	60
LSD (0.05)	NS	NS

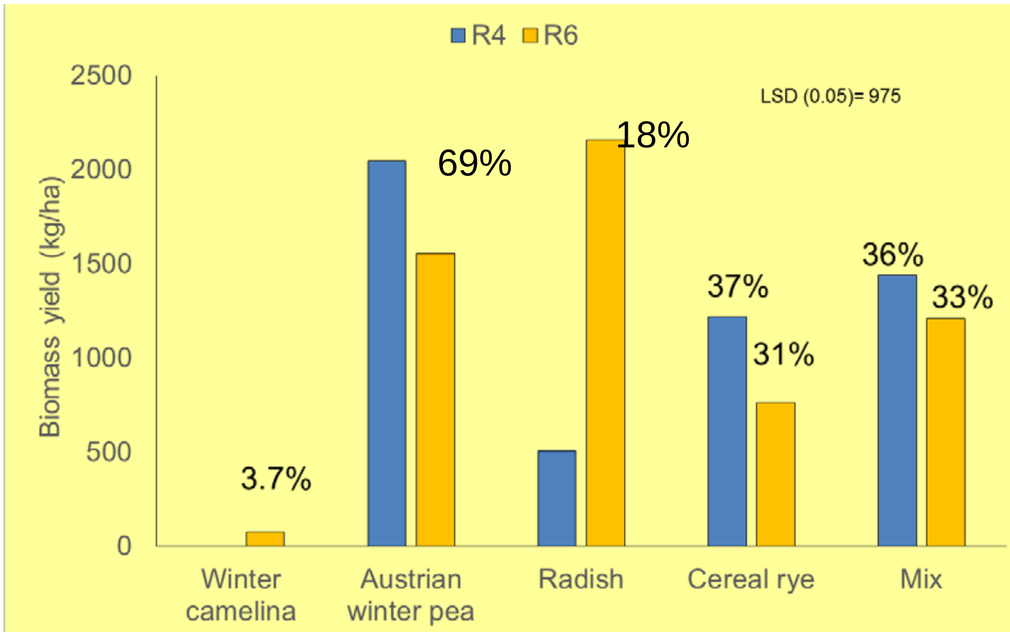

Fig. 20. Biomass yield and green cover interseeded into standing soybean at R4 and R6 stages averaged across two locations Fargo and Prosper in 2016. Biomass sampling was done on 21 October.

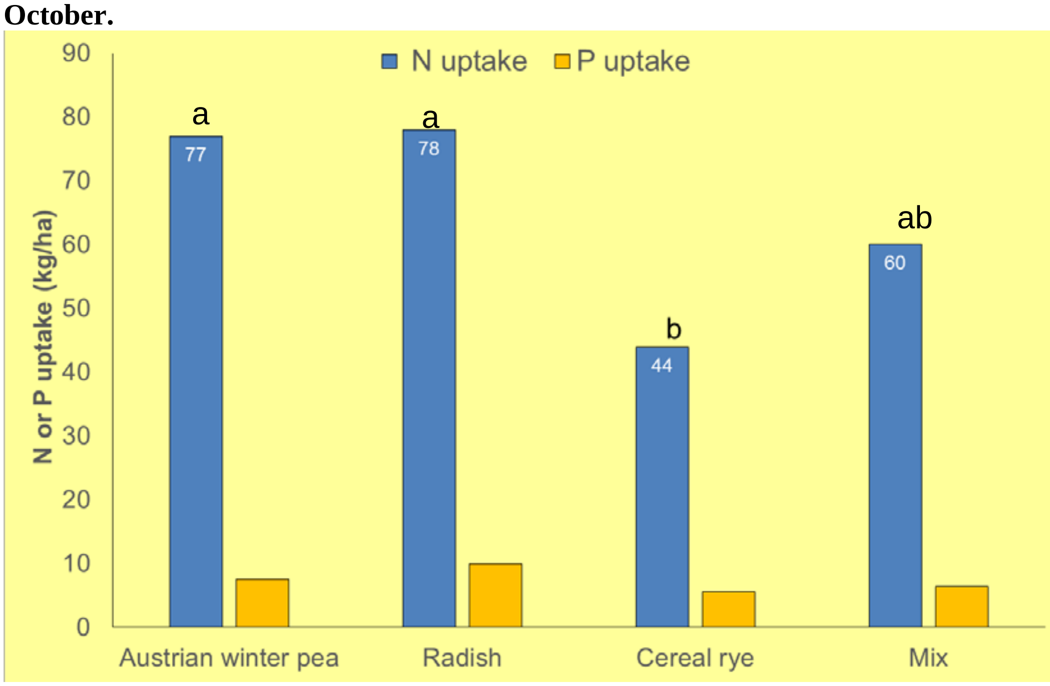

Fig. 21. N and P uptake of cover crops interseeded into standing soybean averaged across seeding dates (R4 and R6) and two locations Fargo and Prosper, ND, in 2016. Biomas samples were collecte on 21 October 2016. Means followed by the different letter indicate significant differences among N uptake by different cover crops. P uptake was not significantly different (*P*≤0.05).

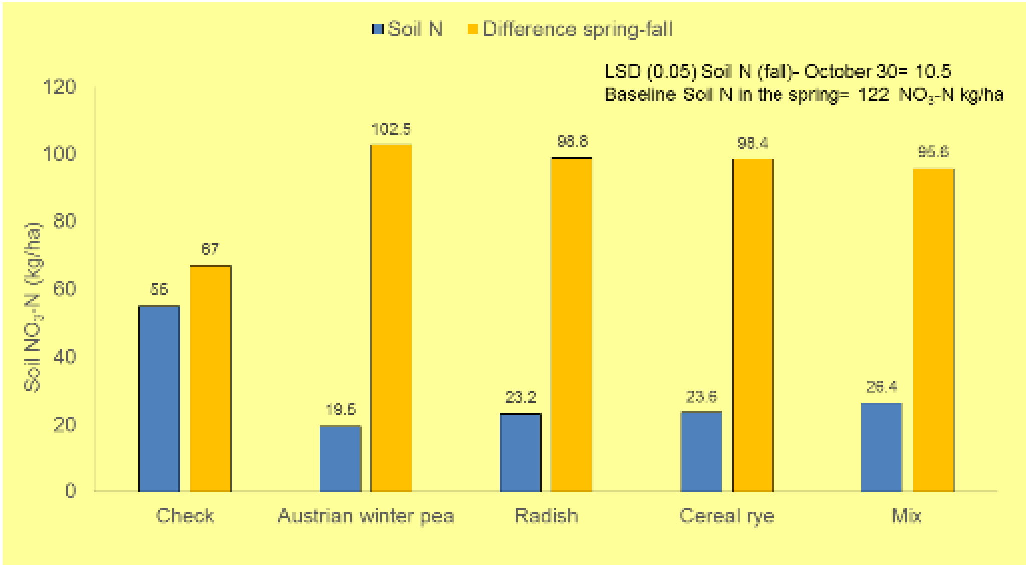

Fig. 22. Soil NO_3-N in the fall (0-60cm depth) and difference from spring N in cover crops interseede into soybean. Values averaged across seeding dates and locations.

4) ***Interseeding camelina and rye in corn at different stages, row spacing and hybrid maturity (Ransom and Geizler)***

Two experiments were established in Forman and Prosper, ND. Experiment 1: the experimental design was a randomized complete block (RCBD) arranged as a split-plot with three replicates. The treatments were a factorial combination of row spacing, cover crop, and date of cover crop interseeding. An additional no-cover crop check plot was included in each main plot. Row spacing was the main plot with cover crop and date of interseeding as the subplots. Row spacing treatments were narrow (56 cm) or wide (76 cm). Plots with a 56 cm row spacing were 2.2 m wide and 6.1 m long. Plots with a 76 cm row spacing were 3.0 m wide and 6.1 m long. All plots were planted with four corn rows to depth of 5.1 cm at a seeding rate of 79,000 live seeds/ha. The hybrid used was Dekalb brand 'DKC 36-28' which has a relative maturity of 86 d. Cover crops were sown when the corn reached the V7 or the R4 growth stage. Cover crops were camelina, rye and a mix of camelina and rye (Fig. 13). Experiment 2: The experimental design was a RCBD with four replicates; treatments were a factorial combination of corn hybrid RM and cover crop.

Fig. 23. Camelina and rye mix interseeded at V7 stage of corn.

The corn was planted in four rows spaced 76 cm apart to a depth of 5.1 cm at a seeding rate of 79,000 live seeds ha^{-1}. Plot dimensions were 3.0 m wide by 6.1 m long. Dekalb brand 'DKC 30-19' with a RM of 80 d was used as the early maturing hybrid. Dekalb brand 'DKC 39-27' with a RM of 89 d was used as the later maturing hybrid. Cover crop treatments were sown when the corn reached the V7 growth stage.

Corn grain yield was not affected by the interseeded cover crop and any of the seeding dates in both experiments. However, grain yield was greater at the 76-cm row spacing and with the later maturing hybrid (Fig. 24 and 25).

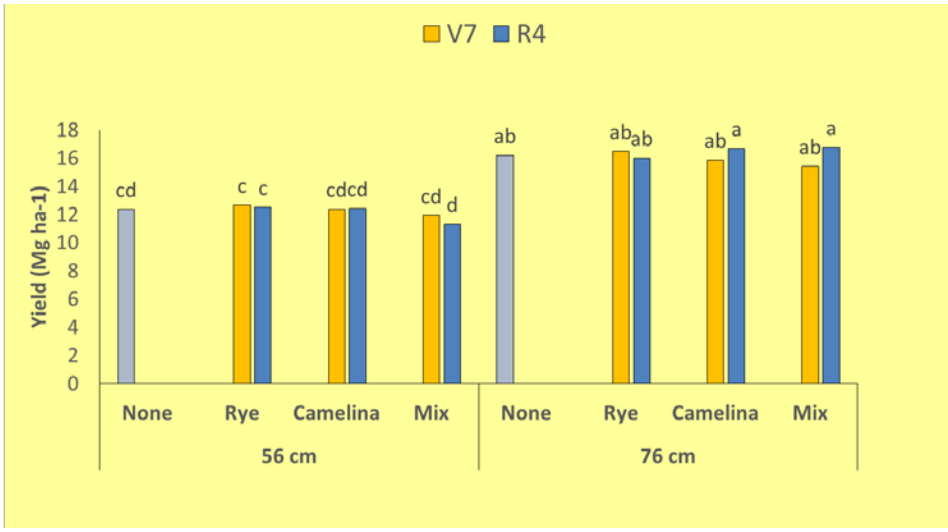

Fig. 24. Corn grain yield at two row spacings, as affected by three interseeded cover crops treatments in 2016. Data are an average of two cover crop seeding dates. Means followed by the same letter are not statistically different at the 5% level.

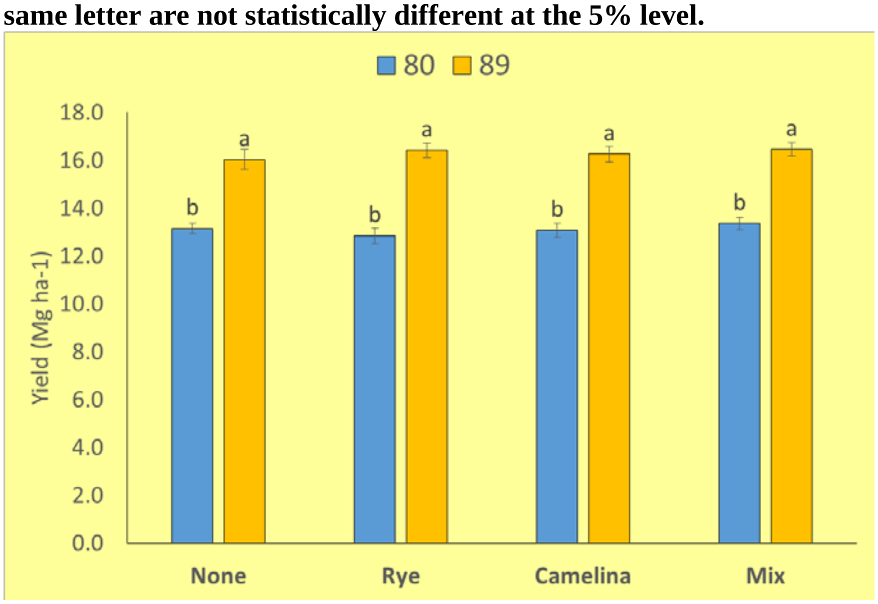

Fig. 25. Corn grain yield of two hybrid with differing maturities averaged across two seeding dates. Means followed by the same letter are not statistically different at the 5% level.

5) Cover crops variety and seeding date trial (Berti, Peterson, Samarappuli, Cabello)

The experiment was established in 2016 in Fargo on two seeding dates, July 28 and August 20. Twenty cover crops were established and biomass yield and N uptake was evaluated. Biomass and coverage was highest for forage sorghum planted on Date 1. Brassica crops, forage radish, turnip and rape had the highest biomass yield when planted on 20 August. This experiment was shown in the cover crops field day. (Fig. 26).

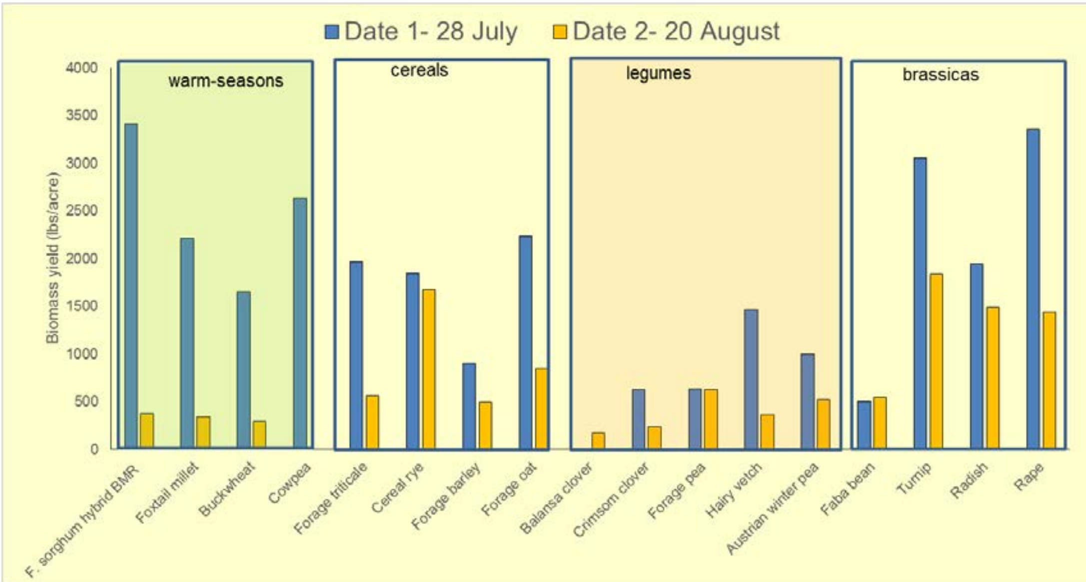

Fig. 26. Biomas yield of cover crops seeded on two seeding dates in Fargo, ND in 2016. Cover crops biomass was collected on 21 October 2016.

6) ***Winter camelina and pennycress variety trial (Berti)***

Three winter camelina varieties, Joelle, Luna and Maczuga and one pennycress selection were established on two seeding dates 16 August and 1 September in Fargo, ND in the fall of 2016. Biomass dry matter was 1672 kg /ha on Date 1 and only 641 kg/ha on Date 2 across all varieties. There were no significant differences among cultivars. However, Polish varieties Luna and Maczuga planted on Date 1 bolted and some flowered, this might reduce their ability to survive the winter. Camelina cv. Joelle and pennycress did not bolt.

Fig. 27 Winter camelina variety trial. Photo taken 9 October 2016

7) Cover crops at Carrington, ND, REC

a) Winter rye/soybean *(Ostlie, Zwinger, Endres)*

This season we experienced an extremely dry spring. This is the first time in 4 four years that we had stand failure when soybeans were planted into living rye. All removal strategies where rye was terminated prior to soybean planting were still successful (strategies included having no rye, spraying 2 weeks prior to planting, sprayed PRE, and sprayed at anthesis). The emphasis this season was looking at soybean planting dates. Early May and mid-May plantings had similar behavior. There was more available moisture at the end of May and so soybeans planted at the end of May into living rye had much better success than earlier planting dates. The conclusion from the study being that risk management of planting soybeans into winter rye should be based on soil moisture status, though the particular level of soil moisture for safe soybean planting remains unknown.

Rye planting date was also evaluated for the second year. Planting dates ranged from Mid-Sept to the first week of Nov. Rye planted in Nov has always survived even though in the fall of 2014 the soil froze the day after planting. Nov. seeded rye has never emerged in the fall, and has resulted in reduced spring vigor, delayed development, and somewhat reduced stands (~25% less stand than earlier seeded treatments). This is important since it shows that rye can be planted even after corn harvest in the fall and still serve its biological purpose in a soybean cropping system. I would recommend higher seeding rates if rye is planted late Oct-early Nov.

This coming season we will focus on soybean and rye planting dates again.

Misc crops: sunflower, field peas, and dry beans were also evaluated with rye termination strategies. Field peas performed poorly with all rye removal strategies but could have been influenced by the dry conditions. Sunflower and dry beans were planted later when soil moisture was better. Sunflowers performed better than expected but all treatments where sunflowers were planted with living rye caused moderate damage. Dry beans performed very well in the rye system and will be evaluated further in 2017.

b) Interseeding cover crops *(Ostlie, Nielsen, Eberle)*

Two interseeding systems were evaluated in 2016. The first was looking at lentils and corn seed at the same time. The focus was to identify an herbicide strategy that can be used early season to manage the weeds until the lentil got established. Several products were identified that would be safe to corn and cause no or little damage to lentils. Unfortunately the site was heavily infested with green foxtail and so only products which had activity on grasses (2 treatments) could be kept. The study was terminated prior to harvest to prevent green foxtail from reproducing. This will be evaluated further in 2017 with tank mixtures of products so that grass and broadleaf activity will exist in all treatments.

The second study was a demonstration with interseeding clover species and wheat, at wheat planting. We tried sweet, red, crimson, alsike, and subterranean clover (Fig. 28). Subterranean and sweetclover were the two species that stood out. As a demonstration there was no data for this trial. Again to develop an herbicide system we did a greenhouse study this winter to evaluate herbicide options. This study is still on-going but it appears that Clearfield wheat can be used in this system with subterranean, alsike, and sweet clover so that Beyond would be an herbicide option for this system. Replicated field trials will be conducted in 2017 to look at wheat yield responses to interseeding.

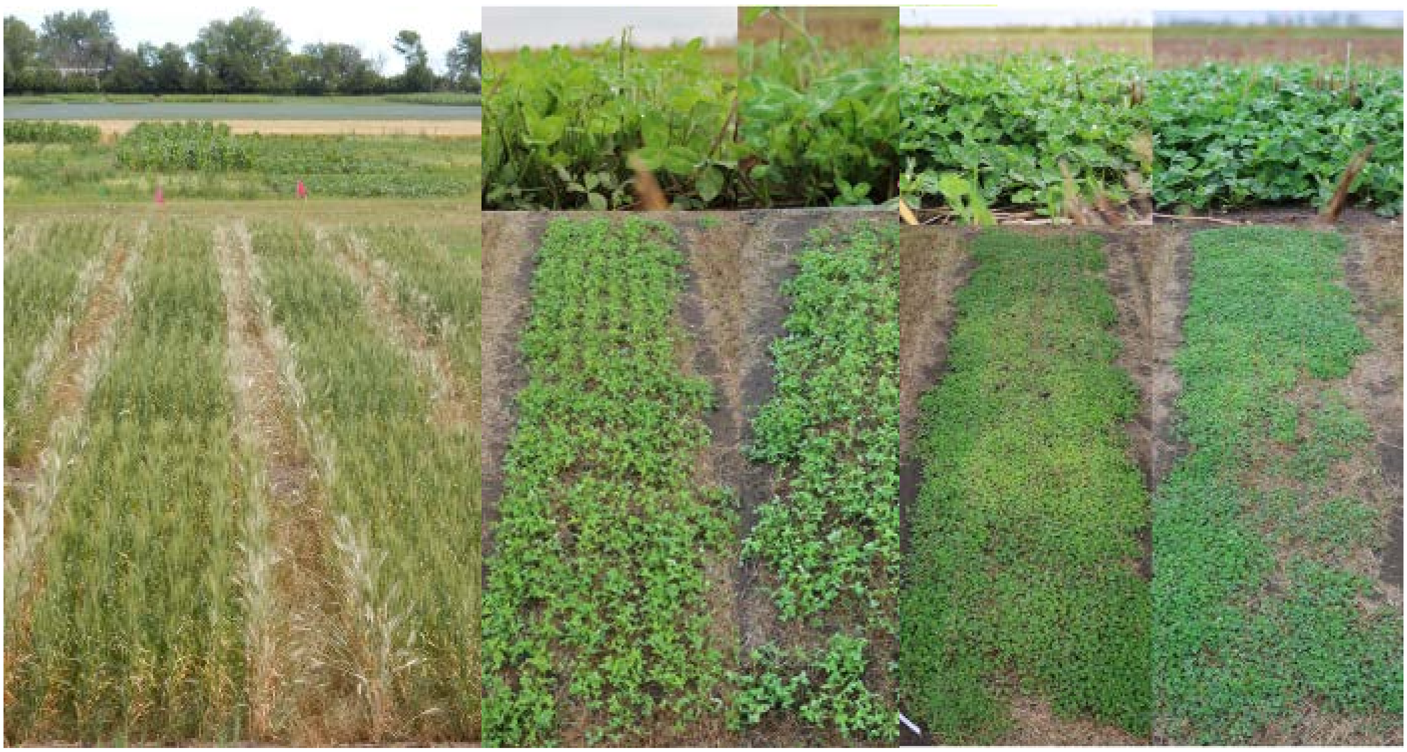

Fig. 28. Clover interseeded in spring wheat. Red and subterranean clover in conventional and no-till after wheat harvest. (Phot: J. Nielsen)

c) Cover crop safety following wheat (Nielsen, Ostlie)

A study was established to measure safety of 9 cover crop species following application of 9 wheat herbicide treatments known to have medium to long residuals. Herbicides were applied at the 3-4 wheat leaf stage and cover crops were planted ~10 days after wheat harvest. This study was conducted at Carrington, Fargo, and Hettinger. The goal was to generate a table that identifies a risk level of for each cover crop/herbicide combination. Carrington had the highest level of herbicide damage. Hettinger had low levels of damage except to the combinations of field peas and lentils with Widematch. Fargo had no cover crop injury levels over 20%. A compiled table was generated to list the highest damage received between all locations as a conservative method of identifying cover crop injury risk. This trial will be repeated in 2017 and include Minot.

Fig. 29. Herbicide sensitivity of sweetclover (left) and red clover (right). Photo: Nielsen.

d) Buckwheat P credit *(Ostlie, Teboh, Nielsen, Zwinger)*
A trial was established in 2016 to try estimate if a P credit would be more heavily based on buckwheat plant population or biomass production, and to what extent buckwheat P uptake affects the subsequent crop (corn). Three buckwheat populations (25, 50, 75 lbs/a) were used, along with check crops wheat, soybean, and sugarbeet. Buckwheat was sampled for P at first flower, first brown seed, and at harvest. All other crops were sampled at harvest only. For all crops, P content was determined for grain and residue. Unfortunately a hail event caused significant damage on 7/9. Only the first flower P determination was made prior to that event. Prior to hail, the P content per acre in buckwheat correlated to biomass (r^2=0.9) and to a much lesser degree, plant population (r^2=0.48). After hail there was only a small correlation to either plant pop or biomass. Average P per acre was ~3 lb/a at first flower, ~13 lb/a at first brown seed, and ~17 lb/a at harvest (roughly half was in grain and half in residue). Further analysis is still ongoing. In 2017 the trial will begin again, and also the test crop will be planted on the 2016 trial footprint.
In a similar test, P content was determined for 5 buckwheat varieties at first flower (before hail). No differences in P uptake existed but there were trends that suggest after additional study, differences may possible occur.

<u>2017 research plans</u>
In addition to the above, we are starting a pollinator emphasis. If funding is approved we will be looking at whether pollinators (native and honey bees) will affect dry bean yields. This will hopefully expand in future years to include other flowering crops like flax, canola, and peas but due to deadlines this is where we are starting.
Also pending funding we may look at pollinator preference between buckwheat varieties.

e) Using winter rye as a forage for the integration of crop and livestock production.
Steve Zwinger, Chanda Engel, Dale Burr, Tim Schroeder, and Steve Schaubert
Winter rye is an extremely hardy winter cereal crop that can handle a wide range of environmental conditions. Winter rye germinates and grows at very low temperatures and can be sown quite late in the fall; providing a wide window of opportunity to plant. Rye is the earliest, of the winter cereal grasses, to initiate growth and produce forage/biomass in the spring. Winter rye tends to require less inputs to raise, competing excellent with weeds and performing well under low fertility or moisture conditions along with providing reliable cover for erosion control. These traits are the impetus for the increasing popularity of rye as a major component in cover cropping, double cropping forages, or integrated crop-livestock systems in many regions including North Dakota.
The winter rye focus at the Carrington Research Extension Center (CREC) is quite broad ranging from small plot research related to grain, forage, cover crop, weed control, and variety development to field scale seed and forage production. Winter rye has been evaluated as a forage crop at the CREC demonstrating its value as a reliable forage crop that provides cover and can extend the haying/grazing season. The use of winter rye for forage is a method of integrating cropland into a livestock system. The

CREC has evaluated winter cereals as forage or cover crops for a number of years and have found rye to be a very reliable winter crop in south central North Dakota. Data gathered from multiple years demonstrate an average dry matter forage yield of 2.5 tons/acre as compared to triticale, wheat, and spelt at 2.5, 2.6 and 3.2 ton/ac DM respectively (https://www.ag.ndsu.edu/carringtonrec/documents/annual-reports/2012-annual-report; page 24). Average harvest dates for these crops illustrate rye reaches maturity sooner compared to other winter cereals. Harvest dates gathered from multiple years show rye to be June 12, compared to June 21 for triticale, June 24 for wheat, and July 5 for spelt.

The data demonstrating the early growth habit and forage production of rye, made it apparent there is ample time to raise a second forage crop following a rye crop. These observations directed further research exploring options utilizing rye and sudangrass, as the double crop, after harvesting rye for forage rye produced consistent early yields and tendency for higher yields of the subsequent forage crop (Table 5).

Table 5. Forage yield of several winter cereals established after harvesting sudangrass the previous season.

Planting date	Forage crop	Variety	Plant height	Harvest moisture	Forage yield DM
			inches	%	ton/ac
16-Jun	wheat	Jerry	73.6	75.7	3.01
29-Jun	wheat	Willow Creek	65.8	78.7	1.98
16-Jun	triticale	Metzger	73.9	77.0	2.29
22-Jun	triticale	Pika	63.3	80.6	1.33
8-Jun	triticale	Traction	72.1	73.7	2.48
8-Jun	rye	ND Dylan	76.0	74.4	2.78
8-Jun	rye	Wheeler	77.0	73.2	3.33
8-Jun	rye	Rymin	79.9	73.7	3.03
29-Jun	spelt	Frank	62.0	79.0	2.22
16-Jun	spelt	Maverick	74.5	74.7	2.58
		Mean	76.1	2.5	2.50
		LSD.10	1.6	0.76	0.76
		LSD.05	1.9	0.91	0.91

All sudangrass treatments harvested September 16.

These higher yields from double cropping the rye are related to the earlier harvest dates and the associated earlier planting date of the sudangrass.

After evaluating the small plot research trials conducted with rye forage and doubling cropping we started looking at how to take the proof of concept from the plots to a field scale model.

In the fall of 2015, a 30 acre field at the NDSU Carrington Research Extension Center was seeded to "Rymin" winter rye at a rate of 70 lbs./acre, following a buckwheat crop. The fall soil test indicated 40 lbs./acre available N, an additional 80 lbs./acre N was applied in the fall. The goals were: to harvest the rye crop in the spring as silage for comparing winter rye and corn silage in feedlot finishing diets for yearling steers; followed by double cropping with an annual forage crop for fall grazing. Additionally one acre of the field was fenced with temporary fencing for rye grazing observations.

10 May, ten yearling heifers and three, dry, mature beef cows, averaging 1155 lbs., were grazed for 10 days on the one acre of rye designated for grazing. The estimated average available dry matter was 1.14

tons/acre. The re-growth on 10 June was an estimated at 1.5 tons dry matter/acre and was grazed with 6 yearling steers for fifteen days. Initial observations indicate grazing sooner along with higher stocking densities, to more fully utilize the rye forage, would have been more effective; for both grazing timings. On 16 June, the remaining twenty-nine acres were cut, wilted, chopped and bagged for silage. The average yield was estimated to be 3.5 tons dry matter/acre. The forage quality measured was: 8% crude protein, 37% ADF, 61% NDF, 62% TDN. The rye was a few weeks past anthesis at the time of harvest. Quality will be higher if rye is cut at anthesis. While timing is critical for rye harvest and re-seeding of the second crop, to maximize forage quality and production from both crops, logistics and weather conditions can cause delays in both harvest and re-seeding windows. The field was re-seeded to German millet at a rate of 20 lbs./acre on 24 June. The double crop was sown as a monoculture as it was felt to be dry to seed multiple species (turnips, lentils, and radish) as planned. On September 15th, the German millet was swathed, allowed to dry and three windrows were combined to be used for fall and winter grazing of mature beef cows. Although not determined, estimated forage yield from this second crop is approximately 2 tons dry matter/acre. The forage quality of the German millet was: 8% crude protein, 51% ADF, 69% NDF, 47% TDN. The German millet was cut when the crop was in the seed development stage, again quality will be higher if cut in the early heading stage. In hindsight, moisture was not limiting as we had anticipated. Coupled with extended excellent fall growing conditions, we feel it would have been advantageous to have other plants growing in the field when we swath grazed. This could have been accomplished with the addition of turnips to the original seeding mix.

The rye silage is currently being fed in a feedlot trial to evaluate rye silage compared to corn silage in steer finishing diets. Seventy one head of 990 lb. steers are being fed diets with either corn silage (19% of the diet dry matter) or rye silage (11% of the diet dry matter) as the forage base. The steers have gained an average of 5 lbs./head/day. Animal performance, feed efficiency, and carcass data will be evaluated and summarized at the end of this feeding trial. Amazingly, we were able to harvest the rye crop in the spring and start feeding it in the feedlot within a few weeks. The corn silage used in this trial was harvested the previous fall. In addition to the feedlot research, we also have a year-round dry lot cow herd at the research center. We produced more rye silage than was needed for the feedlot trial, so have been feeding rye silage in our dry lot cow rations throughout the summer. Rye can fill the gap to provide forage between corn silage harvests.

Following weaning, on October 31, 109 head of mature cows were placed on the field to swath graze the millet crop that was re-seeded following the rye harvest. The field was split into four sections, cows grazed for approximately one week per section cows will be in the field for approximately 30 days. Additionally, the small one acre area that was used for rye grazing observations in the spring was re-seeded to winter rye in the fall. The cows have been allowed to graze and use this area to travel to access water while grazing the millet swaths. We will observe how hoof traffic and grazing in the fall will affect the spring growth of this fall seeded rye.

Overall this demonstration project has allowed us to take research from the plots to a field scale proof of concept. Demonstrating the dual cropping role rye can play in utilizing a small number of cropland acres for harvested forage and grazing production. Additionally, demonstrating how feedlots and dry lot cow/calf operations can utilize a small number of cropland acres as a forage base for silage, hay and grazing. Ultimately demonstrating the quantity and quality of forage that can be raised in a semi-arid short growing season when winter rye is a key component of the production system.

f) **Cover crops variety trials results. (Zwinger)**

Table. 6. Organic radish variety trial.

Variety	Seedling vigor	Plants bolted-10/25	Plant height	Harvested plant stand	Tops harvest moisture	Tops yield DM	Roots harvest moisture	Roots yield DM
	1-5	sqft	cms	sqft	%	lbs/ac	%	lbs/ac
Minowase	4.0	0.03	35.8	6.3	86.1	3462.9	90.1	2268.7
Tillage Radish	3.8	0.02	43.3	4.2	87.5	2975.4	90.3	2876.0
Nitro	2.8	0.01	40.0	4.6	87.8	3221.5	90.6	2740.4
Miyashige	2.8	0.00	34.3	4.5	84.0	3024.7	90.3	2320.6
Graza	1.0	0.00	22.5	1.3	82.7	2215.2	81.5	2276.6
Jackhammer	3.0	0.01	40.8	5.1	86.4	2551.2	89.2	2438.3
FBC bulk	4.0	0.52	39.3	3.5	83.6	2343.4	85.1	1999.5
Mean	3.0	0.08	35.5	4.2	85.4	2827.8	88.2	2417.2
C.V.%	30.6	60.1	12.7	28.5	1.9	21.4	2.5	14.4
LSD.10	1.1	0.06	5.7	1.5	2.0	741.9	2.7	427.6
LSD.05	1.4	0.08	6.9	1.8	2.4	898.9	3.3	518.1

Trial planted, August 9

Trial harvested, November 3-4

Previous crop, cowpeas that were hailed damaged on July 9

Seedling vigor taken August 24, 1=worst & 5= best

7) Cover crops interseeded with barley at Minot, ND North Central Research Extension center REC (Ericksmoen)

Table 7. Barley yield and quality with interseeded cover crops at different dates.

Cover Crop Treatment	Planting Date	Heading	% Plump	% Thin	Test weight	Protein	Grain yield	Cover crop biomass[3]
		DAP[1]	>6/64	<5/64	lbs/bu	%	bu/A	lbs/A
No cover crop	--	59	95	0	49.0	10.0	76.8	1609
CC planted with barley	May 1	59	96	0	49.8	9.5	81.1	2865
CC broadcast over 4 leaf barley	May 29	59	95	0	49.9	9.7	73.7	3057
CC broadcast over early headed barley	July 6	59	95	1	49.5	9.7	75.0	1809
CC planted after barley harvest	Aug. 7	59	95	0	49.0	9.6	79.3	1745
CC planted with barley + flax post-harvest	5/1 + 8/7	59	95	1	49.5	10.0	80.6	1304
Trial Mean		59	95	0	49.4	9.8	77.7	2065
LSD 5%		NS	NS	NS	NS	NS	NS	828

[1]*DAP = Days after planting.*

NS = no statistical difference between cover crop treatments.

Planting Date: May 1

Cover Crop Mix: turnip, radish, lentil and flax

Tillage: no-till

Table 8. Spring wheat yield planted in 2016 after cover crops interseeding treatments.

2015 Cover Crop Treatment	Days to Head	15-Jul NDVI	Plant height	Test weight	Protein	Grain yield
	DAP[1]	0 - 1	inches	lbs/bu	%	bu/A
No cover crop	51	0.47	30	61.0	11.2	33.8
CC planted with barley	51	0.49	31	60.7	10.9	34.2
CC broadcast over 4 leaf barley	51	0.49	30	61.6	11.3	36.8
CC broadcast over early headed barley	51	0.47	29	60.5	11.4	31.8
CC planted after barley harvest	51	0.50	29	60.9	11.0	35.1
CC planted with barley + flax post-harvest	50	0.50	29	60.9	11.6	38.7
Trial Mean	51	0.48	30	60.9	11.2	35.1
C.V.%	1.6	5.58	4.2	1.1	4.6	8.5
LSD 5%	NS	NS	NS	NS	NS	NS

[1]*DAP = Days after planting.*
Planting Date: May 6 Variety: Barlow, Harvest Date: August 12
Notes: The trial did not receive any applied fertilizer. NDVI reading on adjacent fertilized spring wheat was 0.74 and had a yield of 64 bu/A.

8) **Evaluation of cover crops for hosts and population reduction of soybean cyst nematode**
Krishna Acharya (1), Addison Plaisance (1), Guiping Yan (1), and Marisol Berti (2)
(1)

Host resistance and crop rotations are common practices for managing soybean cyst nematode (SCN), *Heterodera glycines*, in North Dakota, but the role of cover crops in SCN management is not fully understood. To evaluate this, twenty-one cover crop species and cultivars plus two susceptible soybean cultivars were planted in two naturally infested soils (initial population densities: 5,000 and 10,000 eggs/100 cm^3) from Richland and Cass counties, ND, in a growth chamber at 27 ^oC for 35 days. Host range was evaluated based upon numbers of SCN white females on roots and the effect on population reduction was determined by comparing initial and final SCN egg population densities. Out of the tested crops, SCN white females were not found on roots of annual ryegrass, camelina, carinata, ethiopian cabbage, faba bean, foxtail millet, radish, rape dwarf essex, red clover, sweet clover, triticale, and winter rye. Cowpea, crimson clover and turnips showed very few white females ranging from 1 to 13, but Austrian winter pea, field pea, forage pea and hairy vetch showed some levels of reproduction (white females: 13 to 173). SCN reproduced less in all tested cultivars compared to the susceptible checks (827 to 1,251). All the tested cover crops reduced the SCN population except field pea (Aragon) and forage pea which increased the population from 10,000 to 18,240 eggs/100 cm^3 soil for Aragon and to 25,560 eggs/100 cm^3 for forage pea. Cover crops which were non-host or poor host will be evaluated in the microplot study for reducing SCN populations.

Fig. Cover crops growing in a growth chamber at 27C

PUBLICATIONS

Peer-reviewed journal publications

Berti, M.T., R.W. Gesch, C. Eynck, J. Anderson, and S. Cermak. 2016. Camelina uses, genetics, genomics, production and management. Ind. Crops Prod. 94:690-710.

Berti, M.T., B.L. Johnson, R.W. Gesch, and A. Aponte, 2016. Environmental impact assessment of double- and relay-cropping with winter camelina in the northern Great Plains, USA. Agricultural Systems *(submitted, under review)*

Berti, M.T., D. Samarappuli, B.L., Johnson, and R.W., Gesch. 2017. Integrating winter camelina into maize and soybean cropping systems. Ind. Crops Prod. (*Submitted, under review*)

Abstracts and Presentations

Berti., M.T., B.L. Johnson, R.W. Gesch, J. Ransom, H.H. Kandel, M. Kazula, M.S. Wells, and A. Lenssen. 2016 Integrating camelina into corn and soybean cropping systems. p. 9 *In* Berti, M.T. and E. Alexopoulou (Eds.) 28th Annual Meeting of the Association for the Advancement of Industrial Crops (AAIC), Rochester, NY, 14-19 September, 2016.

Berti, M.T., J. Lukaschewsky, and M. Kazula. 2016. Alfalfa silage corn interseeding in North Dakota. North American Alfalfa Improvement Conference, Trifolium Conference and Grass Breeders Conference. Madison, WI. 12-14 July, 2016.

Forcella F., D. Wyse D, and R.W. Gesch 2016. Keep it green: Ecosystem services of year-round cropping. ASA-CSSA-SSSA Symposium – IPM Resistance Management. November 7, 2016. (30 attendees + continuous on-line access)
https://scisoc.confex.com/scisoc/2016am/videogateway.cgi/id/25419?recordingid=25419

Dose, H.L., R. Gesch, F. Forcella, B.L. Johnson, K. Aasand, M.S. Wells, A. Lenssen, S. Patel, M.T. Berti. 2017. Determining optimum time to seed winter cover crops into standing corn and soybean in the northern Corn Belt. Production Agriculture Symposium, University of Minnesota, St .Paul, MN, 22-23 February, 2017.

Berti, M.T. Interseeding cover crops into standing corn and soybean: what, when and how. Agriculture Production Symposium, University of Minnesota, 22-23 February 2017.

Book chapter

Wick, A.F., M. Berti, Y. Lawley, M. Liebig. 2016. Chapter 6: Integration of Annual and Perennial Cover Crops for Improving Soil Health. Soil Health and Intensification of Agroecosystem (Ed.M. Al-Kaisi, B. Lowery)

Proceedings publications

Berti, M.T., A. Aponte, B.L. Johnson, and D. Ripplinger. 2016. Environmental sustainability of double- and relay-cropping of food, feed, and fuel crops in the northern Great Plains, USA. In 24th European Biomass Conf. and Exhibition.5-9 June, 2016, Amsterdam, The Netherlands Available at http://www.etaflorence.it/proceedings/index.asp (verified 10 December 2016).

Grants

Berti, M., Seames, E, Yun J., Morris, G. SUNGRANT, 10/2016-09/2018. $187,496. Improving cold tolerance in sorghum: a promising feedstock for biofuels and biobased products in the northern Great Plains.

Extension publications, material, news, videos

Holin, F. 2016. New research on interseeding cover crops into standing corn begins. Clippings 17 June, 2016. Midwest Forage Association, St. Paul, MN. Available athttps://www.midwestforage.org/pdf/1041.pdf (**M. Berti** and **R. Gesch** mentioned in the article)

Wick, A. 2016. Planting Soybean into Cereal Rye – Observations. NDSU Soil Health, Fact Sheet.

Videos

A.F. Wick, M. Berti and C. Langseth. 2016. Cover Crop Selection: Grasses, Extension Education Video, InHouse Productions, https://www.youtube.com/watch?v=Ac1aH-R2U-4

A.F. Wick, M. Berti and C. Langseth. 2016. Cover Crop Selection 2: Legumes, Extension Education Video, InHouse Productions, https://www.youtube.com/watch?v=uzwFPCR8kUQ

A.F. Wick, M. Berti and C. Langseth. 2016. Cover Crop Selection 3: Cover Crops after a Cereal Crop, Extension Education Video, InHouse Productions, https://www.youtube.com/watch?v=YTBw8dF4sdo

A.F. Wick, T. DeSutter and C. Langseth. 2016. Cover Crop Selection 4: Soil Temp and Soil Respiration, Extension Education Video, InHouse Productions, https://www.youtube.com/watch?v=ehEMPf0CWHo

Field days

1. Using Cover Crops in Rotation – Tour of Wagner and Wilson Farms Jamestown, ND, 27 October 2016 (100 participants)
2. Grant County Soil Health Tour, Soil pit and how cover crops improve soil health, 26 October 2016
3. Cover Crops and Soil Health – Tour for NDSCS Students Wahpeton, ND 25 October 2016 (100 participants)
4. Cover crop field day at Conservation Cropping Systems Project farm 7 October 2016, Forman, ND, (30 participants) (Ransom, Berti, Wick)
5. Cover crop field day 4 October, 2016 Fargo, ND, (72 participants) Soil health and cover crops field day at the SHARE-NDSU farm in Rutland and Delamere, ND. 27 September 2017 (135 participants).
6. Big Iron Show – Featuring the new interseeder/fertilizer drill- and Extension booth with cover crop plants in pots and cover crop hand-out, September 14-15, Fargo ND.(100 participants)
7. Field day cover crop tour Highlights Grazing and Soil Health Benefits, 19 August 2016 Streeter, ND, (13 participants)
8. Cover crop field day 18 August 2016 Dickinson, ND (18 participants).
9. Field Day: Using Cover Crops in Rotation (Interseeding Corn; Toussaint Farm) 4 August 2016. Dwight, ND (100 participants).
10. Field Day: Using Cover Crops in Rotation (Interseeding Corn; Speich Farm), 3 August, Delamere, ND. (100 participants)
11. Field Day: Using Cover Crops in Rotation (Interseeding Corn; Wehlander Farm), Milnor ND, 2 August 2016 (100 participants)
12. Cover crop interseeding into sunflower, 18 July 2016, Dwight, ND (15 participants)
13. Gave a field tour to 15 visiting Australian university undergraduate students of the Swan Lake Research Farm in Morris and demonstrated and discussed CAP research on new cash cover crops (camelina and pennycress) and cropping systems (July 2016).

14. Field day on the Conservation Cropping Systems Project board, 14 July 2016, Forman, ND spoke about our research on cover crops (12 growers)
15. Field day, cover crop interseeding demonstration, Gardner, ND, 7 July 2016 (42 participants).
16. Field demonstrations , visiting farms with cover crops Milnor (15 people), Delamere (22 people), and Forman (20 people) July 2016
17. McLean county Crop Tour , Soil pit and how cover crops improve soil health, 12 July 2016
18. NCREC Field Day, Salinity management with cover crops, Langdon, ND, 20 July 2016
19. Cover crops field day. Soil Health Bus Tour (visiting all commodity funded soil health sites. Interseeding with the new interseeder was demonstrated. Wahpeton, ND 29-20 June, 2016
20. NPAIA, Salinity management with cover crops 1 June 2016
21. Planting Green – Soybean into Cereal Rye (tour for commodity office staff). Delamere, ND 18 May 2016

Workshops and professional training

-2016 Cover crops for weed Management. Crop in-service for extension agricultural Agents for Carrington Research Extension Center, 20 December, Carrington, ND (24 participants)

-2016 Northeast Extension Ag. Agent Research and extension update. Cover crops extension agents training, 26 August 2016, Langdon, ND (10 participants)

Café Talks

Q&A session with farmers about cover crops, soil fertility, soil health. Café Talks are an informal setting for farmers to be able to talk and learn from each other about cover crops. Different specialists participate in the Café Talks to aid the discussion. Numbers of farmers at the Café talks varies from 5 to 15 in each session impacting over 100 farmers.

5 January and 2 February, 2017, Milnor ND
12 January and 15 February, 2017, Colfax, ND
17 and 31 January and 14 February, 2017, Fort Ransom, ND
19 January and 16 February, 2017, Lakota, ND
26 January, and 23 February, Kulm, ND
27 January and 24 February, 2017, Jamestown, ND

Graduate students

Sergio Cabello, Ph.D. Nutrient credits from cover crops in no-till systems in the northern Great Plains. North Dakota State University. (Dr. Berti and Dr. Franzen) August 2016- May 2020.

Dulan Samarappuli, Ph.D. Productivity and life cycle analysis of novel cropping systems in North Dakota. North Dakota State University. (Dr. Berti) April 2016- August 2017.

Nadia Delarvarpour, PhD., North Dakota State University, Improving the twin-row interseeder guidance system. (Dr. Bajwa and Mr. Nowatzki) January 2017-May 2019.

Swetabh Patel, PhD. Interseeding cover crops and alfalfa into standing corn and soybean. Iowa State University. (Dr. Lenssen) May 2016- May 2019

Alan Peterson, MS, Interseeding camelina on standing soybean. North Dakota State University. (Dr. Berti) June 2016-December 2018

Melissa Geizler, MS, Corn row spacing and hybrid maturity effects on establishment of interseeded cover crops. North Dakota State University. (Dr. Ransom) April 2016- May 2018

Bryce Andersen, MS Integrating faba bean (*Vicia faba* Roth.) into cropping systems as a cover crop, intercrop, and late-season forage for grazing. North Dakota State University. Dr. Berti). January 2017- May 2019

Kyle Aasand, MS, corn and soybean relay cropping with winter rye, field pennycress, and winter Camelina. North Dakota State University (Dr. Johnson) June 2016- December 2018

Nick Steff, MS, Interseeding winter rye, field pennycress, and winter camelina in standing corn and soybean. North Dakota State University (Dr. Johnson) January 2017-May 2019

Kory Johnson, MS. Interseeding camelina into narrow row spacing soybean of different maturity groups. North Dakota State University (Dr. Kandel) January 2017-May 2019

Nancy Stenger, MS, North Dakota State University, Microclimate under corn and soybean canopy. (Dr. Akyuz and Dr. Berti) January 2017-May 2019

IMPACT STATEMENT

Cover crops adoption in North Dakota is increasing exponentially thanks to the many researchers involved in cover crops in the state. Soil erosion by wind is a serious problem in our state especially in winter with little snow cover or dry springs. The positive impact to the environment will not be measurable until a few more years.