MCCC-NORTH DAKOTA ANNUAL REPORT

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Marisol Berti[1], Dulan Samarappuli[1], Alan Peterson[1], Sergio Cabello[1], Swarup Podder[1], Bryce Andersen[1], Alex Wittenberg[1], Joel Ransom[1], Mattie Schmitt[1], Hans Kandel[1], Kory Johnson[1], Greta Gramig[1], Jesse Puka-Beals[1], Kirk Howatt[1], Burton Johnson[1], David Ripplinger[2], Abbey Wick[3], David Franzen[3], Caley Gasch[3], Tom DeSutter[3], R. Jay Goos[3], Jeremy Wirtz[3], Larry Cihacek[3], Aaron Daigh[3], Luke Ressler[3], Guiping Yan[4], Krishna Acharya[4], Mike Ostlie[5], Greg Endres[5], Ezra Aberle[5], Erik Eriksmoen[6], Christopher Augustin[6], Justin Jacobs[7], Ryan Buetow[8], Douglas Landblom[8], Songul Senturklu[8], John Nowatzki[9], Jason Harmon[10], and James V. Anderson.

[1]Dept. of Plant Sciences, NDSU
[2]Dept. of Agribusiness and Applied Sciences, NDSU
[3]Dept. of Soil Science, NDSU
[4] Department of Plant Pathology, NDSU
[5]Carrington Research Extension Center, NDSU
[6]Minot Research Extension Center, NDSU
[7]Williston Research Extension Center, NDSU
[8]Dickinson Research Extension Center, NDSU
[9]Agriculture and Biosystems Engineering, NDSU
[10]School of Natural Resource- Entomology, NDSU
[11]USDA-ARS, Edward T. Schafer Agricultural Research Center
Sunflower and Plant Biology Research Unit

COMPLETED RESEARCH

1. ***Cover crops and intercropping research*** (*Mike Ostlie and Justin Jacobs)*

*Determining rye safety to soybeans with soil moisture***.** This study focused on how different rye termination dates affects soil moisture content. There was a perfect correlation this season between decreased soil water concentration as a result of rye presence and soybean yield. This year it was ok for our soybeans to be 'planted green', which is different than the previous two years.
Utilizing buckwheat as a P source. This trial just finished and results are being processed. Buckwheat was the only crop in the study that had a higher P content in the residue than the grain, providing some evidence for a P credit. However, corn yields were negatively affected by having buckwheat as a previous crop, even though soil plus residue P indicates much more P should be available in that rotation. Suspect P tie-up or some type of biological antagonism. AMF could be part of it, but sugarbeets were also included as a previous crop and did not reduce corn yields.

Intercropping pea with canola, and flax with chickpea. Justin Jacobs at the WREC is leading this study as part of his Master's project. We were looking at different seeding rates of the species combinations. For both systems we were able to generate up to 30% additional productivity per acre (LER = 1.3) with some seeding rate combinations, while others provided little to no benefit over monocropping.

Corn silage intercropping. Nine legume and sunflower combinations were planted between corn rows at-planting. Crops were ground and mixed and vacuum packed into bags to simulate a silage pile. Silage quality was measured after 42 days. Performance of intercrops varied greatly. Field peas, soybeans, and sunflowers showed very modest improvements to silage yield (~5% more), with increases to protein ranging from 0.5-2%. Some crops such as fababean, lupine, and edible beans did not ensile very well, likely due to low moisture. Field peas were also very dry but did still ensile. Harvest timing and populations need to be evaluated more.

2. ***Modification of planters, or improved seeding strategies for establishing cover crops in standing corn and soybean [at different growth stages.*** *(G. Breker, J. Nowatzki, and PhD student N. Delanvarpour)*

We conducted a comparative analyses of Tactile sensor and Ultrasonic sensor performances of the guidance system for the grain cart attached to the interseeder. The study was conducted because the grain cart wheels, as initially designed, were running over the grain rows during field operation. From the studies, the following conclusions are drawn:

- Both sensors identify plants in varying row patterns in different machine speeds sufficiently accurate. However, their readings (signals) need to be filtered with adequate digital filters, viz. Butterworth low pass and Gaussian filters.
- These sensors do not have limitations, such as requiring good GPS signals or daylights or weather conditions required by image processing technology based sensors.
- These sensors have their own limitations. TAC sensor cannot be used for small, thin and delicate plants, while Ultrasonic cannot be used in dense fields, or fields with lots of weeds, or the plants with long leaves. Therefore, they need to be employed accordingly.
- The found fit model for TAC sensor readings (the distance between the paddles of the sensor and output voltage) to compute the actual distance is in a nonlinear nature and its accuracy is sufficiently accurate ($r^2 = 0.99$) that enables the system to compute the actual distance with the deviation of about $\pm 4.5\ mm$.
- The hitch never got to its desired position in time, since hydraulic actuator of the test bench steering system was not fast enough. An appropriate controller and actuator need to be designed.
- Noises and disturbances would cause inconsistency in reading and consequently in steering. Therefore, it is very important to apply analog and digital filters according to a sensor type and operational speed.
- Both sensors have better performances in finding the rows in higher speeds.
- Due to inherent disturbances, Ultrasonic sensor is less accurate in identifying the rows in comparison to the TAC sensor.

We collaborated with Amity Technologies, the manufacturer of the interseeder, to strengthen parts of the interseeder that malfunctioned and broke as originally manufactured.

3. ***Interseeding of cover crops into standing soybean*** *(Marisol Berti and Alan Peterson)*

In order to reduce nutrient losses and soil erosion in the northern Great Plains following soybean, cover crops should be interseeded into standing soybean, since after soybean harvest there is not enough time for a cover crop to grow. If the cover crops cannot provide adequate growth and cover, the soil is exposed to degradation throughout the winter months, and loss of crop productivity in following years. The objective of this study was to determine the establishment and green cover of interseeded cover crops and their impact on soybean yield and quality. This experiment was conducted at two locations, Fargo and Prosper, ND, in 2016 and 2017. The experimental design was a RCBD with four replicates in a split-plot arrangement. Soybean reproductive stages R4 and R6 were the main plots and cover crops were the sub-plots. Four cover crops, winter camelina cv. Joelle, Austrian winter pea [*Pisum sativum ssp.* arvense (L.) Poir], winter rye cv. Rymin, and forage radish cv. Daikon, were sown at R4 and R6 stages of soybean. Cover crop biomass yield in the fall was highest in radish and winter pea, 2 Mg/ha and 1.85 Mg/ha respectively. Austrian winter pea provided the greatest soil cover. Cover crop above-ground biomass N accumulation ranged from 28.7 to 73.2 kg/ha. Results indicate interseeding cover crops have no impact on soybean yield and quality. Interseeding cover crops at later soybean reproductive stages has good potential to mitigate soil nitrate losses and soil erosion in areas that grow soybean.

4. ***Relative maturities and row spacing effect on establishment of interseeded cover crops into soybean*** *(Hans Kandel, MS student Kory Johnson)*

An experiment to determine the effect of soybean maturities on cover crops growth was conducted in 2016 and 2017, and observations of surviving cover crops was done in the spring of 2017 and 2018. Winter camelina and cereal rye were interseeded into established soybean. Four cultivars were used including 0.4, 0.5, 0.8, and 0.9 soybean maturities. All cover crops were interseeded into established soybean at the R7 growth stage (beginning of senescence) of the 0.4 variety, using direct and broadcast seeding methods. Two cover crop seeding rates were used, 100 and 75 percent of recommended rates, with winter camelina cv.'Joelle' seeded at 6.0 and 4.5 pounds per acre and cereal rye cv. Rymin seeded at 60 and 45 pounds per acre, respectively. Data collected included soybean yield, cover crop canopy coverage percentage in late fall of 2016 and 2017 before first snow and before termination in the spring of 2017 and 2018. Cover crop biomass was measured in the spring of 2017and 2018. Following termination of cover crops, hard red spring wheat was planted in the previous year's soybean/cover crop plots. Data were collected from wheat plots to determine effects of cover crops on wheat growth and yield.

Table 1 shows combined cover crop data of both growing seasons. Cover crop canopeo is expressed as a percentage. Readings were taken before first snowfall and before termination in following spring (2017, 2018). Cereal rye produced significantly greater percent cover in both readings and had additional growth in the spring. The spring winter camelina cover reading was nearly 50% less than the fall reading. This is primarily attributed to ice-sheeting which resulted in high winter mortality. Cereal rye produced nearly four times the biomass compared with that of winter camelina. Cover crops interseeded in early-maturing varieties produced significantly greater coverage in the fall, but the differences became non-significant in the following spring observation. Although canopy coverage was non-significant, there was a relationship of soybean variety and cover crop biomass with the cover crops following the 0.4 variety producing significantly more biomass than the 0.9 variety. Since cover crops were planted at the R7 stage of the 0.4 variety, the light competition in later maturating soybean varieties resulted in less biomass and canopy coverage.

Soybean yield results are provided in Table 2. A yield difference was observed between cover crop treatments and the check. Disruption to soybean plant roots during seeding of cover crops may have caused yield differences, as check plots were undisrupted during planting of cover crops. Significant yield differences were observed among difference soybean varieties, respectively.

Wheat (spring 2017 and 2018) canopeo is a measurement of canopy coverage and was used to determine wheat cover following the cover crop trials in 2016 and 2017. Wheat was planted directly into cover crop trial plots following termination of cover crops (10 days prior to planting of the wheat). Rye produced over two times the biomass of camelina in the fall. High rye biomass directly resulted in poor wheat stand and coverage (Table 2). Despite this reduction in stand, no yield differences were observed between treatments.

Wheat after cover crops 8 August 2018.

Table 2. Soybean yield and wheat canopeo, height, and yield 2016, 2017, and 2018 for four soybean maturity group (MG) cultivars (04-09) and two cover crops at two seeding rates.

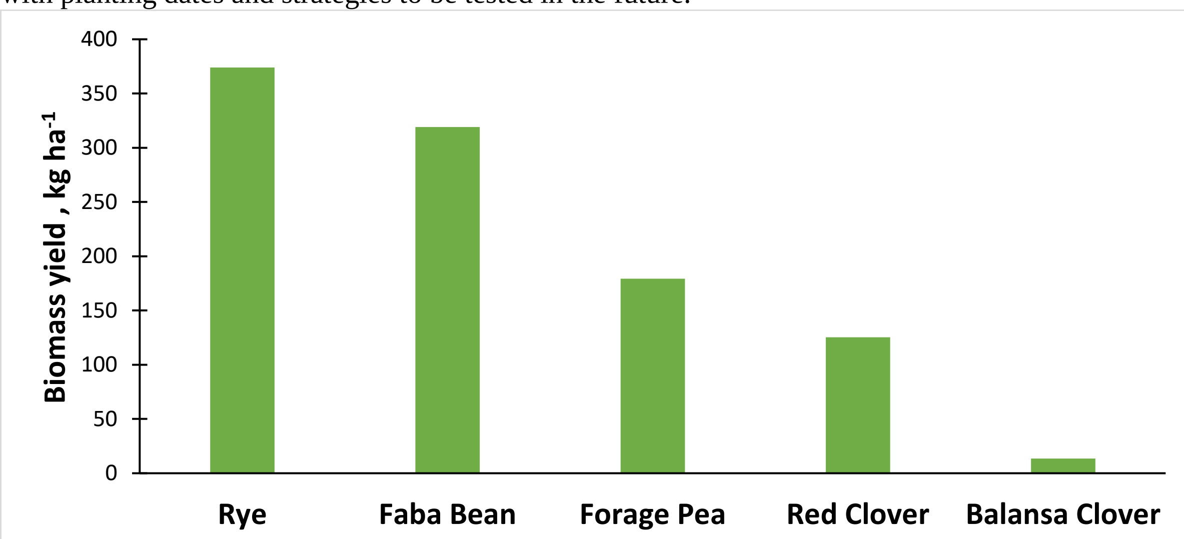
	Cover crop Canopeo				Cover crop biomass	
Cover crop	Fall		Spring		Spring	
	2016-2017		2017-2018		2017-2018	
	-------------%------------				---------kg ha^{-1}---------	
Camelina100	7	c	4.0	b	293	b
Camelina75	6.4	c	3.7	b	286	b
Rye100	16.2	a	16.1	a	512	a
Rye75	12.7	b	15.5	a	493	a
Check	0	d	0	c	0	c
LSD	2.0		2.1		24	
_Soybean MG						
AG04	14.4		11.2		341	
AG05	12.4		10.1		306	
AG08	10.9		10.3		325	
AG09	8.9		8.8		295	

Table 2. Soybean and wheat canopeo, height, and yield 2016, 2017, and 2018 for four soybean maturity group (MG) cultivars (04-09), two cover crops at two seeding rates.

	Soybean yield		Wheat Canopeo		Spring wheat height		Wheat yield	
Crop	2016-2017		2017-2018		2017-208		2017-208	
	bu/A		------%------		--------cm----------		bu/A	
Camelina100	39.9	b	52.0	b	34.5	a	49.5	a
Camelina75	39.4	b	51.7	b	34.6	a	49.9	a
Rye100	39.9	b	40.0	c	33.0	b	43.1	b
Rye75	39.9	b	41.9	c	32.7	b	44.4	b
Check	40.9	a	54.3	a	34.6	a	49.7	a
LSD	0.5		2.1		0.5		1.8	
Soybean MG								
AG04	37.3	d	48.1		33.9		48.4	a
AG05	39.0	c	45.9		34.0		47.0	a
AG08	41.1	b	46.4		34.0		47.3	a
AG09	42.6	a	46.8		33.8		46.6	b
LSD	0.7		ns		ns		1.7	

5. ***Interseeding faba bean, forage pea, clovers and rye into standing corn*** (Marisol Berti, MS student Bryce Andersen)

Quality forage late in the season in North Dakota is not always easy to come by. Often cattle graze corn stalks after harvest, but their protein requirements cannot be fulfilled by post-harvest residue alone. Faba bean has been shown to have higher crude protein than other commonly grazed legumes. Adding faba bean to the mixture by interseeding during the season could be a crucial nutrient supplement, provide cheaper feed, and help to keep cattle out of the feedlot later into the fall. Faba bean, forage pea, balansa clover (*Trifolium balansae* L.), red clover (*Trifolium pratense* L.), and rye, were interseeded into corn in a twin-row, 15 cm apart, at two different seeding dates, V8 and R4. Once corn was harvested or shortly before the first expected hard frost, biomass samples were collected by hand clipping all aboveground biomass in two 1-m length rows. Differences were seen in intercrop biomass with rye yielding greatest at 375 kg ha^{-1}, followed by faba bean, then forage pea, red clover. Balansa clover was lost in a large majority of the plots. A significant interaction was seed between cover crop biomass and planting date, with the second date typically yielding more. This is due to summers being dry and the earlier planting date typically saw large reductions in stand throughout a dry June and August. Phosphorous was the only biomass component where a significant difference was seen, with forage pea, rye, and faba bean having more than red clover. Corn stand count, biomass, test weight, and yield were not influenced by the intercrops. Rye, faba bean, and late intercropped forage pea showed the most promise, however, intercrop yields were relatively low due to abnormal summer droughts. There are many other cover crops, along with planting dates and strategies to be tested in the future.



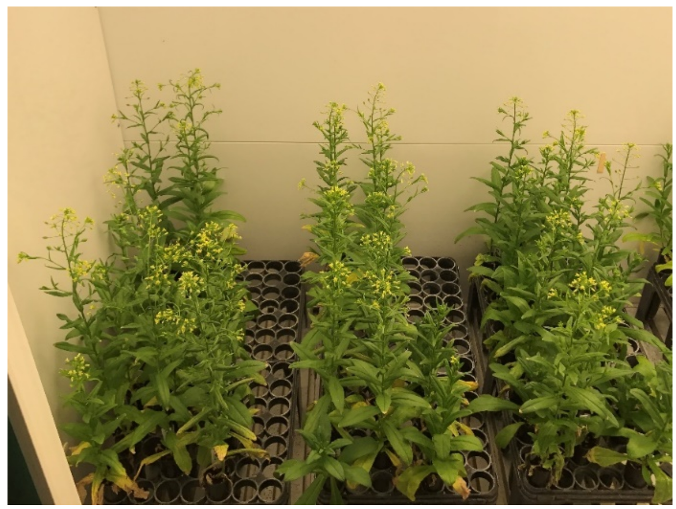
Biomass yield of five cover crops interseeded into corn at V8 and R4. Data averaged across two seeding dates and four environments.

6. ***High Throughput Phenotyping of Camelina sativa Seeds for Crude Protein, Total Oil and Fatty Acids Profile by Near Infrared Spectroscopy*** *(James Anderson, Marisol Berti, MS student Alex Wittenberg)*

Fast, non-destructive methods for determining the seed composition of camelina would be beneficial in evaluating germplasm for important agronomic traits. In this study, near infrared spectroscopy (NIRS) methods were developed and evaluated for conducting non-destructive, high throughput phenotyping of seed quality traits. Nitrogen and total oil concentration for 85 accessions (63 summer- and 22 winter-biotypes) were first determined by established wet chemistry methodology; whereas, for fatty acid profiles 173 accessions (149 summer- and 24 winter-biotypes) were determined using Gas Chromatography (GC). The wet chemistry and GC data were used to develop NIRS calibration equations for each trait. Based on the wet chemistry data obtained from 85 accessions, mean crude protein (calculated from N concentration) was significantly less in summer (300 g kg^{-1}) than in winter (315 g kg^{-1}) biotypes ($P \leq 0.05$) and total oil was greater in seeds of summer (351 g kg^{-1}) than that of winter (326 g kg^{-1}) biotypes. Coefficient of determination (r^2=0.979 and 0.894, respectively) and ratio of performance to deviation (RPD=9.15 and 4.33, respectively) for crude protein and oil content indicated a high level of confidence for predicting these traits using NIRS. Evaluation of all 173 accessions by NIRS did not appreciably change the predicted mean crude protein content of summer- and winter-biotypes; however, it did change the predicted mean total oil content of summer biotypes (260 g kg^{-1}), which was significantly less than predicted for winter biotypes (323 g kg^{-1}). Fatty acids contents were not significantly different between summer- and winter-biotypes. The most abundant fatty acid was linolenic acid (18:3) ranging from 22.8 to 38.4%, followed by linoleic acid (18:2) at 15.2-27.1%, eicosenoic acid (20:1) at 11.6-18.2%, and oleic acid (18:1) at 9.1-22.1%. Calibration models for the main fatty acids oleic, linoleic, linolenic, and eicosenoic acids had r^2 values of 0.718, 0.790, 0.828, and 0.586, respectively. Results of this study indicate that NIRS has potential as a non-destructive, high throughput method for determining quality traits of camelina seed.

7. ***Morphological characteristics of winter- and summer-biotypes of camelina*** *(James Anderson, Marisol Berti, MS student Alex Wittenberg)*

With the increased interest from producers, private seed companies outsourced winter camelina in the summer of 2017. Regrettably, all outsourced seed that seed companies sourced in 2017 from other states was the summer type which does not survive the winter in North Dakota. While differences in the morphology of summer and winter biotypes have previously been observed and noted by other researchers, no research has been conducted to determine exact differences. The objective of this study was to determine the morphological characteristics of seeds and seedlings from summer- and winter-biotypes. To determine differences in seed wavelength absorbance between winter- and summer-biotypes both visible and near-infrared spectra were examined, which encompass 400 to 2498 nm wavelengths.



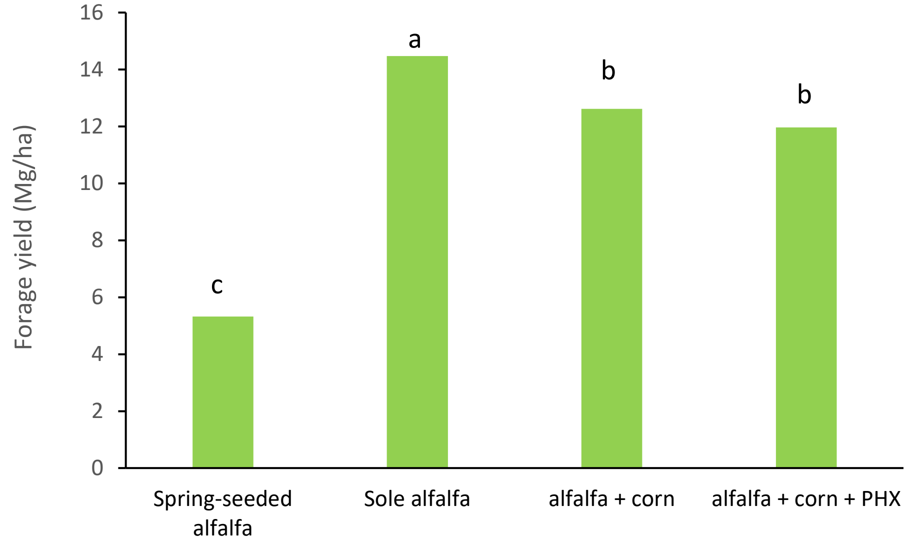
Summer camelina biotypes bolting.

Mixtures of cultivars Joelle (winter) and Blaine Creek, Shoshone, and Pronghorn (summer) were analyzed using near-infrared spectroscopy (NIRS), XDS Analyzer. Seed mixtures were prepared in increments of 5% of 'Joelle' with the other summer cultivars. Morphological characteristics of seedlings were determined by growing fifteen summer- and fifteen winter-biotypes in an environmental chamber. Spectra data and developed equation can successfully determine if an unknown-biotype seed lot is a winter or summer biotype. Plant height range from 1 to 562 mm at five weeks after planting. Interactions between measured traits of pairs of vegetative leaves, growth stage, leaf width, leaf length, lobes, and height. Differences in seed and seedling morphological characteristics can be used to differentiate winter- or summer-biotypes.

8. Intercropping of corn and alfalfa (*Marisol Berti, Dulan Samarappuli)*

The experiment was conducted at three environments in Prosper and Forman, ND established in 2016 and Prosper established in 2017. The results across the three environments, indicate that alfalfa yield was greater for alfalfa established alone the first year compared with the other treatments. Alfalfa intercropped into corn at establishment, with or without prohexadione application, had lower yield than alfalfa seeded alone, but 2.2 to 2.5 times greater yield than the spring-seeded alfalfa following corn (business-as-usual). In the third year of production (alfalfa established at Forman or Prosper in 2016), alfalfa yield was similar for all four treatments.

Quick economics calculation with the results in North Dakota indicate this system has a positive outcome. In Year 1, corn yield decreases on average 30 bu/acre due to the competition alfalfa imposes. In Year 2, alfalfa yield increases in about 2.5 tons/acre compared with spring-seeded alfalfa. With corn at $3/bu and alfalfa at $100/ton. 30 x 3=$90/acre loss in Year 1 and $100 x 2.5= $250 gain in Year 2, with a balance of



$160/acre.

Alfalfa total seasonal yield for alfalfa alone, alfalfa intercropped into corn at establishment, with and without prohexadione (PHX) application, averaged across three environments (Prosper 2016-2017, Prosper 2017-2018, and Forman 2016-2017).

9. ***Interseeding on farm-replicated trials*** (AbbeyWick, David Franzen, Hans Kandel, Joel Ransom,; farmers Breker, Bell, Toussaint, Hohenhause, Thilmony)

Interseeding cover crops: The project's twin row high-clearance planter interseeded cover crops at five farmer's fields. Total acres interseeded with the interplanter was approximately 600 acres. Farmers who used our interseeder were Joe Breker (corn-cover crops) and Jeff Breker (corn-sorghum), Rutland, ND; Joe Bell (soybean-covercrops), Gardner, ND, Doug Toussaint (sunflower-cover crops), Wahpeton, ND, at the Soil Health and Agriculture Research Extension (SHARE) farm Mooreton, ND and M. and A. Hohenhause, Lisbon, ND. Cover crops interseeded were radish, rye, winter camelina mix into corn at V6, forage sorghum into corn, cut for silage at the end of the season, cover crops mix in sunflower. Grain yield did not decrease at any of the interseeded locations.

Intersseded faba bean, pea, radish winter camelina and rye mix and rye, radish winter camelina mix into standing corn, Joe Breker farm, Rutland, ND.

Joe Breker and Doug Toussaint planted 50 acres each of winter camelina in the fall of 2017. One field was drilled after a wheat crop and the other field was aerially seeded. Camelina stands in the spring were spotty with areas with very good stands and few weeds while some lower spots had lower stands and many weeds, mainly field pennycress. To avoid seed contamination, field pennycress was hand weeded in both fields as much as possible. Both farmers were able to harvest about 20-30 acres each out of the 50 acres of camelina planted in the fall with an average yield of about 800 lbs seed/ acre. Seed harvested still had field pennycress seed so it was sent to a cleaning facility and the seed was cleaned to 99% purity using and optical sensor. Both North Dakota growers established winter camelina again in the fall of 2018, with the intent of double relaying soybean into green camelina in the spring.

An alfalfa-corn intercropping on-farm replicated trial was started in 2018 at the Anthony Thilmony farm in Valley City, ND. Three strips 20 ft wide and 100 ft in length were planted with corn, alfalfa or alfalfa +corn. The experiment had three replicates. The alfalfa variety was Vamoose RR. This variety was selected because it has leafhopper resistance. In the plot trials from 2016 and 2017 it was clear that alfalfa planted with the corn had increased leafhopper damage, probably because the conditions within the canopy were favorable for the leafhopper development. Using Vamoose solved this problem and this on-farm trial did not need insecticide spraying for leafhoppers. Corn was planted by the farmer at the same time as the rest of his corn field and then a 20ft drill from NRCS was used to plant alfalfa on the strips with corn (3 strips).

Alfalfa-corn intercropping on-farm trial at Anthony Thilmony farm, Valley City, ND.

Results of this experiment were similar to what was observed in the plot trials across locations and years. Corn yield decreased by 27 bu/acre in the plot with alfalfa in it, although the difference was not statistically significant. This was expected since alfalfa planted at the same time as corn competes for water and nutrients with corn. Alfalfa established well under the corn canopy and plant density was not different from that of sole alfalfa. In this system the loss of corn yield in Year 1 is offset by the 2.5 ton/acre gain in alfalfa yield in the following season.

10. Cover crops extension activities *(Abbey Wick, Marisol Berti, Hans Kandel, Joel Ransom, David Franzen)*

Cover crops field day in Fargo, ND, 18 September 2018. In the picture Dr. Abbey Wick and Dr. Marisol Berti.

Field day in Rutland, ND, 28 August 2018. In the picture PhD student Sergio Cabello-Leiva and Dr. Dave Franzen show the results on nutrient cycling of cover crops in corn.

11. ***Cover crops in barley trial in Carrington 2018*** *(Ezra Aberle)*

Cover crop biomass includes all green above ground plant material at the end of the growing season. No biomass was produced due to drought conditions. There was not even any volunteer barley.

Cover Crop Treatment	Cover Crop Planting Date	Test weight	Protein	Grain Yield
		lbs/bu	%	bu/A
No cover crop	--	43.3	13.3	50.5
CC planted with Barley	5/2/18	44.8	13.0	51.1
CC broadcast into 4-5 leaf Barley	5/31/18	43.9	13.2	50.0
CC drilled into 4-5 leaf Barley	5/31/18	43.7	13.4	50.7
CC broadcast over early headed Barley	6/25/18	43.7	13.2	50.7
CC planted after Barley harvest	8/1/18	44.5	13.0	51.2
Trial Mean		44	13	51
C.V.%		2.3	4.1	1.7
LSD 5%		NS	NS	NS

NS = no statistical difference between treatments

Barley Variety: Pinnacle

Planting Date: 5/2/18

Harvest Date: 7/31/18

Previous Crop: HRSW

12. ***Mineral N Cycling in an Integrated Crop-Grazing System*** (*Larry J. Cihacek, Songul Senturklu, and Douglas Landblom)*

A long-term integrated crop-grazing system study has been ongoing for more than seven years in western North Dakota. Objectives of this study are to diversify cropping systems dominated by small grains with other crops as well as reduce costs in finishing beef animals by grazing high quality crops rather than all grain. Continuous hard red spring wheat (*Triticum aestivium* L.) (HRSW) is being compared to a 5 season rotation consisting of hard red spring wheat (rotation), winter triticale-hairy vetch (*Triticale hexaploid* Lart.-*Vica villosa* Roth), field pea-barley intercrop (*Pisum sativum* L.-*Hordeum vulgare* L.), mixed species cover crop, corn (*Zea mays* L.) and sunflower (*Helianthus annus* L.) under no-till management. Our previous work tracking residual mineral N (NH_4^+ + NO_3^-) in this system based on periodic profile N sampling to 0.6 m has indicated a substantial N availability (100 to 200 kg/ha) in the crop rooting zone throughout the growing season. This is in a region that is limited in rainfall (325-450 mm). We have also observed that with our study crop of HRSW, N fertilizer requirements based on soil tests have been declining as the system has "matured" while yields have been slightly increasing in the rotation plots.The objective of this study was to identify the differences in N mineralization ability between soils in continuous spring wheat and in spring wheat in rotation with other crops with grazing.

Soil were collected at six (6) points in time throughout the growing season in 2014 and four (4) points in time in 2016 to a depth of 0.6 m as recommended by NDSU for determining residual soil N (Table 1). We analyzed the surface 0-15 cm of the soil samples from the continuous and rotation HRSW plots that were collected in the season that HRSW was grown (either 2014 or 2016) for potentially mineralizable N (PMN) based on the methodology of Waring and Bremner (1964) and Keeney (1982). This utilizes an anaerobic incubation at 40°C for 7 days with determination of NH_4^+-N at the end of the incubation period. Data was statistically analyzed using SASv9.4.

Figures 1A and 1B show the potentially mineralizable N in 2014 and 2016.Changes in mineral N cycling were observed as changes in PMN during the two years evaluated thus far in this study. PMN is higher in the RSW soils due to several factors:

a. A continuous system of diverse crops is growing in the rotational system which then are available for animal forage. This is an ideal system to consider the effects of cover crops in maintaining soil health over a long-term period. Some of the crops included are cover crops but fall seeded crops such as the triticale/vetch crop also act as cover crops.
b. A diversity of crops that include legumes as forage crops enhance soil N because of the roots that remain in the soil after harvest/grazing.
c. Animals grazing the crops also distribute dung and urine across the field as they graze which add to the N budget of the soil.
d. These are not found in traditional systems similar to the CSW treatment.
e. In this semi-arid environment, the no-till system also conserves precious soil moisture to be utilized more efficiently by both crops and microorganisms in cycling N.
f. Regression analysis between SOM and PMN this far indicate that about 8.4 mg N/1% SOM/kg soil are being mineralized across this study (n = 148, R^2 = 0.21***).

Table 1. Soil sampling dates for 2014 and 2016.

2014 Sampling Dates	2016 Sampling Dates
June 2 (6/2)	June 2 (6/2)
June 16 (6/16)	July 27 (7/27)
June 30 (6/30)	August 31 (8/31)
July 14 (7/14)	October 13 (10/13)
August 11 (8/11)	
September 14 (9/14)	

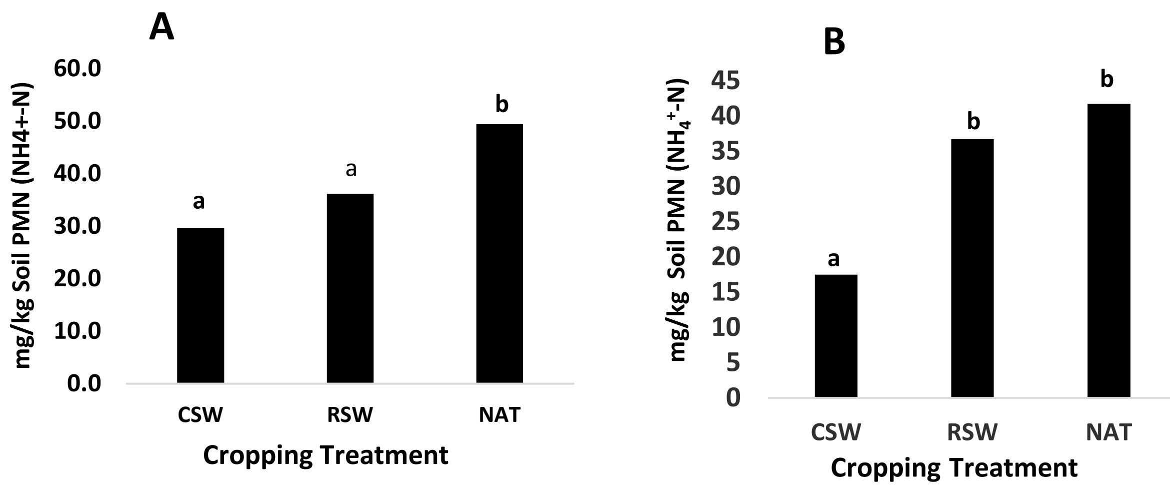


Figure 1. Potentially mineralizable N as influenced by cropping treatment for the 2014 (A) and 2016 (B) cropping seasons. CSW – continuous spring wheat; RSW – rotation spring wheat; NAT – native grassland.

Our work continues to show the dynamic nature of N cycling in an integrated crop-grazing system in a semi-arid environment. We have and are continuing to evaluate the soil PMN dynamics for the 2017 and 2018 cropping seasons with mineralization studies that are currently ongoing. The rotation utilizes crops that function as both cover crops as well as livestock forage crops and due to its long-term nature is in effect a study of the long-term effects of cover crops within cropping systems.

The authors gratefully acknowledge the partial support of this research through the Sustainable Agriculture Research & Education Program (SARE) under projects LNC1-335 (completed) and LNC16-381 (current).

13. ***Alternative Forage-Based Growing and Finishing within an Integrated Crop and Beef Production System*** *(Douglas Landblom, Ryan Buetow and Tim Petry)*

The Dickinson Research Extension Center (DREC) is engaged in a long-term, 10-year, integrated systems study to determine the effect of integrating beef cattle grazing into a multi-crop rotation comprised of cash crops and grazing forage for beef production. Beef cattle yearling steers are used in the study, which are subsequently finished and sold on a carcass value basis. Crop sequence consists of spring wheat

(Cash), dual cover crop (winter and summer crops- Graze), corn (Graze), pea-barley mix (Graze), and sunflower (Cash). For the system, cover crops serve an essential role in soil health and are a grazing crop in the multi-crop annual forage grazing system. Research funding source is SARE Grant #NCR16-381. The project objectives are to document the effect of grazing and crop rotation on seasonal soil nitrogen fertility, intermediate and long-term soil carbon pools, water storage and management, GHG emissions, environmental sustainability, and enterprise profitability. Outreach and deliverables consist of annual reports, journal publication, invited speaker presentations, and YouTube video presentations.

RESEARCH IN PROGRESS

1. ***Combining Cover Crops, Strip Tillage and Novel Mulches to Manage Weeds in Carrot***

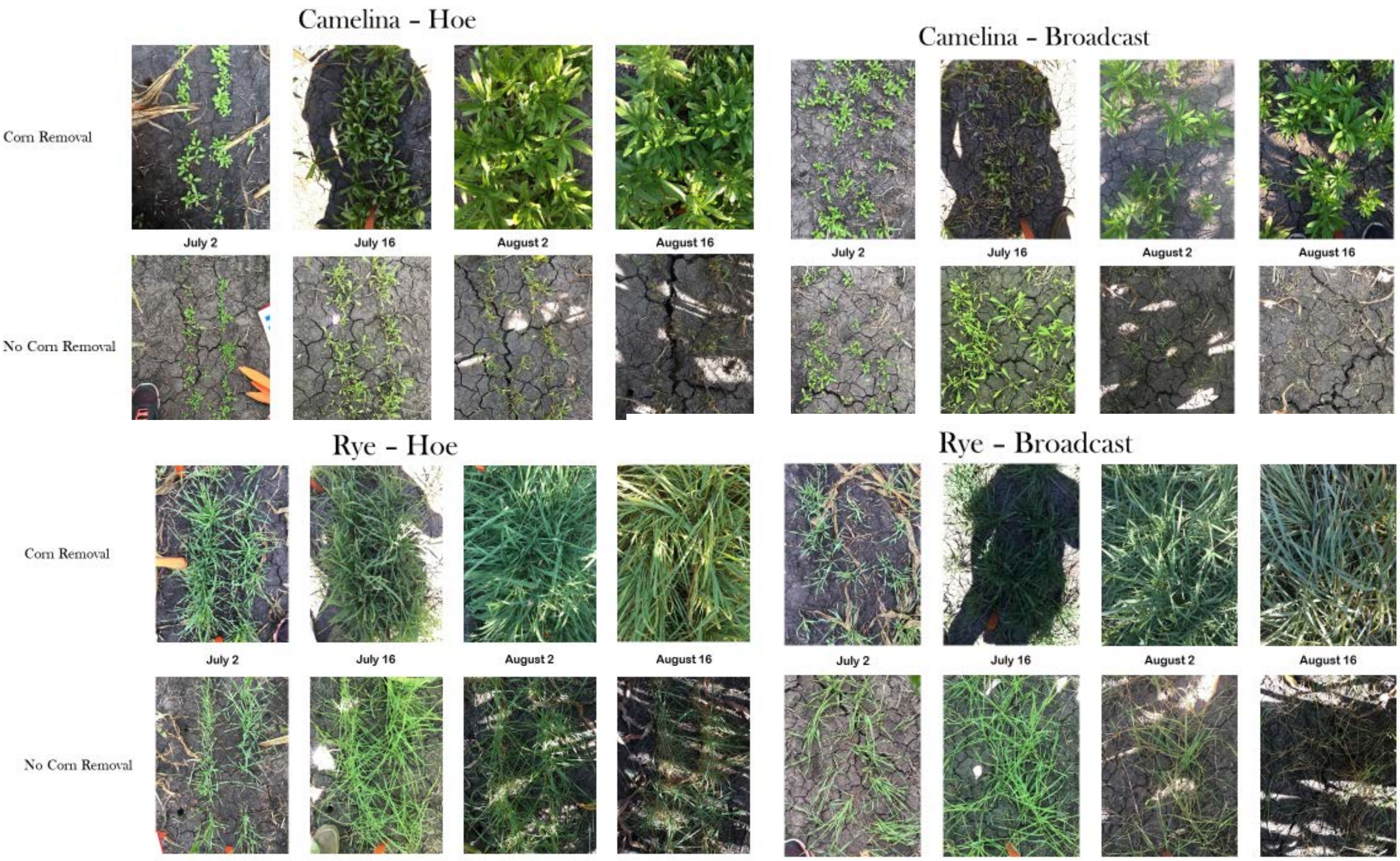
(Greta Gramig (PI) and MS student Jesse Puka-BealsJesse)

Direct seeding into strip tilled zones (STZ) of living mulches (LM) may require weed suppression tactics for soil within the STZ. Surface mulches (SM) applied in the STZ could suppress weeds and improve crop performance. We evaluated three SM treatments [hydromulch (HM), compost blanket (CB), untreated control] applied on STZs seeded to carrot (*Daucus carota* L.) within five LM treatments [red clover (RC), white clover (WC), perennial ryegrass (PR), weed-free check (WF) and weedy check (WK)] for carrot emergence, weed suppression, and carrot yield. Weed density and biomass in the STZ were lower in HM and CB treatments than the control, but no differences between HM and CB were observed. Differences in carrot emergence were site specific, with greater emergence in CB (16 ct m-1) than control (6 ct m-1) in Fargo ND and lesser emergence in CB than control in Absaraka ND. Carrot yield was not influenced by SM, but WF average carrot weight (96 g carrot-1) was approximately triple of RC, WC, and PR (31, 34 and 35 g carrot-1 respectively). The HM and CB were effective at weed suppression, but had no effect on average carrot weight.   Average carrot weight was lower when grown in the STZ of a LM compared to WF, but no yield differences were observed between RC, WC and PR. Consistent mowing of living mulches may reduce yield loss associated with living mulches and further development of SMs may improve crop performance and provide biodegradable alternatives to poly-ethylene mulches .

2. ***Effect of planting date, corn shading, and sowing method on the establishment of camelina, rye and radish.*** *(Joel Ransom and MS student, Mattie Schmitt)*

An experiment was established in two locations, Casselton and Hickson, ND, during the 2018 cropping season to look at the effect of planting date, corn shading, and method of sowing on the establishment of winter camelina [(*Camelina sativa* (L.) Crantz.], radish (*Raphanus sativus* L.), and winter rye (*Secale cereale* L.) in a corn crop. In addition to cover crop establishment and biomass production, measurements were made on soil moisture in the top 7.5-cm of the soil. This was done in order to help quantify soil moisture conditions during the time of cover crop establishment within a corn crop. The assumption is that poor cover crop establishment is not only due to shading of the corn, but also due to limited soil moisture, since corn is a heavy water user during the period of that cover crops are normally planted. . This work was part of the MS thesis research of Mattie Schmitt. Conditions were favorable for the germination and initial establishment of cover crops at the V7 stage of corn, but generally once emerged they developed slowly, with most of the radishes dying prior to corn harvest. At corn harvest, the cover crops produced less than 35 kg ha^{-1} of biomass on average. At the later planting date, radish development was better and on average, the cover crops produced between 50 and 100 kg ha^{-1} of biomass at corn harvest. Camelina and rye were similar in biomass accumulation at this later planting date at Casselton, with camelina superior to rye at Hickson. Planting cover crops in a furrow and covering was slightly better than broadcasting, but cover crop emergence was adequate when broadcast. There was some evidence of diseases developing on cover crops planted at the earliest date.

Soil moisture levels in the top 7.5-cm were generally less when there was a corn crop growing, when compared with plots without corn, though this difference expanded during dry periods. However, the difference was not so great to be considered the primary reason for poor cover crop development.

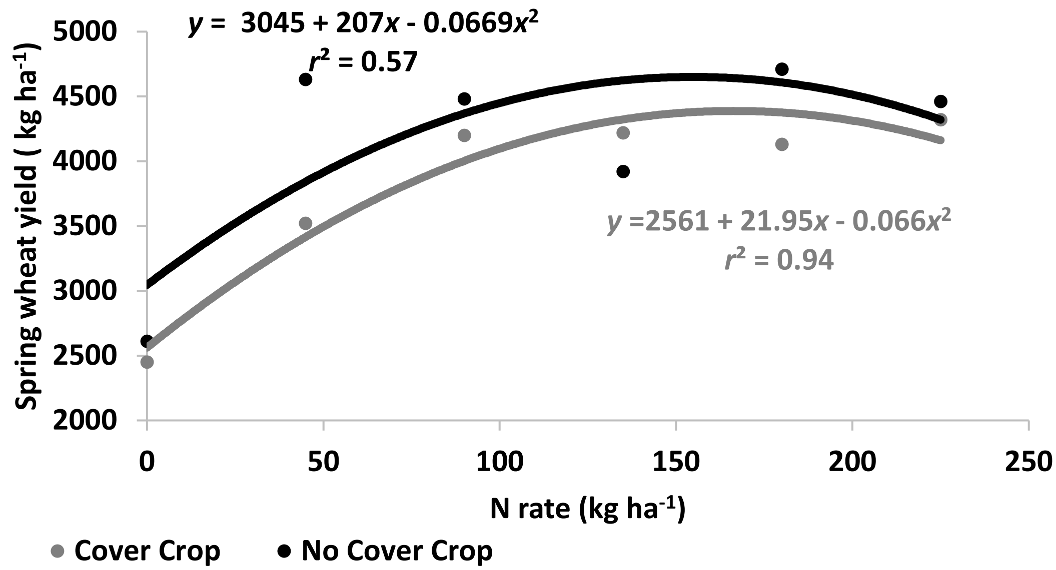


3. ***Nitrogen credits from cover crops to wheat*** *(David Franzen and Abbey Wick)*

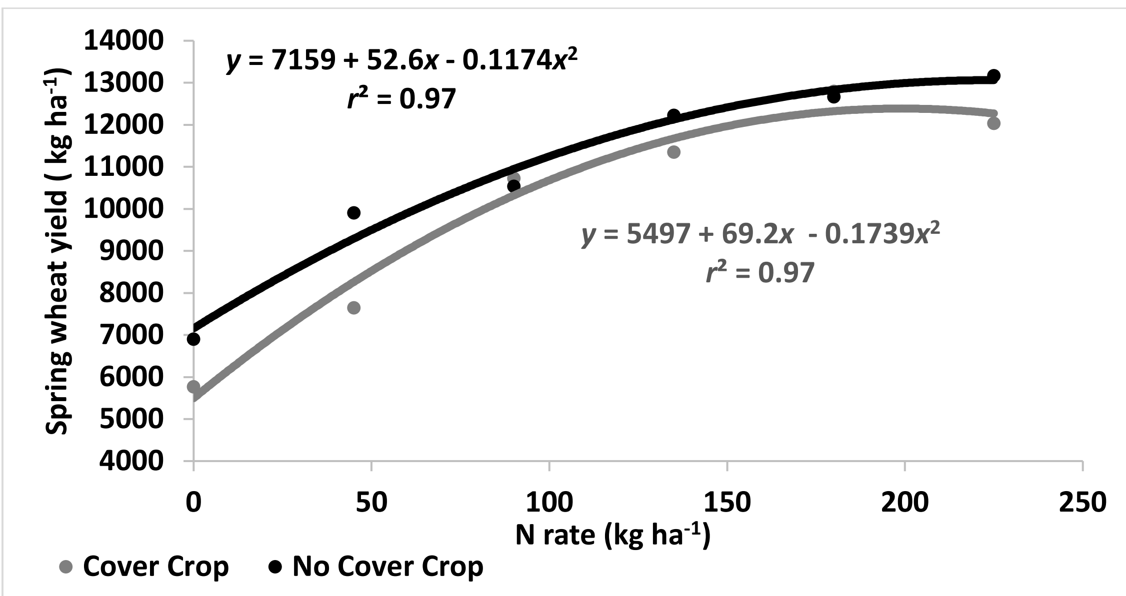
The study this year had three N-requiring crops following cover crop and no cover crop treatments. Spring wheat (*Triticum aestivum* L.) at Gardner, ND, following soybean (oat (*Avena sativa* L.) and radish with camelina, with camelina growing into the spring. Estimated N uptake based on poor stand (about 4 plants m^{-2}) was 22 kg ha^{-1}. Corn at Gardner following spring wheat with oat and radish with camelina, with camelina growing into the spring. Estimated N uptake by camelina (oat and radish growth fall 2017 was negligible) was 22 kg ha^{-1}.

Corn at Rutland following bio strip-till after spring wheat with faba bean (*Vicia faba* Roth), flax (*Linum usitatissimum* L.), volunteer spring wheat, forage radish. Nitrogen tied up in cover crop residue from the fall 2017, sampled 9 October 2018 was 78 kg N ha^{-1}.

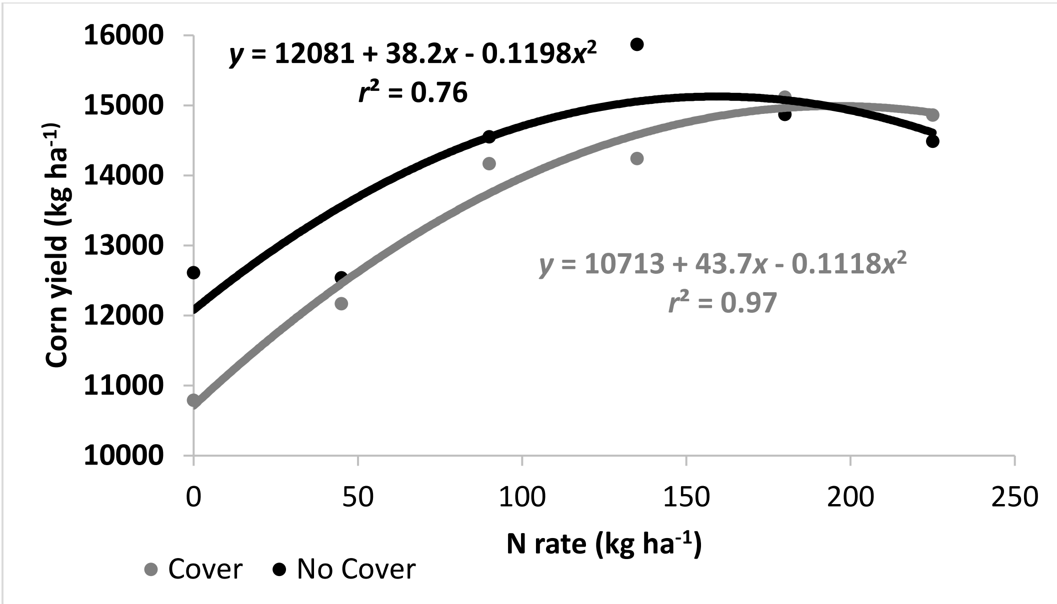
As in 2017, the N in the cover crops is not recycled as expected from the C/N ratios of the residues. Work is proceeding to determine where the N is going, since 2017 and 2018 were not years where excessive rain would result in N losses.



Spring wheat following soybean (2017) with and without cover crop, in Gardner, ND. The yield reduction with cover crop would be recovered with about 20 kg ha^{-1} N, which was about the value in the cover crop at seeding.



Corn following spring wheat (2017) with and without cover crop in Gardner, ND. The yield reduction with cover crop at 0 N rate would be recovered with about 20 kg ha^{-1}, which was about the value in the cover crop at seeding.

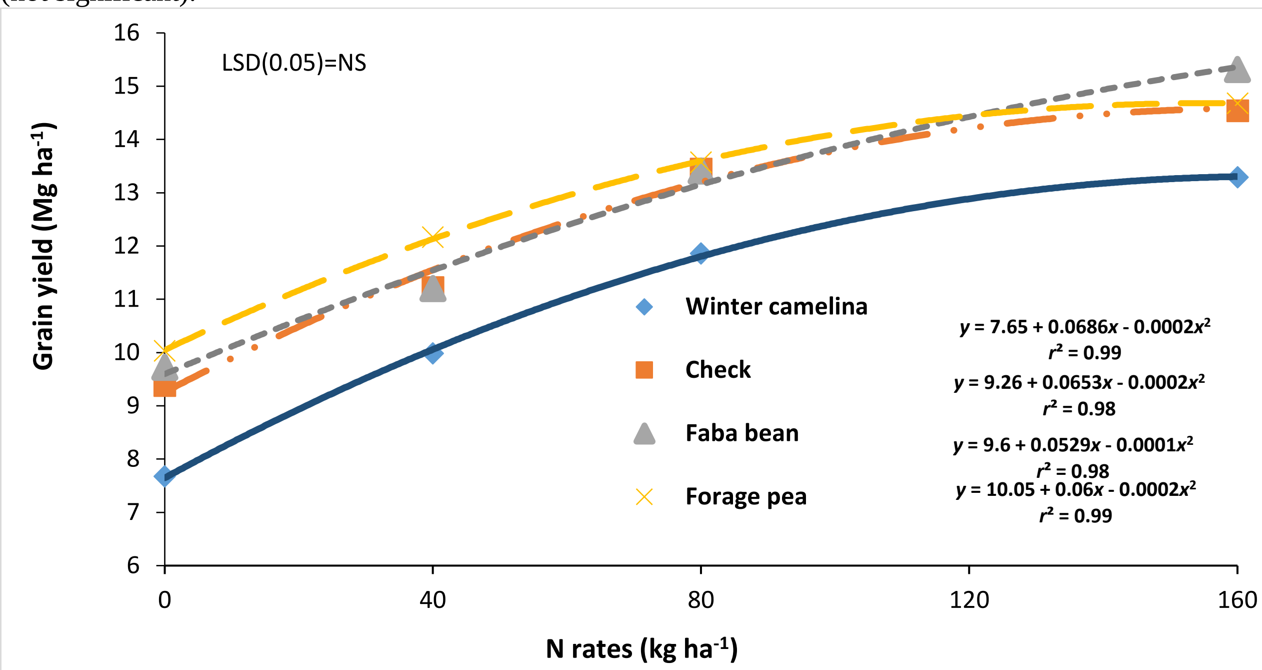


Corn following spring wheat with and without cover crops in Rutland, ND. The yield reduction due to cover crop at the 0 N rate would be recovered with an N rate of about 40 kg ha^{-1}, which is about 60% of the N in the cover crops at seeding.

4. ***Legume cover crops slightly increased corn yield with different nitrogen rates in the northern Great Plains.*** *(Marisol Berti, David Franzen, PhD student Sergio Cabello-Leiva)*

Corn and wheat are major crops in the northern Great Plains. Conventional management has reduced winter soil coverage, impacting negatively on soil health. In this scenario, soil has been exposed to water and wind erosion which decreases soil productivity. On top of that, high levels of residual deep nitrogen, after cereal production, are easily lost by leaching, resulting in a negative economic and environmental impact in this cropping system. Cover crops and no-tillage provides soil coverage, preventing soil erosion, and reducing NO_3-N leaching. This experiment was conducted at two locations, Prosper and Hickson, ND, in 2017. The experimental design used was a RCBD with four replicates. The cover crops on study were forage pea (*Pisum sativum* L.), faba bean, winter camelina and a check plot (without cover crop) which were established into spring wheat stubble in August 2017. Biomass production and nitrogen accumulation on tissue averaged across locations was 1.92 Mg ha^{-1} and 88 kg ha^{-1}, respectively with no significant differences between treatments. Soil NO_3-N, in late fall, was lower in winter camelina plots (36.0 kg ha^{-1}) in comparison with the rest of treatments (44.6 kg ha^{-1}), but there were not significant differences in the spring. Soil green coverage provides important protection against wind soil erosion. Plots with cover crops had 60% of green coverage while in check plots was 16.3% (volunteer wheat regrowth), leaving the soil with lack of coverage.

In May 2018, corn was planted in a RCB design with a split-plot arrangement, where the main plot was cover crops (from the previous year) and the sub-plot was nitrogen rates (0, 40, 80, and 160 kg N ha^{-1}). Winter camelina, as a winter hardy cover crop, was actively growing during spring, using soil resources and water, and because of this, gravimetric water content (0-15 cm depth) was significantly lower in winter camelina plots (17.9%) than the rest of treatments (24.1%). In addition to that, spring 2018 was dry and corn growth was more affected in early stages in the winter camelina plots. This was observed also with NDVI measurements in mid-June, where winter camelina plots were significantly lower (0.76 NDVI index) in comparison with the rest of the treatments (0.77 NDVI index) correlating less development and growth in corn plants, because of the lack of water into the winter camelina plots. Corn yield was also affected by winter camelina treatments. In Hickson, winter camelina plots showed significantly lower corn yield (10.3 Mg ha^{-1}) than corn planted in previous year faba bean (12.2 Mg ha^{-1}), forage pea (12.0 Mg ha^{-1}) and check (12.3 Mg ha^{-1}) plots. A similar situation was observed at Prosper, where winter camelina (11.1 Mg ha^{-1}) showed lower yields than faba bean (12.6 Mg ha^{-1}), forage pea (13.2 Mg ha^{-1}) and check (12.0 Mg ha^{-1}). However, in this location the differences were not significant. In the combined analysis across two locations, there were not significant differences in the cover crop, nitrogen rates or the interaction between them. Thus there is no evidence of decreased corn yield with the legume cover crops. In fact, legume cover crops increased the yield slightly in all the N rates in this study (not significant).

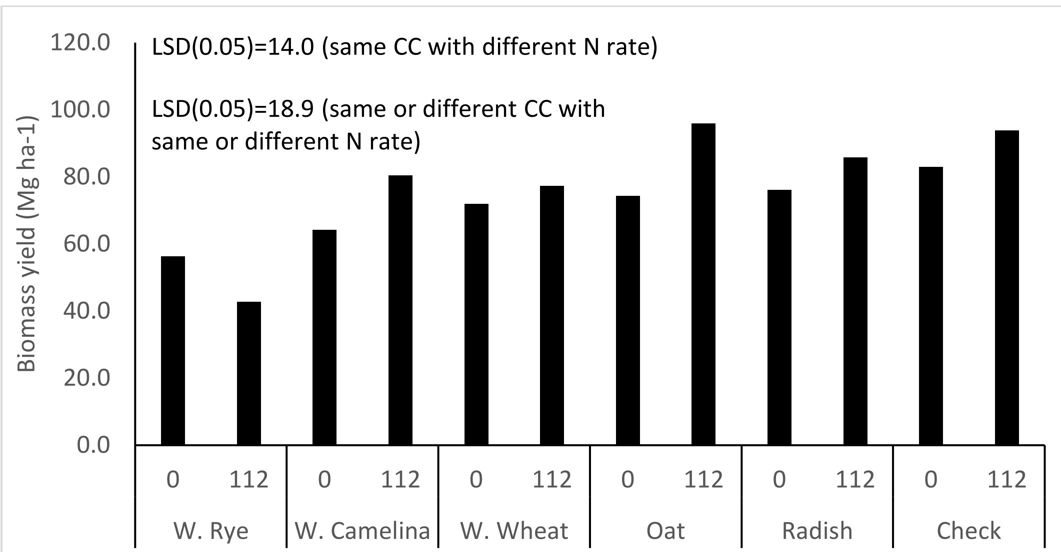


Corn yield averaged across two locations. There was not significant differences (*P*>0.05).

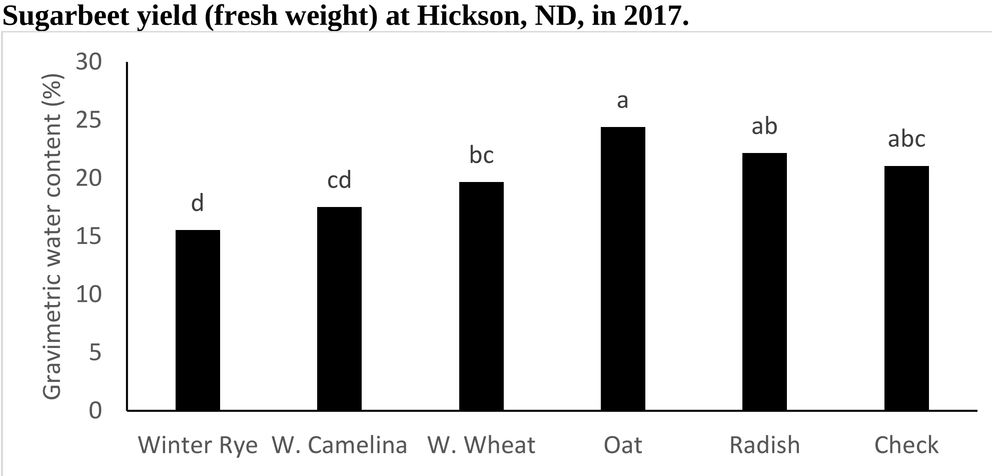
5. ***Cover crops decreased initial water content, sugarbeet yield and residual N- NO3 in the northern Great Plains*** *(Marisol Berti, Amitava Chaterjee, PhD student Sergio Cabello-Leiva)*

Sugarbeet is a valuable crop in North Dakota, but it leaves the soil uncovered after harvest, decreasing soil health. The lack of soil coverage during the winter increases soil losses due to wind erosion. In addition to that, high levels of residual deep nitrogen after cereal production can decrease sugar yield in sugarbeet. Cover crops and no-tillage provide soil coverage, preventing soil erosion, and reducing NO_3-N leaching. The experiment was conducted at two locations, Prosper and Hickson, ND, in 2017. The experimental design used was a RCB with four replicates. The cover crops were radish, winter camelina, winter wheat, oat, winter rye, and a check plot (without cover crop), established into spring wheat residue in August 2017. Biomass production averaged across locations was 2.2 Mg ha^{-1} in both radish and oat. Soil green cover was 70% for both oat and radish while in rye it was 57%, all providing soil protection from wind. Nitrogen accumulation in the biomass was significantly higher in oat, radish, and winter rye than in winter wheat and winter camelina biomass. Soil NO_3-N, in late fall was significantly higher in the check plots (25.9 kg ha^{-1}) than in plots with a cover crop; oat (12.3 kg ha^{-1}), winter rye (13.2 kg ha^{-1}), and radish (16 kg ha^{-1}) This indicates cover crops are scavenging residual NO_3-N and keeping it in their biomass. In conclusion, radish, winter rye, and oat provided soil cover in the fall by protecting the soil from erosion and reduced soil residual NO_3-N prone to leaching during fall which likely contributes to deep soil NO_3-N accumulation.
In May 2018, a sugarbeet experiment was planted with RCBD design with a split-plot arrangement, where the main plot was cover crops (from the previous experiment) and the sub plot was nitrogen rate (0 and 112 kg ha^{-1}). Winter camelina, winter rye, and winter wheat survived the winter and were actively

growing early in the spring. Due to this, gravimetric water content was significantly lower in winter rye (21.4%) and winter camelina (23.7%) than in the no cover crop plots (26.0%). Also, the sugarbeet stand count was strongly decreased because of the lack of water in the winter hardy cover crop plots. This situation was clearly observed in Hickson, where the main plot as winter rye (48,438 plants ha^{-1}) had lower sugarbeet stands than sugarbeet following winter camelina and winter wheat (77,239 plants ha^{-1}). Sugarbeet density following these winter hardy cover crops were lower than when following check, oat, and radish (98,245 plants ha^{-1}). The interaction of cover crop and N rate was significant in sugarbeet yield at Hickson, distinguishing a low yield in winter rye cover crop plots with 0 kg ha^{-1} N application (56.3 Mg ha^{-1}) in comparison with check plots with 0 kg ha^{-1} N (83 Mg ha^{-1}). Similar trends were observed at Prosper but differences were not significant at this location. In conclusion, winter wheat, winter rye and winter camelina provided green soil cover in early spring and decreased gravimetric water content, which produced a decreased stand count and decreased sugarbeet yield. This situation also opens the possibility of earlier sugarbeet planting in comparison with soils with no green cover, being an opportunity in the wet springs and heavy clay soils of the northern Great Plains.



Sugarbeet yield (fresh weight) at Hickson, ND, in 2017.



Gravimetric water content at Hickson, ND, in 2017. (Columns with different letters are significantly different at *P* = 0.05).

6. ***Interseeding cover crops in sugarbeet*** *(Amitava Chatterjee, Marisol Berti, Alan Peterson)*

This field experiment was conducted at Ada and Sabin, MN. Field experiment was laid out in a randomized complete block design with a split-plot arrangement with five cover crop treatments, (i) check (no cover crop), (ii) winter rye, (iii) winter camelina, (iv) winter Austrian pea, (v) brown mustard (*Brasica juncea* L.) cv. Kodiak, as main plot and two cover crop planting times (end of July and end of Aug.) as sub plot with four replicates. Cover crops were interseeded between sugarbeet rows using a hoe to mimic the large-scale interseeder developed by Amity Technology for this CAP project. Just before beet harvest, cover crop biomass was measured.

Interseeded cover crops in June or July did not reduce sugarbeet yield or recoverable sugar (Table 3, Fig. 9). Interestingly, sugar content (kg ha^{-1}) was significantly higher than sugarbeet in the no cover crop treatment compared with winter rye, winter camelina, and brown mustard interseeded in June and winter rye interseeded in July in Downer, MN. In Ada, MN, sugar content was significantly higher for all cover crops except for winter camelina and winter pea interseeded in July. When sugarbeet roots hit a deep soil layer high in available nitrate at the end of the season, the late N will typically decrease sugar content. We assume the interseeded cover crops acted as scavengers of residual nitrate increasing root sugar content. Rye was the only crop that was still alive after sugarbeet lifting and harvest. This would allow a cover to protect soil from erosion following harvest. Sugarbeet fields are the most prone to soil erosion in late fall and spring. This research will be repeated in 2019.

Sugarbeet plot interseeded with winter rye before (left) and after harvest (right) of plots at Downer, MN during 2018 growing season.

Table 3. Sugarbeet yield, sugar content, and recoverable sugar per acre in response to interseeding with four cover crop species in June and July at Ada and Downer, MN, in 2018.

Planting	Treatment	Yield (tons/ac)	Sugar %	RSA (lbs/ac)
			Downer, MN	
	No cover crop	18.4ab	14.3d	4910ab
June	Winter rye	18.9 ab	15.3a	5445ab
	Winter camelina	21.1a	14.8abc	5848a
	Austrian pea	16.1ab	14.7bcd	4433ab
	Brown mustard	14.5b	14.8abc	4050b
July	Winter rye	16.2ab	15.0ab	4553ab
	Winter camelina	17.5ab	14.6cd	4791ab
	Austrian pea	16.9ab	14.4cd	4511ab
	Brown mustard	19.3ab	14.7bcd	5301ab
	LSD (*p*=0.05)	6.05	0.46	1723
			Ada, MN	
	No cover crop	37.6abc	16.2c	11562 bc
June	Winter rye	36.1c	16.5ab	11386c
	Winter camelina	37.0bc	16.7ab	11757abc
	Austrian pea	36.3c	16.8a	11657bc
	Brown mustard	39.0a	16.6ab	12354a
July	Winter rye	38.1ab	16.6ab	12062ab
	Winter camelina	38.2ab	16.5bc	11957abc
	Austrian pea	38.4ab	16.4bc	11996ab
	Brown mustard	37.1bc	16.83 a	11860abc
	LSD (*p*=0.05)	1.72	0.34	605

7. ***Interseeding camelina, crambe and mustard to reduce soybean cyst nematode (Heterodera glycines) (SCN) Guipin Yan, Marisol Berti, Alan Peterson)***

The results of the first year of field experiments indicate cover crops did not reduce soybean yield, plant height, crude protein, and oil content at both locations. Interaction between cover crop treatments and soybean varieties was not significant. In Prosper, soybean yield in the susceptible variety, averaged across all cover crop treatments, was about half of that of the resistant variety. Similarly, the susceptible soybean was shorter than the resistant variety. In Casselton, both varieties yield and plant height were similar but significantly lower than in Prosper. The experiment in Casselton was very dry this year and weed control was delayed at the beginning of the season, which were probably two of the causes of low yield in both varieties. In addition, the initial SCN egg numbers in Casselton were lower than in Prosper. Biomass for the interseeded cover crops was similar among cover crops at both locations. The biomass yield in the resistant variety was less than in the susceptible variety at both locations, indicating the resistant soybean competed with the cover crops suppressing their growth.

In Prosper, SCN egg numbers increased in the susceptible variety in all treatments except in the treatment with camelina interseeded at V6, which reduced the SCN egg numbers in 32%. In the resistant variety, SCN eggs numbers decreased or stayed about the same in all treatments regardless of the initial SCN egg count. Although not significant, crambe and brown mustard interseeded at V6 had the lowest final egg population in the resistant variety, which may indicate these cover crops are providing an additional SCN-reduction to the resistant variety. However, further research will be needed to assess this.

In Casselton, the initial and final SCN egg counts were much lower than in Casselton and not significant for any treatment. However, the clear effect of the resistant variety on reducing SCN population observed in Prosper was not observed in Casselton. The populations stayed about the same. Although there were not significant difference due to the uneven distribution of SCN in the soil, the increase in number of eggs in the check treatment before initial and final counts was much greater than for the plot with cover crops.

It is clear that none of the cover crop treatments was able to overcome the SCN reproduction in the susceptible variety. A check treatment with only cover crop (no soybean) would be needed to estimate if the presence of the susceptible soybean is responsible for the increase in SCN egg numbers. Winter camelina and brown mustard are non-hosts of SCN so they should not increase the population of SCN.

Winter camelina interseeded at V6 stage into standing SCN-susceptible soybean in Prosper, ND. Photo taken 17 October 2018.

8. ***Greenhouse experiment to determine hosting and reducing ability of camelina, crambe and brown mustard*** *(Guiping Yan, Marisol Berti and PhD student Krishna Acharya)*

Industrial oilseeds have a great potential in the northern Great Plains both as oilseeds and as cover crops sown following wheat harvest and before soybean sowing in the following spring. One of the most important biotic stresses in soybean production is soybean cyst nematode, a serious pest that affects 90% of the soybean areas in the U.S. The objective of this study was to evaluate the hosting and SCN population reduction abilities of winter camelina cv. Joelle, crambe (*Crambe abyssinica* L. cv. BelAnn), and brown mustard (*Brassica juncea* L. cv. Kodiak). The experiments were performed in the greenhouse by planting the crops on naturally SCN-infested soils and sandy soil artificially inoculated with two SCN populations HG type 7 and 0 from two fields in North Dakota. Soybean cyst nematode did not reproduce on brown mustard or camelina with a female index (FI) of 0, suggesting these are non-hosts, while SCN reproduced on crambe. The numbers of white females on crambe ranged from 1 to 13 with FI of 0.17 to 1.06 in naturally infested soils, and 1 to 4 with FI of 1.15 to 2.46 in artificially infested soils, classified as a poor-host (FI < 10). All the tested crops were able to reduce the SCN populations by an average of 51% by brown mustard, 48% by winter camelina, and 24% by crambe across all the experiments with naturally infested soils compared with the initial population levels. Both brown mustard and camelina consistently reduced the SCN populations compared with the non-planted control (fallow). Although these crops were non- or poor hosts for SCN, limited reproduction could help reduce SCN survival in fields. Hence, host status and population reduction ability are important while selecting as a cover crop in SCN-infested soybean fields.

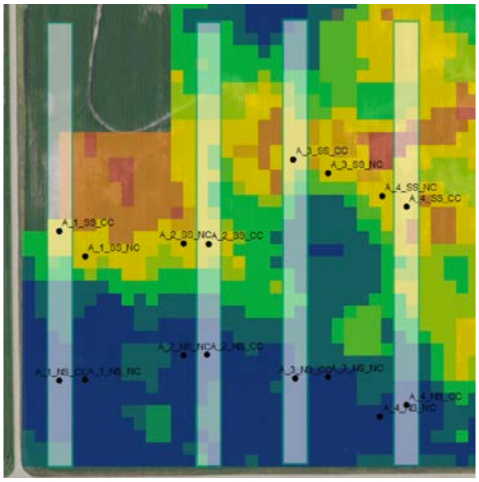
9. ***Winter camelina fall seeding date effect on stand survival*** *(Marisol Berti, James Anderson, and MS student Alex Wittenberg)*

Camelina has two distinctive biotypes, summer and winter, with winter biotypes requiring a vernalization treatment to enter the reproductive phase. Until recently, most research focused on the summer biotype. Increased interest in using winter camelina in the northern Great Plains has led to questions from producers wanting to produce seed and to achieve the maximum amount of fall and spring biomass growth, adequate stands, and reduce soil nitrate leaching. This study was established to determine the appropriate fall sowing date to achieve these objectives for producers to adopt large-scale planting and production of winter camelina. Establishing productive stands of camelina can be complex, because of its very small seed and need to be sown shallow in order to ensure adequate emergence and stand. Sowing dates starting 1 August and tentatively every two weeks until the middle of October for a total of six different sowing dates were evaluated in this study. Fall stands ranged from no emerged plants to 570 plants m^{-2} with higher stands obtained with sowing dates in early- to mid-October. Fall biomass averaged 327 kg ha^{-1} across all sowing dates.

Winter camelina after snow storm in October 2018.

10. ***Managing salinity with cover crops: a whole system response*** *(Caley Gasch, Abbey Wick, Jason Harmon, Tom DeSutter)*

We are measuring the benefits and risks of using a cereal rye cover crop in a soybean-corn rotation to determine its potential for salinity management and building soil health. We use a whole-system approach to measure soil, crop, weed, and insect responses to the salts and the cover crop. These field-scale experiments compare cover crop and no cover crop treatments across a gradient of saline soils, replicated across four farms, and spanning two rotation cycles to capture variability in responses across different soil types and climates. Interactions between soybeans and cereal rye (specifically water use and soil health) are also being investigated in the greenhouse. In addition to the field research and graduate student training, this project includes extension activities on soil salinity management. During the first two years of the project, we accomplished the following: established field sites located in Aneta, Northwood, and Jamestown, North Dakota; we have Veris mapped and ground-truthed each field to locate four replicated sets of plots that span saline and non-saline areas; we installed weather stations at each of the four sites (air temperature, precipitation, wind direction and speed, relative humidity, and solar intensity); in 2017, the Aneta and Northwood sites were planted to corn and the two Jamestown sites were planted to soybean (in 2018, the other phases of the respective rotations were planted in each field); mid-season in each year, we interseed treatment strips of cereal rye (40 lb/ac) into growing cash crops and immediately began monitoring soil water content every other week; mid-season in each year, we sample soil microbial and insect communities, to examine baseline differences between soil and insect communities in saline and non-saline soils; end-of-season in each year, we collect plant biomass for cash crop yield, cover crop biomass, and weed biomass; we monitor water use, cover crop biomass, and surface residue accumulation until freeze-up and upon thaw in the spring; at the end-of-season in each year, we sample soil for fertility and soil health measurements.



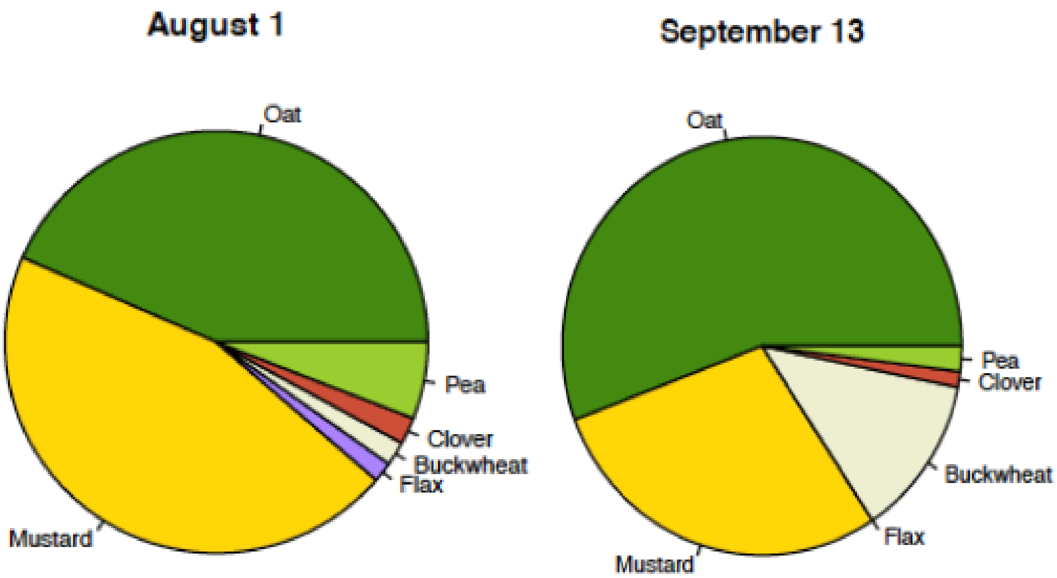
Veris map of the Aneta field site, with warm colors indicating higher salinity. Cover crop treatments are indicated by gray strips, and small points are plot locations.

A saline patch within a soybean field. Moderately saline soils ($EC_{1:1}$ of 2-4 dS/m) are not productive for crops, but cereal rye and other small grains are tolerant of salts at this level and are being assessed to manage water, improve soil structure, and reduce effects of salinity in these areas.

11. **Cover Crops with Sunflower** *(Wick, A.F., C.K. Gasch, D. Toussaint, T. Wehlander)*

As part of a ND Department of Health and NCR SARE project, the third year of cover crops seeded within a day of planting sunflower was completed. The first year (2016), several mixes were seeded in single strips on two fields to observe and species that would be reasonable to fully evaluate. The second year (2017), replicated strips of a relatively cost-effective mix ($18/ac) were seeded on three fields at the

Toussaint farm in Wahpeton and one field at the Wehlander farm in Delamere, ND. Cover crop biomass, sunflower yield and oil content and soil samples were collected from each site. This study was repeated in 2018 at the Toussaint farm, again using replicated strips on three different fields. Overall, there were no significant differences between cover crop and non-cover crop strips for yield or seed oil content of the conoil sunflowers in 2017 or 2018. That being said, the farmers were uncomfortable (regardless of what the statistics showed) with the variability and potential 200 lb/ac reduction in yield that their yield monitors showed. There were no difference in soil properties between the cover crop and non-cover crop strips.
This practice may not be adopted whole-field, but farmers see potential for use around field borders or in strips across the interior of the sunflower field.



12. **Bio Strip-Till after Small Grain** *(Wick, A.F., A.L. Daigh, M. Berti, J. Breker, K. Johnson, S. Landman, K. Jodock, L. Trautman)*

Farmers are interested in the concept of bio strip-till after small grain harvest with the goals of creating a dark strip using cover crop residue to plant the following years cash crop, to reduce seed costs by not covering the entire field and to have the ability to use a planter with residue managers to push residue aside in the fall (rather than using a strip till machine). Several farmers used this approach in eastern North Dakota, some of those fields being established research sites.
At the Soil Health and Agriculture Research Extension (SHARE) Farm in Mooreton, ND, a mix of faba bean, radish and flax (20/2/2 lbs/ac) were seeded on 30” row spacing in wheat stubble to prepare the field

for corn planting in 2019. Temperature and moisture sensors were installed in the fall in the bio strip, under the residue between the bio strips and in the chisel plow check strips. Data will be collected and downloaded until planting. Another location in northeastern ND, a second SHARE Farm location in Larimore, ND had 2 lbs of radish seeded after wheat harvest on 30" row spacing using a sugar beet plate in a planter. This field will be planted to pinto beans in 2019. No measurements were collected on this field in 2018.

Farmers are typically using mixes which include faba bean, radish, turnip and flax (or some combination of those cover crops) depending on equipment available and goals on-site.

Faba bean biostrips at Trautman farm- Jamestown

Biostrip till at SHARE farm in Mooreton, ND.

13. **Cover crops for Saline Soil Remediation** ***(****A.F. Wick, T. Wehlander, D. Mueller, D. Burkland, T. Kozojed, J. Hoffman, L. Trautman)*

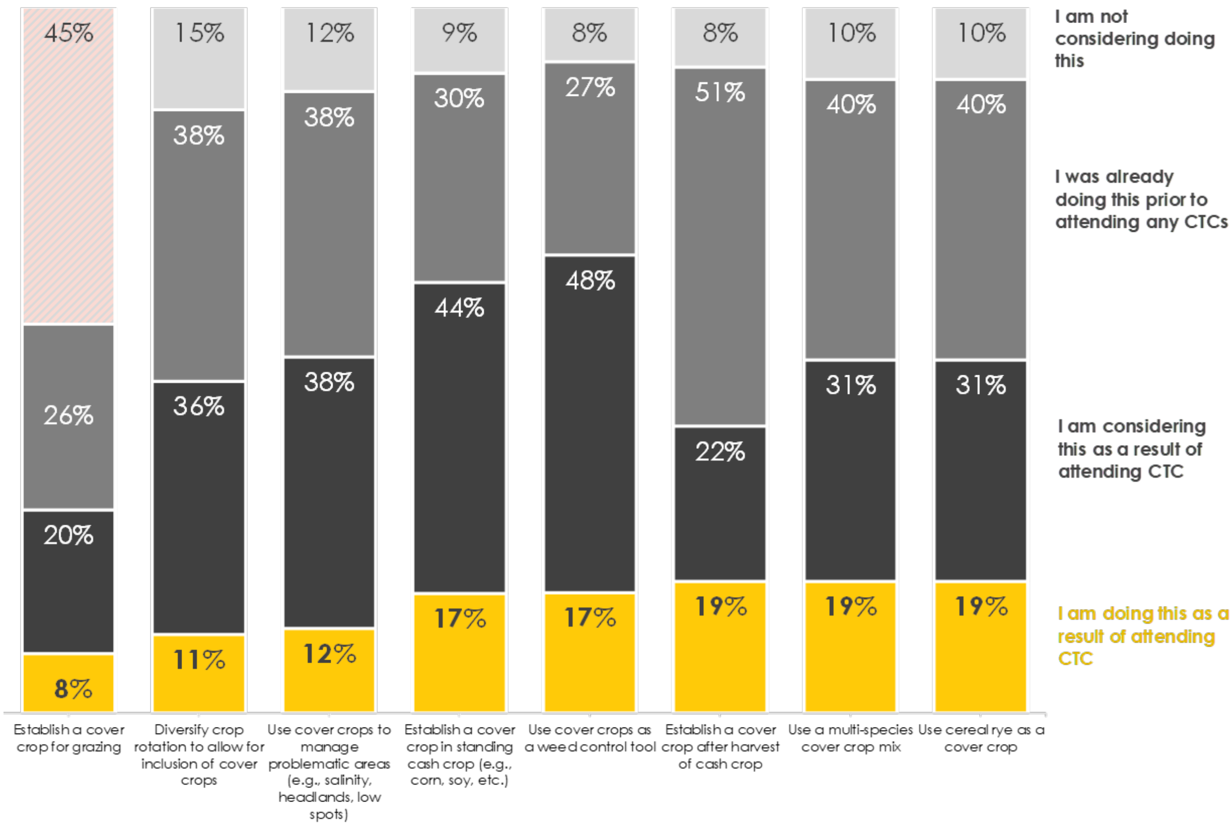
Cover crops continue to be a good option for managing salt-affected areas. Forage barley is the primary cover crop used; however, sometimes radish, turnip, dwarf essex rapeseed and cereal rye are used. As part of a ND Department of Health project, several demonstration sites were setup across eastern North Dakota in 2014. Many of these sites have continued through 2018. At the Sargent County (T. Wehlander) site, a mix of barley, radish and dwarf essex rapeseed was seeded in June on a ten acre ditch-effect salinity spot in a field. Due to excessive rainfall and standing water, cover crops had issues establishing and the saline areas were dominated by foxtail barley. The site was sprayed and re-seeded to salt-tolerant alfalfa in August with very poor establishment. In Traill County (Mueller, Kozojed) salt-affected borders along ditches and CRP were seeded with barley and radish. The cover crops established and farmers will continue to seed cover crops in these areas in 2019. Grand Forks (Burkland) demonstration sites turned into several headlands being seeded to a barley cover crop after harvest to manage salinity with again, decent establishment. The Cass County (Hoffman) site salinity has been reduced over the past several years using cover crops, so the entire field was planted to corn with a oat, radish, turnip cover crop aerial seeded at tasseling. In Stustman County (Trautman), saline areas within fields had cereal rye and barley broadcast into them mid-season with decent establishment and management of salinity. More farmers across North Dakota are adopting use of cover crops to manage salt-affected areas.

Barley into vertical tilled saline area, Hillsboro, ND.

14. ***Water Stress Development and Mitigation in West Central ND*** *(R. Jay Goos, MS student Jeremy Wirtz, and Eric Eriksmoen)*

    Soybean production is expanding into semi-arid regions, such as west central North Dakota. One of the objectives of this research is to measure the effect of pre-plant water depletion by a rye cover crop, on the development and severity of water stress in a subsequent soybean crop. The cover crop treatments include seeding rate and termination date. In-season measurements include soil water content, and plant water stress indicators. The plant water stress indicators include leaf relative water content and abnormal levels of ureide accumulation.
15. ***Rye as a cover crop with dry bean*** (*Greg Endres and Mike Ostlie)*– conducted 2017-2018 at Carrington to examine pinto bean response and weed management to different timings of rye termination.
16. ***Rye as a cover crop with soybean*** (*Greg Endres and Mike Ostli*e)– conducted 2018 near Wishek to examine soybean response to different timings of rye termination.
17. ***Fall-seeded cover crop tolerance to soybean herbicides*** *(Greg Endres, Mike Ostlie, and Kirk Howatt)* – conducted in 2018 at Fargo and Carrington to determine tolerance of several cover crops grown on soybean ground treated with commonly used herbicides with soil residual.

18. **Cover crops adoption in North Dakota** *(Jean Haley, Abbey Wick, Marisol Berti)*
According to survey respondents (n=120) who participated in one or more of our extension activities in North Dakota, indicated their primary concern is nutrient management followed by water management and wind erosion. Cover crops adoption is growing with increasing interest in establishing a cover crop in standing in corn and soybean (44%) and use cover crops as weed control (48%). In addition, 38% of participants indicated they are considering using cover crops to manage problematic areas (salinity, headlands, low spots). The respondents to this survey represent an area of 230,000 acres.



Results of survey to participants in Café talks and CTC conference 2018

PUBLICATIONS

Peer-reviewed journal publications

1. Senturklu, S., D. G. Landblom, R. Maddock, T. Petry, C. J. Wachenheim, and S. I. Paisley. 2018. Effect of yearling steer sequence grazing of perennial and annual forages in an integrated crop and livestock system on grazing performance, delayed feedlot entry, finishing performance, carcass measurements, and systems economics. J. Anim. Sci. 96:2204-2218. doi:10.1093/jas/sky 150
2. Wick, A.F., J. Haley, C. Gasch, T. Wehlander, L. Briese, and S. Samson-Liebig. 2019. Network-based Approaches for Soil Health Research and Extension Programming in North Dakota, USA. Invited Submission, Soil Use and Management, Special Issue: Soil Knowledge Sharing and Exchange. (*in press*).

Abstracts and Presentations

1. Puka-Beals J and Gramig G. 2019. Surface and Living Mulches for Strip-Tilled Vegetable Production. Wild World of Weeds, Fargo, ND. 15 January 2019.
2. Puka-Beals J and Gramig G. 2019. Surface and Living Mulches for Strip-Tilled Vegetable Production. Weed Science Society of America Annual Meeting. New Orleans, LA. 11-14 February 2019.
3. Puka-Beals J. and Gramig G. 2019. Surface and Living Mulches for Strip-Tilled Vegetable Production. Midwest Organic and Sustainable Education Service Organic Farming Conference. La Crosse, WI, 21-23 February 2019
4. Gasch, C., J. Harmon, T. DeSutter, and A. Wick. 2019. Beyond salt chemistry: how the whole soil-plant-insect system responds to salinity and what it means for crop production and management (Oral presentation). Manitoba Soil Science Society Meeting, Winnipeg, MB: February 2019.
5. Franzen, D., A.F. Wick, H. Bu, L. Ressler, J. Bell, M.T. Berti, and C. Gasch, 2018. Nitrogen non-cycling from cover crops grown before corn and spring wheat- Unexpected early project results. Advanced Crops Advisor's Workshop. Fargo, ND. 13 February 2018.
6. Peterson, A. M.T. Berti, D.P. Samarappuli, S. Cabello, B. Andersen, and S. Podder. 2019. Interseeding Cover Crops into Standing Soybean. Advanced Crops Advisor's Workshop. Fargo, ND. 13 February 2019.
7. Jacobs, J. 2018. Improving efficiency with intercropping. Columbia Grain Incorporated, Growers Meeting. 8 February 2019.
8. Jacobs, J. 2018. Improving efficiency with intercropping. Burke County Ag Improvement Annual meeting and ASg Show. 12 February 2019.
9. Berti, M.T. 2018. Where to start with cover crops. 14th Annual Conservation Tillage Conference, Fargo, ND, 18-19 December 2018. (40 participants)
10. Wick, A.F. and S. Schenk. 2018. Cover Crops and Crop Insurance.14th Annual Conservation Tillage Conference, Fargo, ND, 18-19 December 2018. (45 participants)
11. Wick, A.F. 2018. SHARE Farm Research and Extension Updates. 14th Annual Conservation Tillage Conference, Fargo, ND, 18-19 December 2018. (80 participants)
12. Wick, A.F. 2018. Cover Crop Ideas. 14th Annual Conservation Tillage Conference, Fargo, ND, 18-19 December 2018. (75 participants).
13. Wick, A.F. and T. Wagner. 2018. Using Soil Health Practices On-Farm. Central Dakota Ag Day, Carrington, ND. 13 December 2018. (75 participants).
14. Wick, A.F., Endres, G. and M. Vig. 2018. Cover Crop ID and Use, Central Dakota Ag Day. Carrington, ND. 13 December 2018. (75 participants).
15. Wick, A.F. 2018. Getting Started with Soil Health Discussion, Central Dakota Ag Day, Carrington, ND. 13 December 2018. (75 participants).
16. Wick, A.F. and D. Franzen. 2018. In depth look at using cover crops. Northern AgExpo. Fargo, ND, 25 November 2018. (80 participants).
17. Franzen, D., A.F. Wick, H. Bu, L. Ressler, J. Bell, M.T. Berti, and C. Gasch, 2018. Nitrogen non-cycling from cover crops grown before corn and spring wheat- Unexpected early project results. Northern AgExpo. Fargo, ND, 25 November 2018. (80 participants)
18. Wick, A.F. and D. Franzen. 2018. Soil Health Q and A, ND Association of Soil Conservation Districts Annual Meeting. Bismarck, ND. 19 November 2018. (65 participants).
19. Gasch, C., J. Harmon, T. DeSutter, and A. Wick. 2018. Beyond salt chemistry: how the whole soil-plant-insect system responds to salinity and what it means for crop production and management (Oral presentation). ASA, CSSA Annual Meeting, Baltimore, MD: November 2018.
20. Franzen, D., A.F. Wick, H. Bu, L. Ressler, J. Bell, M.T. Berti, and C. Gasch, 2018. Nitrogen non-cycling from cover crops grown before corn and spring wheat- Unexpected early project results. North Central Extension-Industry Soil Fertility Conference, Des Moines, IA, 14 November, 2018.

21. Wick, A.F. and D. Franzen. 2018. Nitrogen non-cycling in cover crops in a dry season. ASA-CSSA International Annual Meetings, Baltimore, MD, 4-7 November 2018.
22. Cabello-Leiva, S., M.T. Berti, A. Peterson, D. Samarappuli, S. Podder, B. Andersen, and A. Wittenberg. 2018. Cover crops decreased soil N-NO3 prior to sugarbeet production in the northern Great Plains. ASA-CSSA International Annual Meetings, Baltimore, MD, 4-7 November 2018.
23. Andersen, B. and M.T. Berti. 2018. Faba bean (*Vicia faba* Roth.) as a cover crop, intercrop and late-season forage in the Midwest. ASA-CSSA International Annual Meetings, Baltimore, MD, 4-7 November 2018.
24. Franco J.G., Beamer K.P., and Gramig G.G. 2018. Multi-species and monoculture cover crop productivity under contrasting management systems and climates in the northern Great Plains. American Society of Agronomy Annual Meeting. November 4-7, Baltimore, MD.
25. Jacobs, J. 2018. Improving Efficiency with Intercropping. NDSU Fall Conference. Fargo, ND. October 23-25.
26. Peterson, A., M.T. Berti, D.P. Samarappuli, S. Cabello, B. Andersen, and S. Podder. 2018. Maximizing cover crop performance by interseeding cover crops into standing soybean. 30th Annual Meeting of the Association for the Advancement of Industrial Crops (AAIC). Pathway to commercialization of Industrial Crops. London, Ontario, Canada 23-26 September 2018.
27. Berti, M.T., B.L. Johnson, H. Kandel, J. Ransom, A. Wick, D. Franzen, D. Ripplinger, J. Nowatzki, A. Peterson, M.S. Wells, A. Lenssen, S. Patel, R.W. Gesch, F. Forcella, and H. Matthees. 2018. CROPSYS-CAP- A novel management approach to increase productivity, resilience, and long term sustainability of cropping systems in the northern Great Plains-Research Update. 30th Annual Meeting of the Association for the Advancement of Industrial Crops (AAIC). Pathway to commercialization of Industrial Crops. London, Ontario, Canada 23-26 September 2018.
28. Wittenberg, A., M.T. Berti, D.P. Samarappuli, S. Cabello, B. Andersen, S. Podder, A. Peterson, and J.V. Anderson. 2018. Morphological characteristics of winter and summer biotypes of camelina [Camelina sativa (L.) Crantz.]. 30th Annual Meeting of the Association for the Advancement of Industrial Crops (AAIC). Pathway to commercialization of Industrial Crops. London, Ontario, Canada 23-26 September 2018.
29. Anderson, J.V., A. Wittenberg, and M.T. Berti. 2018. Analysis of fatty acid profiles and percent oil and protein content in seeds of summer and winter-biotypes of Camelina sativa using near infrared spectroscopy. 30th Annual Meeting of the Association for the Advancement of Industrial Crops (AAIC). Pathway to commercialization of Industrial Crops. London, Ontario, Canada 23-26 September 2018.
30. Delavarpour, N., J. Nowatzki, T. Bon, and S. Bajwa. 2018. Evaluations of a novel ultrasonic guidance system for cover crop planter grain cart. Annual International Meeting of the American Society of Agricultural and Biological Engineers, Detroit, MI 30-31 July, 2018.
31. Kandel, H. 2018. How can we incorporate cover crops into the farming system? Challenges and opportunities. Soil Health Workshop. Langdon, ND, 11 April 2018. (17 participants).
32. Landblom, D. G., S. Senturklu, and L. Cihacek. 2018. From land degradation to soil health education. European Geoscience Union annual meeting, Vienna, Austria, Abstract No. EGU2018-522
33. Senturklu, S., D. G. Landblom, and L. Cihacek. 2018. Effect of drought on yield, soil microbial biomass, C:N ratio, water infiltration, wind Erodibility, water stable aggregates, and nitrogen mineralization in an integrated Crop-Livestock System. European Geoscience Union annual meeting, Vienna, Austria, Abstract No. EGU2018-9244
34. Franco JG, Beamer KP, Gramig GG. 2018. Cover crop-weed dynamics in two contrasting management systems in the northern Great Plains. Western Society of Weed Science Annual Meeting. March 12 - March 15, 2018 Garden Grove, CA.

35. Berti, M.T. 2018. Alfalfa-corn intercropping. Midwest Cover Crops Council Annual Conference, Fargo 13-14 March 2018.
36. Cihacek, L. J., D. L. Landblom, and S. Senturklu. 2018. A place for cover crops in integrated crop-grazing systems. Midwest Cover Crops Council Annual Conference, Fargo 13-14 March 2018.
37. Landblom, D. G. and S. Senturklu. Economics of grazing cover crops in a diverse crop rotation. Midwest Cover Crop Council annual meeting, Fargo, ND, March 14, 2018.
38. Peterson, A., M.T. Berti, D. Samarappuli, B. Andersen, S. Cabello, and S. Podder. 2018. Maximizing cover crop performance by interseeding into standing soybean. Midwest Cover Crops Council Annual Conference, Fargo 13-14 March 2018.
39. Andersen, B., M.T. Berti, D. Samarappuli, A. Peterson, S. Cabello, and S. Podder. 2018. Faba bean (*Vicia faba* Roth.) as cover crop, intercrop, and late-season forage. Midwest Cover Crops Council Annual Conference, Fargo 13-14 March 2018.
40. Cabello, S., M.T. Berti, D. Samarappuli, B. Andersen, A. Peterson, and S. Podder. 2018. Cover crops decrease soil nitrogen (N-NO3) previous sugarbeet production in the northern Great Plains. Midwest Cover Crops Council Annual Conference, Fargo, ND, 13-14 March 2018.
41. Franzen, D. 2018. Nutrient cycling in cover crops. Midwest Cover Crops Council Annual Conference, Fargo, ND, 13-14 March 2018.
42. Wick, A.F. 2018.Tips from on-farm cover crop trials. Midwest Cover Crops Council Annual Conference, Fargo, ND, 13-14 March 2018.
43. Wick, A.F., C. Gasch, L.Briese, T. Wehlander, and A. Hohenhause. 2018. Approaches for Cover Crops and Soil Health. Commodity Classic, Anaheim, CA, 28 February 2018.
44. Wick, A.F. and J. DeJong-Hughes. Soil health session. Advanced crop advisors workshop, Fargo, ND. 14 February 2018.

<u>Book chapter</u>

<u>Proceedings publications</u>

Endres, G. Impact of winter rye cover crop on weed control and pinto bean production; Proceedings, Western Society of Weed Science, Volume 71.

<u>Grants</u>

1. Berti, M.T. and G. Yan. ND soybean council and SBARe soybean. 7/2019-6/2020.$32,489 Reducing soybean cyst nematode with brown mustard and winter camelina.
2. Berti, M.T., A. Wick and K. Sedivec. NC-SARE, 10/1/2018-9/30/2020, $74,555. Cover crops and forage grazing training program in North Dakota
3. Berti, M.T. NC-Sungrant, 7/1/2018-6/30/2019, $43,692. Identifying energy sorghum cultivars with chilling tolerance and quality characteristics as a feedstock for energy,
4. Berti, M. and J.V. Anderson. USDA-NACA7/1/2018-6/30/2019, $20,000. Evaluation of ecosystem services provided by *Camelina sativa* as a cover crop for northern climates,
5. Berti, M.T. A. Peltier, and P. Glogoza. Minnesota soybean growers, 3/1/2018/1/4/2019. $27,826. Managing soybean cyst nematode with cover crops in Minnesota- year 1.
6. Berti, M.T. A. Peltier. Minnesota soybean growers, 3/1/2019/1/4/2010. $21,065. Managing soybean cyst nematode with cover crops in Minnesota- year 2.
7. Berti M.T., G. Yan. North Dakota Soybean Council/SBARE, 7/1/2018-6/30/2019. $29,340. Preceding and Interseeding Trap Crops into Standing Soybean to Reduce Soybean Cyst Nematode Population.
8. Chaterjee, A., M.T. Berti. Sugarbeet Research and Education, 3/1/2018-2/28/2019. $26,140. Adopting cover crops in sugarbeet production systems.

9. Daigh, A., J. DeJong-Hughes, and A. Wick. ND Soybean Council,2018-2019. $62,635. Maximizing Soil Warming and Health Under Different Tillage Practices in a Corn-Soybean Rotation.
10. Daigh, A., J. DeJong-Hughes, and A. Wick. ND Corn Council,2018-2019. $63,775. Maximizing Soil Warming and Health Under Different Tillage Practices in a Corn-Soybean Rotation.
11. Daigh, A., C. Gasch, F. Casey, T. DeSutter, A. Wick, D. Ritchison, D. Clay, C. Reese. NRCS CIG, 2017-2020, $999,327. Cover Crops and No-Tillage Enhance Soil Water Management in Frigid Northern Great Plains Soils.
12. Endres, G., K. Howatt, and M. Ostlie.. ND Soybean Council $14,700. 2019-2020. Fall-seeded cover crop tolerance to soybean herbicides.
13. Endres, G. and M. Ostlie. ND Soybean Council. $8000. FY2019. Soybean response to selected plant nutrition inputs and rye as a cover/companion crop.
14. Endres, G. and M. Ostlie. Northarvest Bean Growers Association. $15,500. 2018. Evaluation of selected plant establishment factors and nutrition treatments in dry bean.
15. Franzen, D., C. Gasch, A. Wick. 2019-2021, ND Corn Council, $23,129. Change in Free-Living N-Fixer Activity for Reduction of Corn N Rate Over Time with No-Till Transition.
16. Gasch, C., A. Wick, J. Harmon, T. DeSutter. ND soybean council and ND corn council. 7/2017-6/2018. $90,242. Managing salinity with cover crops: a whole system response.
17. Gasch, C., A. Wick, J. Harmon, T. DeSutter. ND soybean council and ND corn council. 7/2018-6/2019. $109,130 Managing salinity with cover crops: a whole system response – year 2.
18. Gasch, C., A. Wick, J. Harmon, T. DeSutter. ND soybean council and ND corn council. 7/2018-2/2019 $115,803. Managing salinity with cover crops: a whole system response – year 3.
19. Goos, R. J., and E. Eriksmoen. North Dakota Soybean Council. $33,785. 1 July 2018-30 June 2019.Water Stress Development and Mitigation in West Central ND.
20. Gramig, G. ND Specialty Crop Block Grant Program (USDA-NIFA). 10/1/2017- 9/30/2019. $96,595.00. Combining cover crops, strip tillage, and novel mulches to manage weeds in vegetable cropping systems.
21. Hovick, T., M. Ostlie, B. Geaumont, J. Harmon, R. Limb. 2019-2020. $127,376 Enhancing dry bean production with adjacent pollinator habitats: Quantifying the range and extent of benefits.
22. Ostlie, M., B. Neville, D. Steele, D. Landblom, J. Teboh. J. Lemer, M. Berg, E. Aberle, S. Zwinger, S. Yuja. NC-SARE. 2019-2021. $199,985. Whole system approach to integrated crop/livestock production to enhance soil health and profitability of cropping and livestock systems in the Northern Great Plains.
23. Yuja, S., J. Teboh, G. Endres, S. Zwinger, and E. Aberle. ND soybean council. 2019. $14,550. Determining rye safety to soybeans with soil moisture status
24. Wick, A., F. Casey, C. Gasch, A. Daigh., ND Corn Council, 2019-2021. $167,290. Research and Extension Efforts at the Soil Health and Agriculture Research Extension (SHARE) Farm.
25. Wick, A., F. Casey, C. Gasch, A. Daigh. 2019-2020, ND Corn Council, $24,292. SHARE Farm North: Expanding Soil Health Building Research and Extension Efforts.
26. Wick, A. ND Wheat Commission, 2018-2019. $30,000. Define Wheat Response to Salinity/Soil Health. 2018-2019
27. Wick, A., F. Casey, D. Ripplinger, C. Gasch. ND Soybean Council, 2018-2019. $51,250 Research and Extension Efforts at the Soil Health and Agriculture Research Extension (SHARE) Farm (Year 6).
28. Wick, A., C. Gasch. NCR-SARE, 2017-2019. $29,488. Adoption of Cover Crops to Build Soil Health in the Northern Plains (Continuation).

<u>Graduate students</u>

1. Kenneth Paul Beamer, MS, (Gramig). North Dakota State University. Graduated August 2019.
2. Jesse J. Puka-Beals, MS (Gramig). North Dakota State University. 2018-2019.

3. Sergio Cabello, Ph.D. Nutrient credits from cover crops in no-till systems in the northern Great Plains. North Dakota State University. (Berti and Franzen) August 2016-May 2020.
4. Nadia Delarvarpour, PhD., North Dakota State University, Improving the twin-row interseeder guidance system. (Bajwa and Nowatzki) January 2017-May 2019.
5. Alan Peterson, MS, Interseeding camelina on standing soybean. North Dakota State University. (Berti) June 2016-May 2019.
6. Melissa Geiszler, MS, Corn row spacing and hybrid maturity effects on establishment of interseeded cover crops. North Dakota State University. (Ransom) April 2016-May 2018. Graduated December 2018.
7. 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. (Berti). January 2017 May 2019.
8. Kyle Aasand, MS, Corn and soybean relay cropping with winter rye, field pennycress, and winter Camelina. North Dakota State University (Johnson) June 2016- May 2019.
9. Nick Steffl, MS, Interseeding winter rye, field pennycress, and winter camelina in standing corn and soybean. North Dakota State University (Johnson) January 2017-May 2019.
10. Kory Johnson, MS. Interseeding camelina into narrow row spacing soybean of different maturity groups. North Dakota State University (Kandel) January 2017-May 2019.
11. Alex Wittenberg, MS. Morphological differences between spring and winter camelina types. North Dakota State University (Berti) May 2018-May 2020.
12. Mattie Schmitt, MS Measuring light interception and soil water content while assessing the development of interseeded cover crops in corn. North Dakota State University (Ransom) May 2018-May 2020.
13. Brooke Rockentine, MS, Entomology (Gasch) (Summer 2017 – present)
14. Mackenzie Ries, MS Soil Science (Gasch) (January 2018 – present)
15. Alec Deschene, MS Soil Science (Gasch) (August 2018 – present)
16. Jeremy Wirtz, MS Soil Science (Goos) 2017-2019.
17. Justin Jacobs MS, Improving Efficiency by Intercropping Pea and Canola, and Chickpea and Flax. North Dakota State University. (Johnson and Staricka) August 2016-May 2022

<u>Extension publications, material, news, videos</u>

1. Ostlie, M. 2018. Fact sheet: Cover crop safety following wheat herbicide application
2. Kandel, H. 2018. NDSU Extension Sets Cover Crop Field Day (Fargo). https://www.ag.ndsu.edu/news/newsreleases/2018/aug-27-2018/ndsu-extension-sets-cover-crop-field-day
3. Kandel, H., A. Wick and M. Berti. 2018. NDSU Extension Sets Cover Crop Field Day (Rutland)
4. Kandel, H. 2018. Cover crop field day NDSU campus. Crop Pest Report 30 August, No 16:7.
5. Wick, A., and H. Kandel. NDSU Extension Cover Crop Field Day. Cover Crops Pest Report 16 August, no. 15:5.
6. Kandel, H. 2018. Cover crops Planted during the summer. Cover Crops Pest Report 19 July 2018 no. 12:5.
7. Berti, M.T. and H. Kandel. 2018. Extension cover crop field day August 28. Morning AgClips Farming News, Harvested Daily. August 20, 2018.
8. Berti, M.T. and M.S. Wells. Research update field day. Morning AgClips Farming News, Harvested Daily. September 10, 2018 at https://www.morningagclips.com/ndsu-extension-cover-crop-field-day-sept-18/
9. Berti M.T. and A.W. Wick. 2018. Avoiding another year of ‘snirt’. Country Guide. October 31, 2018.
10. Berti M.T. 2018. Seven soil health takeaways. Dakota Farmer. October 23, 2018
11. Berti, M.T., 2018. Alfalfa-corn intercropping may increase forage and improve soil health. North Dakota Research Report. Forage Focus, December 2018, p. 17.

12. Cihacek, L., D. G. Landblom, S. Senturklu. 2018. Effect of the cropping system on soil physical properties in an integrated crop and livestock system. In DREC annual report - https://www.ag.ndsu.edu/DickinsonREC/annual-reports-1/2017-annual-report/effects-of-cropping-syst-on-soil-phys-prop-in-an.pdf
13. Landblom, D. G. and S. Senturklu. 2018. Ward laboratories microbial and traditional soil health analysis. In DREC annual report -
14. https://www.ag.ndsu.edu/DickinsonREC/annual-reports-1/2017-annual-report/ward-laboratories-microbial-and-traditional-soil.pdf

15. Senturklu, S., D. G. Landblom, and S. I. Paisley. 2018. Effect of bale grazing following annual forage sequence grazing on steer grazing and feedlot performance, muscling ratio, carcass measurements, and carcass value. In DREC annual report -
16. https://www.ag.ndsu.edu/DickinsonREC/annual-reports-1/2017-annual-report/2018-steer-bale-grazing-annual-rpt-v5-senturklu.pdf

Videos

1. Wick, A.F. 2018. Soil Health Minute: Steve Groff Interview, AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=xNn_nJg8fAs (20 views).

2. Wick, A.F. 2018. Soil Health Minute: Steve Groff Interview (extended version), AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=awNkNdsxxP0 (117 views).

3. Wick, A.F. 2018. Soil Health Minute: Rye into Corn Followup, AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=ZdhO5xQ-1J8 (135 views)

4. Wick, A.F. 2018. Soil Health Minute: A Talk with Soil Science Expert Ray Weil (long web version), AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=7DtYq25g9UI (352 views)

5. Wick, A.F. 2018. Soil Health Minute: A Talk with Soil Science Expert Ray Weil (short TV version), AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=xRvx7-kS6U8 (65 views)

6. Wick, A.F. 2018. Soil Health Minute: Soil Health Panel at the Northern Corn and Soybean Expo (short TV version), AgWeek TV Soil Health Minute, Fargo Communications Production. https://www.youtube.com/watch?v=ojD7ptsRD9g (81 views)

7. Wick, A.F. 2018. Soil Health Minute: Soil Health Panel Interview from the 2018 North Dakota Corn and Soybean Expo (long web version), AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=ULFWiLMfqps (147 views)

8. Wick, A.F., 2018. Flying On Cover Crops into Soybean. Extension Education Video, InHouse Productions, https://www.youtube.com/watch?v=oTQulwMUujc (191 views)

9. Wick, A.F., 2018. NDSU Evaluating Cover Crops in Rotation. Extension Education Video, InHouse Productions, https://www.youtube.com/watch?v=yOQOvYc_W9I (205 views)

10. Wick, A.F., 2018. Cover Crops Interseeded into Corn. Extension Education Video, InHouse Productions, https://www.youtube.com/watch?v=6afGyxraH2g (727 views)

11. Wick, A.F., 2018. Cover Crops Flown on into Soybean. Extension Education Video, InHouse Productions, https://www.youtube.com/watch?v=HDdqVqG2Isk (459 views)

12. Wick, A.F., 2018. Soil Health Practices to Improve Trafficability. Extension Education Video, InHouse Productions, https://www.youtube.com/watch?v=mVxDCqNoRC8 (347 views)

Field days

1. DSCS Student Field Tour, Dwight, Mooreton, ND, 22 Oct, 2018. 45 participants. (*Wick)*
2. Cover crops field day, Dickinson and Hettinger, ND. 19 October 2018. 30 participants (***Berti)***
3. Man-Dak Zero Till Early Years Reunion. Rutland, ND, 16-17 October 2018. 35 participants. (*Wick*).
4. Cover Crops Field Day on Campus Plots, Fargo, ND 18 September 2018. 65 participants (*Berti, Kandel, Johnson, Gesch, Wick, Franzen*).
5. Rye and camelina interseeded in soybean and corn Steele County Plot Tour. 15 September, 2018. 21 participants. (*Kandel, Ransom*)
6. NDSU Extension Efforts in Soil Health, Senator Heitkamp and Howard Buffet Visit, Fargo, ND, 14 September 2018. 25 participants. (*Wick*)
7. Big Iron show. Extension booth with cover crop plants and handouts. 11-13 September 2018, Fargo, ND. (*Nowatzki, Kandel, Wick*)
8. Student Focused Research Day at North Dakota State University Fargo Main Campus:6 September 2018 ~30 attendance *(Gramig)*
9. Plot tour. Interseeding soybean and corn with cover crops, Ransom County plot tour, Lisbon, ND, 30 August 2018. (*Kandel, Ransom*)
10. Cover Crop Field Day, Benefits of cover crops in the farming system, including utilization of cover crops as forage, Rutland, ND. 28 August 2018. 100 participants (*Wick, Berti, Franzen, Ransom, Kandel*)
11. Plot tour. Interseeding soybean with cover crops, IDC, Growing Degrees and soybean production. Sargent County plot tour, Gwinner, ND, 21 August 2018. 25 participants. (*Kandel, Ransom*)
12. North Central Soybean Research Program Annual Meeting Tour of the SHARE Farm, Mooreton, ND, 8 August 2018. 45 participants. (*Wick*)
13. Fargo Organic Field Day at North Dakota State University Fargo Main Campus: August 10, 2018. ~40 attendance *(Gramig)*
14. NDSU Horticultural Research Farm Field Day Absaraka ND: August 15, 2018. ~60 attendance *(Gramig)*
15. Soil Health Bus Tour, Valley City-Fort Ransom-Jamestown, ND. 25-26 July 2018. 75 participants (*Wick, Berti, Franzen, Gasch*)
16. NDSU, Williston Research Extension Center. 2018 Irrigated Field Day, July 12, 2018. Intercropping in Irrigated Production. (*Jacobs*)
17. Walsh County Soil Health Extravaganza Tour 28 June 2018, Park River, ND 75 participants. (*Franzen, Wick*)
18. Soil Health Tour of Toussaint Farm Wahpeton, ND. 6 June 2018. 20 participants. *(Wick)*
19. NDSCS Student-Farmer Mentoring Meeting (Soil Health) Rutland, ND, 1 February 2018. 25 participants (*Wick)*

Workshops and professional training

1. Grazing Cover Crops Workshop, Grand Forks, ND, 28 January 2019. (*Berti, Wick, Sedivec, Stokka, Keena, Meehan, Ressler, Kalwar*)

2. Cropping System Economics workshop. Webinar, Learn how to properly evaluate financial, economic, and environmental tradeoffs among alternative cropping systems. Includes exposure to cropping system concepts and application of models to compare alternative cropping systems. A professional development opportunity for Extension specialists and agents. 8 February 2019. *(Ripplinger)*
3. Conservation Tillage Conference. Fargo, ND. 18-19 December 2018. 350 participants. (*Wick, Berti, Franzen)*
4. Midwest Cover Crops Council Annual Conference. Fargo, ND, 13-14 March 2018. 215 participants. (*Berti, Wick, Ripplinger, Johnson, Franzen*)

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.

Café Discussion Groups and Invited Speaker Presentation at Dickinson areas:

Café Discussions (DREC & NRCS Cooperating Presentation) – Average time: 2.5 Hours, Average Attendance: 15 (Total – 135)
Watford City, Beach, Beulah, Williston, Dickinson, Tolley, Powers Lake, Watford City, Amidon

Invited Speaker Presentations – 1 Hour Each
Wall, SD – SD No-Till Association (92 people)
New England, ND – Livestock and Crop Improvement Association Annual Meeting (45 People)
Dickinson, ND – Dickinson State University – Animal Science Class Invited Lecturer (15 Students)
Bison, SD – NRCS and Bird Conservancy of the Rockies (30 People)
Dickinson, ND – NDSU Extension – Cover Crop Haying and Grazing Meeting (45 People)
Williston, ND – ND Hard Red Spring Wheat Show – Incorporating Forges into Grain Rotation (90 People)
Stanley, ND – Mountrail County – Integrated Systems Synergy (40 People)

Websites

1. CropSys CAP website www.cropsyscap.org: 10,190 visits and 24,397 pages viewed in 2018.
2. NDSU Soil Health website: https://www.ndsu.edu/soilhealth/ Continues to be an outlet for soil health information including circulars to download, links and videos. It is also used to do on-line registrations, post conference information. An RSS feed was started in November, 2017 for the "in the news" tab to notify subscribers when a new story highlighting NDSU Soil Health is posted. 568 subscribers to YouTube Channel (30 December 2018). Extension events for the CAP and extension materials are published on this site as well as in the CropSys CAP website.

IMPACT STATEMENT

Cover crops adoption in North Dakota is increasing exponentially thanks to the many researchers (27) and graduate students (17) involved in cover crops research and extension in the state. Researchers were able to secure $2,552,049 in new funding for cover crops research in 2018, in addition to the NIFA CropSys CAP project for 3.7 million, which is in its third year of execution.
Soil erosion by wind is a serious problem in our state especially in winter with little snow cover or dry springs. Cover crops are improving soil health, reducing erosion, and increasing sustainability of cropping

systems. In the long-term cover crops will help reduce N fertilization and improve water quality, and provide forage for grazing.
Research on cover crops interseeding and intercropping has also increased in the last few years and many farmers are interseeding cover crops in standing corn, soybean, and sunflower either by using a interseeder drill or a broadcast system (aerial or modified sprayer). The acres interseeded with cover crops in 2018 were approximately 50,000 acres from reports of farmers and aerial applicators. Total area of cover crops is unknown but we believe it easily surpass 500,000 acres in North Dakota.

According to survey respondents (n=120) who participated in one or more of our extension activities in North Dakota, indicated their primary concern is nutrient management followed by water management and wind erosion. Cover crops adoption is growing with increasing interest in establishing a cover crop in standing in corn and soybean (44%) and use cover crops as weed control (48%). In addition, 38% of participants indicated they are considering using cover crops to manage problematic areas (salinity, headlands, low spots. The respondents to this survey represent an area of 230,000 acres.