MCCC-NORTH DAKOTA ANNUAL REPORT

April 2019 to February 2020

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COMPLETED RESEARCH

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

Experiments were established in Prosper and Hickson, ND in 2019 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. This was the second year for this research. Similar to 2018, measurements were also made on soil moisture in the top 7.5-cm of the soil to help quantify soil moisture conditions during the time of cover crop establishment within a corn crop. This work was part of the MS thesis research of Mattie Schmitt. In 2019, moisture conditions were generally favorable for the establishment cover crops. Radish appears to be more sensitive to shading than the other two species. Consequently, it does not usually establish well when there is a full canopy of corn, especially when planted during V7 stage of corn. In one location, however, when corn had been damaged by hail, radish was the most vigorous of the cover crops. Drilling the cover crop seed established better stands than when broadcast and there was more biomass produced when cover crops were planted at the R4 corn stage than at the V7 stage.

In 2019, soybean was planted into the 2018 cover crops established in corn, and management in fall of 2018 impacted seed yield.Generally, plots where corn stover was removed had greater yield than those where corn stover had not been removed. It is not clear if this was due to better cover crop development where corn had been removed, or the fact that there was less residue in these plots so that the soil could dry and warm up faster for soybean. Yield was greatest when cereal rye was the preceding cover crop in Prosper but at Hickson, soybean had greatest yield when following the 2018 radish cover crop. Much of the 2019 data is still being analyzed due to the very late harvest in fall 2018 due to excess moisture and early snow accumulations.

2. ***Effect of rye termination timing when planting soybean*** *(Joel Ransom and MS student Marcus Mack).*

The 2019 season was the first for this study. Soil moisture in the spring was adequate, so establishing soybeans into a rye cover crop was not constrained by inadequate moisture for establishment. Regardless of rye termination timing, soybean established well. There was little rye biomass if rye was terminated two weeks before soybean planting (middle of May), whereas when rye was terminated two weeks after soybean planting, there was very extensive ground cover. Weed suppression was noted when rye was terminated at the time of, or after, planting soybeans, but not before. Soybean yield was not impacted by any of the termination timing treatments..

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

<u>Gardner, ND site:</u>

Corn grain yields were 40% less than last year, with the site almost continuously saturated with water below 1 foot for the entire season and an entire May that was so wet that I could not walk out to set the moisture sensors, but I can easily estimate that the site was at field capacity for the entire period. The losses of N through denitrification were likely huge- more than 100 pounds of N per acre.
The cover crop the previous season resulted in very low biomass, thus the results you see below-

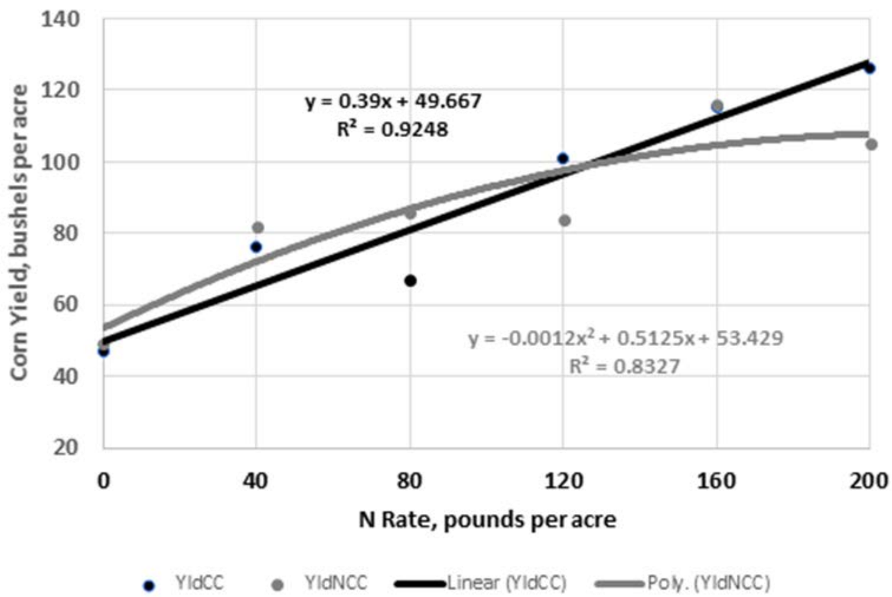


Fig. 1. Corn grain yield in Gardner, ND in 2019 following cover crops and no cover crops

No difference in cover crop, no cover crop, maximum yield achieved with between 120 and 160 pounds N per acre (Fig. 1). Some late emerging rye survived to harvest and a sampling was conducted, with results yet to follow.

Rutland, ND site

There was a 40 lb/acre N lag with cover crop vs no cover crop. All yields are figured at 15.5% moisture- corn moisture varied from about 24% to 31%, average about 28% (Fig. 2).

Table 1. Corn grain yield averaged across treatments in Rutland in 2019.

N rate	Corn grain yield
	Bu/acre
0	125
40	167
80	180
120	187
160	192
200	197
LSD (0.05)	18
Mean with cover crop	170
Mean without cover crop	180

Yield between cover crop and no cover crop was significant at $P \leq 0.10$

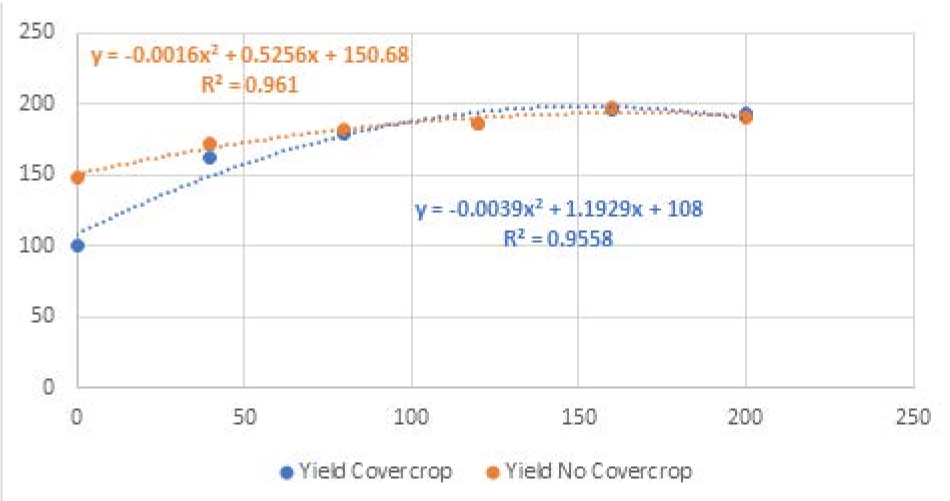


Fig. 2. Corn grain yield (bu/acre) with and without preceding fall cover crop and sixN rates (lbs/acre) in Rutland in 2019.

Soybean yield: There was no influence of previous or in-season cover crop at either site. Gardner cover crop was inconsequential, but the Rutland site had enough cover crop rye that we took as sampling in late October.

Table 2. Soybean yield after cover crop or no cover crops treatments.

Treatment	Gardner	Rutland
	Bu/acre	
With cover crop	32.2	45.5
Without cover crop	28.7	49.1
Mean	29.5	47.3
LSD (0.05)	NS	NS

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, Research scientist Dulan Samarappuli, Research Specialists Alan Peterson and Alex Wittenberg)*

Corn and wheat are major crops in the northern Great Plains, and when produced with conventional tillage and other management practices result in poor soil residue cover through late fall to the next spring. This poor soil residue cover negatively affects soil health and increases water and wind erosion, which further decrease long-term productivity. Additionally, high concentrations of deep, residual nitrogen after cereal production are easily lost by leaching, resulting in large negative environmental impacts from these cropping systems. Cover crops and no-tillage provide greater soil residue cover, preventing soil erosion and reducing NO_3-N leaching. This experiment was conducted at two locations, Prosper and Hickson, ND, in 2017 and 2018. The experimental design was a RCBD with four replicates. The cover crops were forage pea (*Pisum sativum* L.), faba bean (*Vicia faba* Roth.), winter camelina and a check plot (without cover crop), they were established into spring wheat stubble in August of both years. Biomass yield and nitrogen accumulation in cover crops tissue averaged across four environments was 1.53 Mg $ha^{-1}$and 66 kg ha^{-1}, respectively; there were no significant differences between treatments (Fig. 3 & 4). In late fall, soil residual NO_3-N was lower in winter camelina plots (23.1 kg ha^{-1}) in comparison with the other of treatments (28.2 kg ha^{-1}). Soil green coverage was significantly higher in forage pea plots (61.8%) than other treatments (Fig. 5), which decreases wind erosion.

In May 2018-2019, corn was planted with a RCBD design in a split-plot arrangement, where the main plot was cover crops (from the previous season) and the sub plot was fertilizer N rates (0, 40, 80, and 160 kg ha^{-1}). Winter camelina in 2018 was actively growing during spring. Gravimetric soil water content (0-

15 cm depth) was significantly lower with winter camelina (18%) than the rest of treatments (24%). In addition, spring in 2018 was dry and corn growth was decreased. The NDVI in mid-June was significantly lower where camelina was grown in comparison with the rest of the treatments. Averaged across the four locations, corn grain yield was not influenced by the cover crop × N rate interaction. However, corn grain yield was influenced by the main effects of cover crops and N rates. Lower corn grain yield was observed on plots that had winter camelina (8.61 Mg ha^{-1}) in comparison with those that had faba bean (9.71 Mg ha^{-1}) forage pea (10.11 Mg ha^{-1}), or no cover crops (9.83 Mg ha^{-1}) (Fig. 6). Nitrogen rates averaged across cover crop treatments were different. Corn grain yield without N application was 6.8 Mg ha^{-1} and grain yield with 160 kg ha^{-1} N rate was 12.3 Mg ha^{-1} (Fig. 7). In conclusion, legume cover crops did not decrease corn grain yield, and in fact, these cover crops slightly increased yield in all the N rates compared with the no-cover crop (Fig. 8) and camelina cover crop treatments. Cover crop treatments provided winter soil coverage in all the environments.

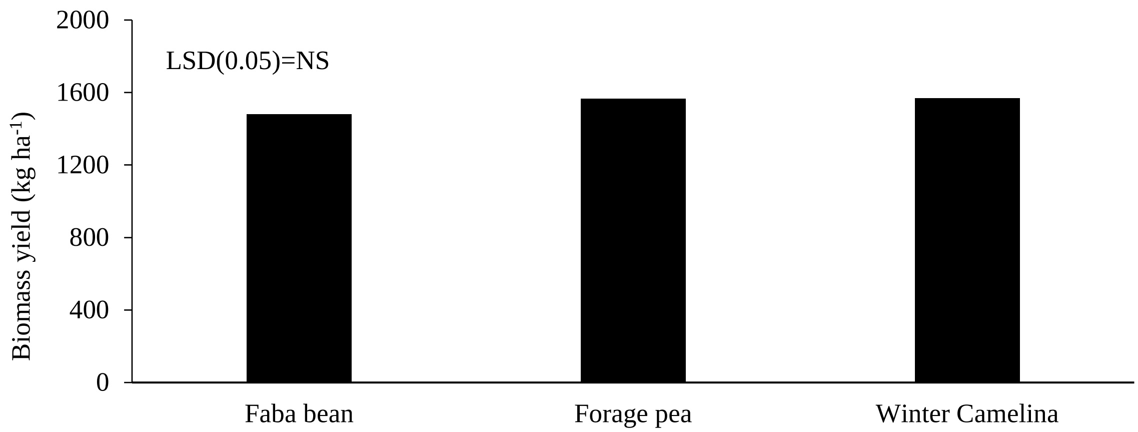


Fig. 3. Mean biomass yield of cover crops averaged across four environments , Hickson and Prosper, ND, in 2017-2018.

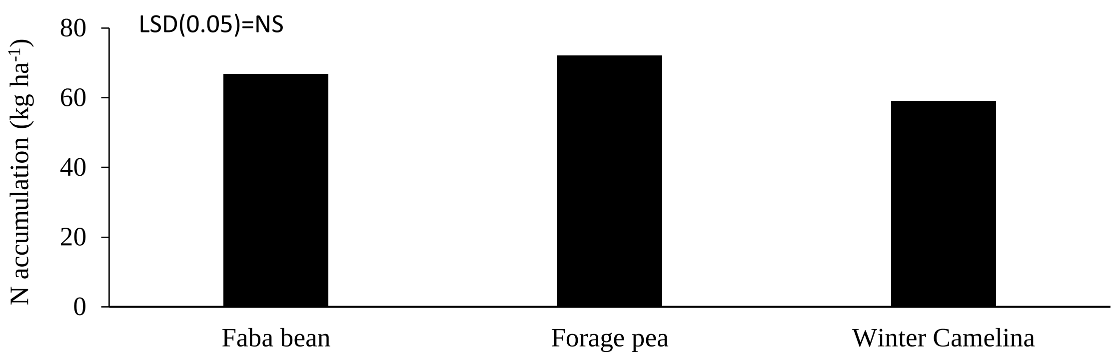


Fig. 4. Nitrogen accumulation of cover crops averaged across two environments in Hickson and Prosper, ND, in 2017-2018.

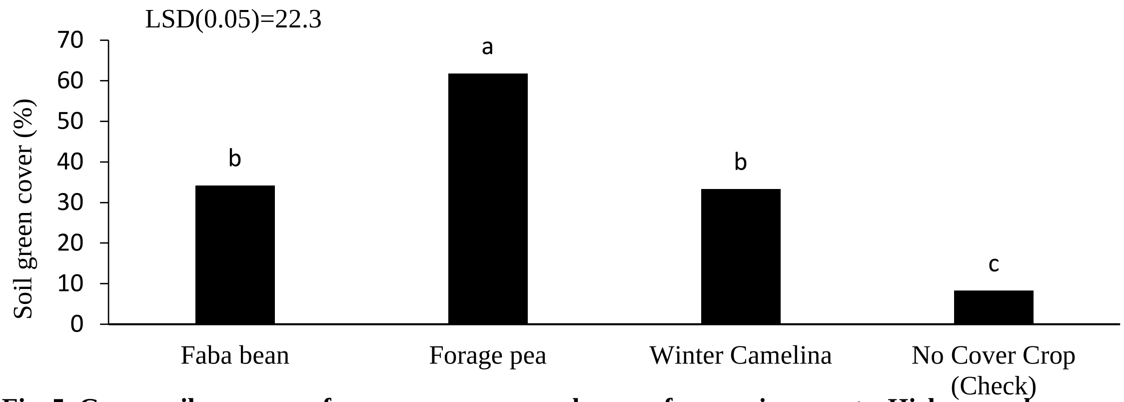


Fig. 5. Green soil coverage of cover crops averaged across four environments, Hickson and Prosper, ND, in 2017-2018. Columns with different letters are significantly different at *P* = 0.05.

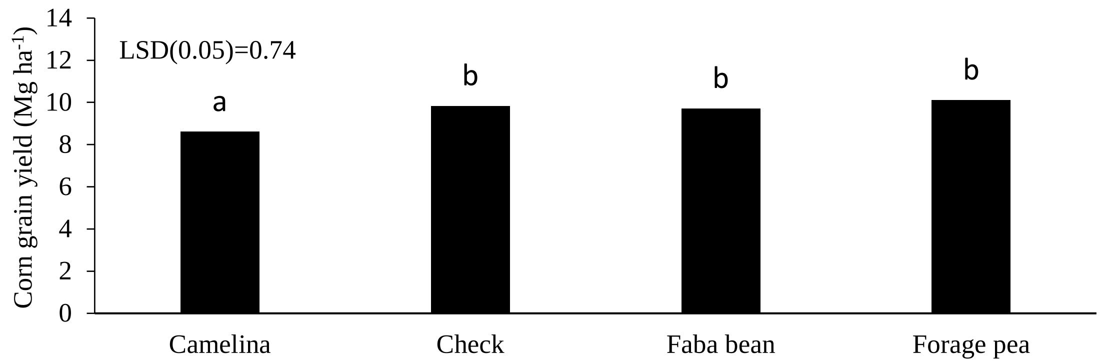


Fig. 6. Corn yield averaged in main plots across four environments. Hickson and Prosper, ND, in 2018-2019. Columns with different letters are significantly different at *P* = 0.05**.**

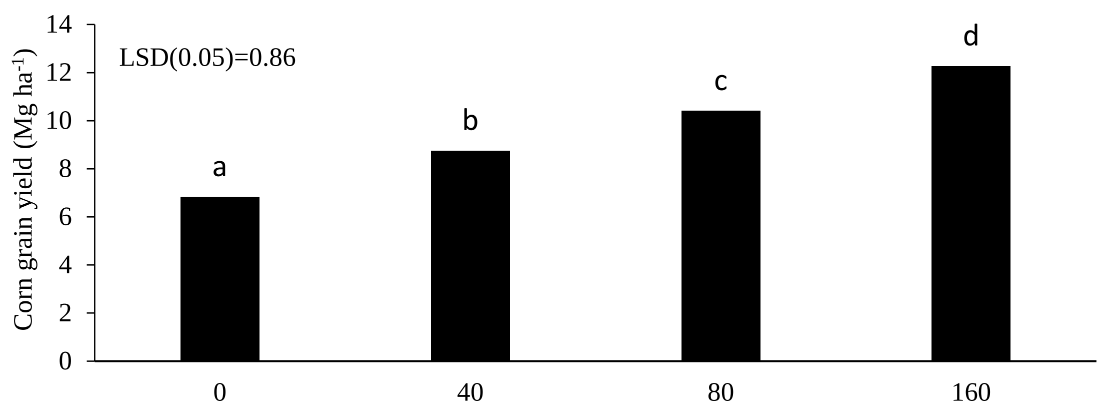


Fig. 7. Corn yield averaged in sub plots across four environments. Hickson and Prosper, ND, in 2018-2019. Columns with different letters are significantly different at *P* = 0.05.

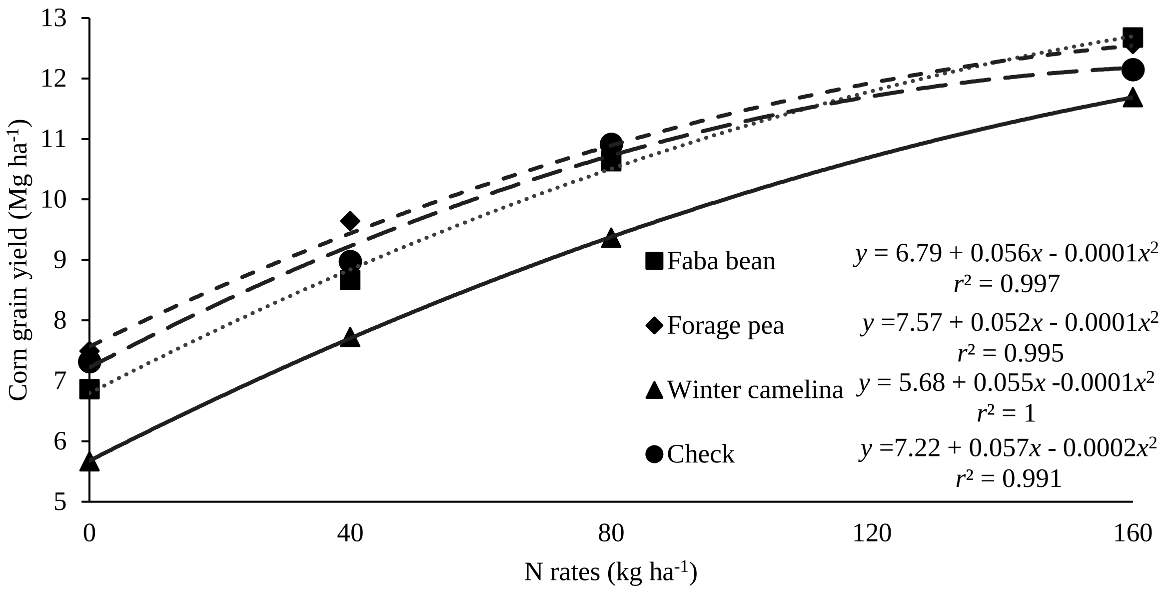


Fig. 8. Corn yield averaged in sub-plots across four environments, Prosper and Hickson 2018-2019,

5. ***Cover crops decreased initial water content, sugarbeet yield and residual N-NO_3*** *(Marisol Berti, Amitava Chatterjee, PhD student Sergio Cabello-Leiva, MS student Sailesh Sigdel)*

Sugarbeet (*Beta vulgaris* L.) is a valuable crop in the Red River Valley, but it leaves the soil uncovered after harvest. The lack of soil coverage during winter increases soil losses due to wind erosion. In addition, high levels of deep residual nitrogen are observed after cereal production, decreasing sugar beet quality, sugar yield, and profitability. Cover crops and no-tillage provides soil coverage, preventing soil erosion, and reducing NO_3-N leaching. The experiment was conducted at four environments, Prosper and Hickson, ND, 2017 and 2018. The experimental design used was a RCBD with four replicates. The cover crops were radish (*Raphanus sativus* L.), winter camelina [(*Camelina sativa* (L.) Crantz.], winter wheat (*Triticum aestivum* L.), spring oat (*Avena sativa* L.), winter rye (*Secale cereale* L.), and a check plot (without cover crop), established into spring wheat residue in August (2017-2018). Summer and fall cover crop biomass production by oat and radish was significantly greater than other treatment, averaging 1.8 Mg ha^{-1} across the four environments (Fig. 9). Soil green cover was 54% for both oat and radish while in rye was 45% (Fig. 10), providing soil protection from wind erosion. Nitrogen accumulation in the biomass was significantly higher in oat and radish in comparison with the other treatments, averaging 47 kg N ha^{-1} (Fig. 11). Soil NO_3-N in the 0-15cm depth in late fall was significantly higher in the check plots (17.9 kg ha^{-1}) than in plots with a cover crop; oat (10.6 kg ha^{-1}), winter rye (11.4 kg ha^{-1}), and radish (12.8 kg ha^{-1}) (Fig. 12). This indicates cover crops are scavenging residual NO_3-N and keeping it in their biomass. Radish, winter rye, and oat provided soil cover in the fall, protecting the soil from erosion and reducing soil residual NO_3-N. In May 2018 and 2019, the experiment was planted with sugarbeet in a RCBD design in a split-plot arrangement. Main plots were cover crops described above and sub plots were nitrogen rates (0 and 112 kg ha^{-1}). Winter camelina and winter rye survived the winter and were actively growing early in the spring until terminated before sugarbeet planting. In Hickson 2018, gravimetric soil water content was significantly lower in winter rye (21.4%) and winter camelina

(23.7%) than in the no cover crop plots (26%) (Fig. 13). Sugarbeet stand counts were significantly lower in plots following the two winter-hardy cover crops. Sugarbeet plant density was 48,438 plants ha^{-1} after winter rye, 73,684 plants ha^{-1} after winter camelina, and 77,794 plants ha^{-1} after winter wheat (Fig. 14). Sugarbeet plant density on plots that had cover crops winterkilled was greater than 99,000 plants ha^{-1}. The interaction of cover crop and N rates was significant for sugarbeet yield at Hickson. Lowest root yield (56 Mg ha^{-1}) was when sugarbeet was planted after winter rye without N fertilizer application (Fig. 15). Sugar beet without N application and not following a cover crop had root yield of 83 Mg ha^{-1}. In conclusion, cover crops scavenge residual NO_3-N well, preventing N from loss via leaching and run-off. Winter-hardy cover crops provided green soil cover in spring and decreased gravimetric water content, stand density, and sugarbeet yield. Reducing water content opens the possibility of earlier sugarbeet planting in heavy clay soils and wet springs. Cover crops averaged across N rates did not decrease sugarbeet yield, but they provided soil coverage in the winter.

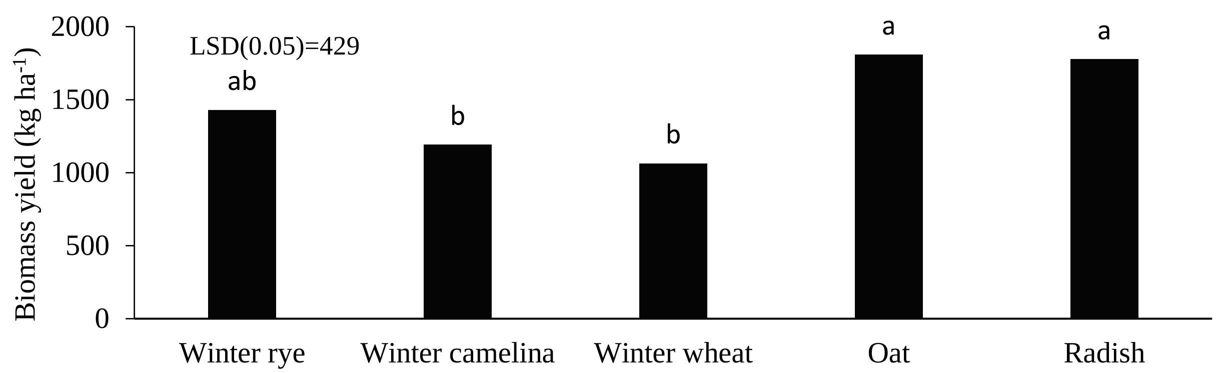


Fig. 9. **Mean biomass yield of cover crops averaged across four environments, Prosper and Hickson, ND, in 2017 and 2018.** Columns with different letters are significantly different at $P = 0.05$.

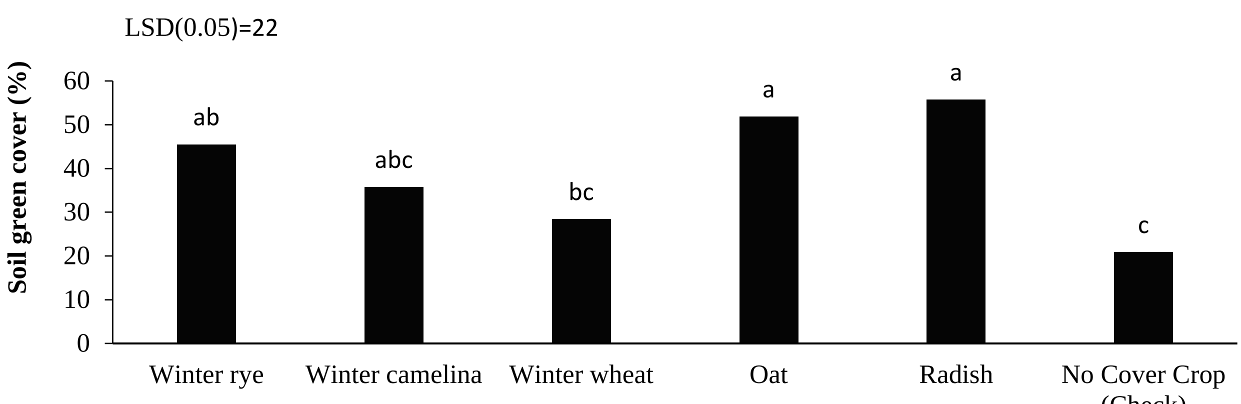


Fig. 10. **Mean fall soil green cover of cover cropsaveraged across four environments, Prosper and Hickson, ND, in 2017 and 2018 .** Columns with different letters are significantly different at $P = 0.05$.

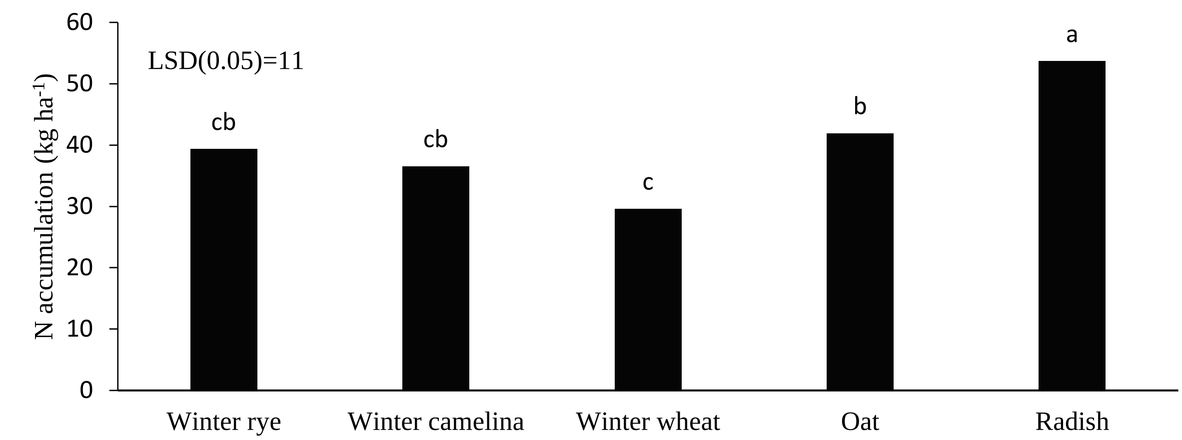


Fig. 11. Mean N accumulation in cover crops biomass avearged across four environments in Prosper and Hickson, ND, 2017 and 2018. Columns with different letters are significantly different at *P* = 0.05.

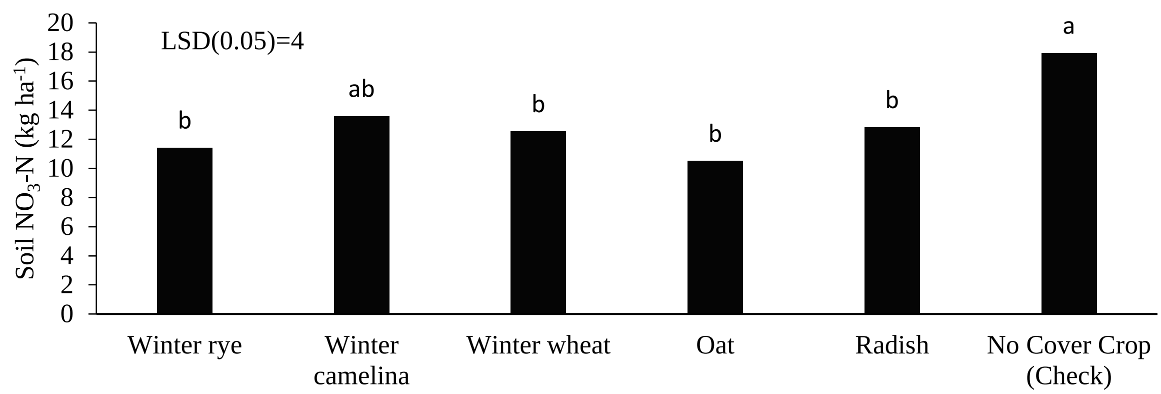


Fig. 12. **Mean soil NO_3-N content at harvest of cover crops averaged across four environments in Prosper and Hickson, ND, in 2017 and 2018.** Columns with different letters are significantly different at *P* = 0.05).

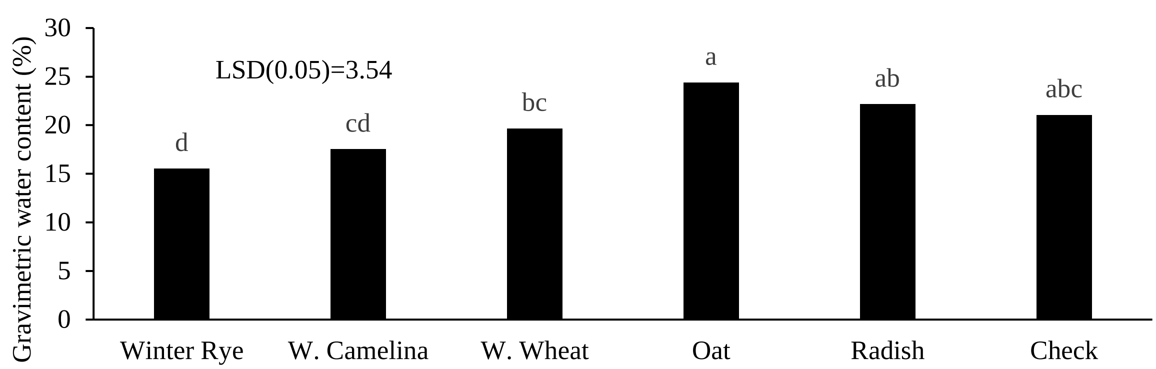


Fig. 13. Gravimetric water content at Hickson, ND, in 2017. *Columns with different letters are significantly different at P = 0.05.*

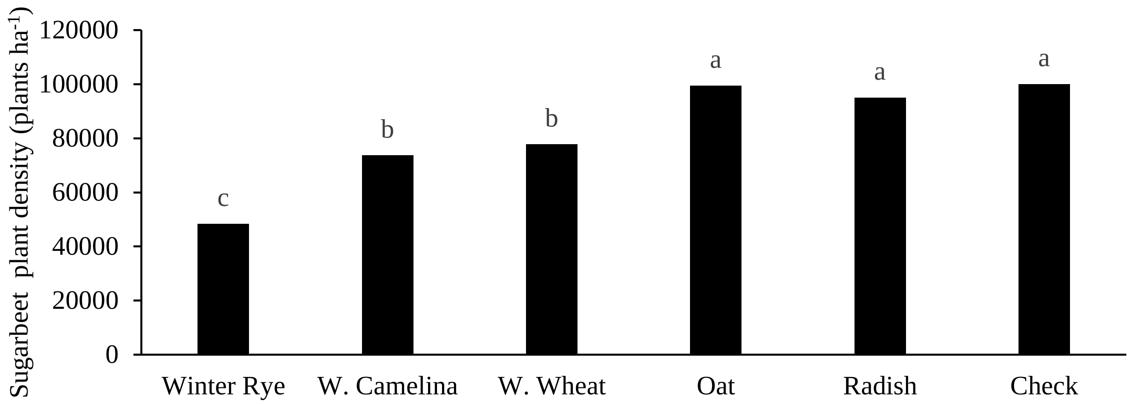


Fig. 14. Sugarbeet plant density after cover crops at Hickson, ND, in 2017. *Columns with different letters are significantly different at P = 0.05.*

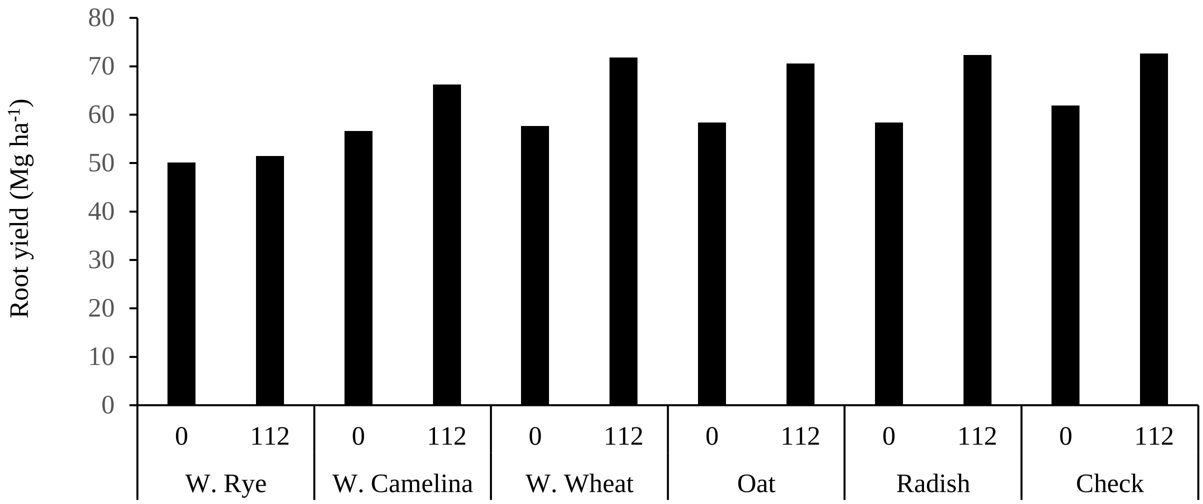


Fig. 15. Sugarbeet root yield after cover crops fertilized with 122 kg N ha^{-1} or no fertilization, averaged across three environments, Prosper and Hickson, ND, 2018 and 2019.

6. ***Interseeding cover crops in sugarbeet*** *(Chatterjee, Berti, MS student Sigdel)*

Wind and water erosion are responsible for soil loss in the Red River Valley (RRV). Fields with minimal residue cover after harvest are particularly prone to erosion. Consequently, the sugar beet planted on these soils suffer wind and water damage at emergence and sometimes re-seeding is necessary if the spring wind occurs before the seedlings become large enough to resist the wind and water damage. After harvest few leaves or groundcover remain to protect soil from wind and water erosion. Sugarbeet crops (especially sugarbeet seedlings) are negatively affected from wind storms in several aspects. Damage ranges from minimal to complete and can result in a need to re-seed entire fields. Re-planting particularly can cause great economic loss particularly when Roundup Ready sugarbeet seed are used and there is a short window for crop establishment. Recently, increased fluctuation in weather with more frequent drought and severe, localized rainstorm events in the region has accelerated these negative effects.

Cover cropping practices have become more widely adopted in the RRV as a way to reduce damage from wind and flood events. The following criteria are some of the most important for selecting a cover crop for sugarbeet production in the RRV: holds soil in place with a sufficiently developed root system, reduces wind damage to young seedlings with its aboveground biomass, is inexpensive, and can be managed and killed so that it does not compete with the main crop for nutrients, water, and light. Establishing cover crops in RRV is not without its challenges. As a solution, we hypothesized that interseeded cover crops will produce more biomass and root will protect soil from erosion during fall, winter, and early spring. This project is focused on identifying the effects of interseeded cover crop species and best time to plant these cover crops and how these interaction effect sugarbeet yield and quality. This will help growers to determine which cover crop species and planting date is most promising for incorporation into their sugarbeet cropping system.

ield study was conducted at two sites, Ada, MN and Prosper, ND. The experiment was laid out in a factorial RCBD which included four different cover crops interseeded at two planting dates; a check (no cover crop), winter rye cv. ND Dylan, winter camelina cv. Joelle, winter Austrian pea, and brown mustard (*Brassica juncea*.) cv. Kodiak were the main plots and two cover crop planting times (June and July) were subplots in four replicates (Table 3)..

Table 3. Seeding rates of inter-seeded cover cropsat Ada and Prosper in 2019.

Cover crop	Cultivar	Seeding rate (lbs/acre)
Austrian Pea		20
Camelina	Joelle	6
Mustard	Kodiak	10
Rye	ND Dylan	20

Individual subplots measured 11 ft wide and 30 ft long. Standard Roundup Ready sugarbeet cultivar was planted. The sugarbeet seeds were planted 4.75” apart. Recommended NPK fertilizers were applied prior to planting based on soil test (Table 4). Sugarbeet planting was done at 13 May and 16 May for Ada and Prosper, respectively. For Ada, first cover crop planting was done on 13 June and second on 24 June whereas for Prosper, first and second cover crop planting was done on 17 June and 2 July, respectively. The cover crops were interseeded between sugarbeet rows using a hoe. A 22-inch row spacing was used. Fungicide applications were done thrice for the control of fungal diseases such as *Cercospora* leafspot. Hand weeding was done to control weeds between rows. The cover crop biomass was measured just before beet harvest and 0-6” depth soil samples were analyzed for inorganic nitrogen concentration. Sugarbeet trials were harvested on 16 September and 9 October for Ada, MN and Prosper, ND respectively. The middle two rows of each plot were harvested and subsamples were used to determine crop yield, sugar percentage and recoverable sugar per acre. Beet quality analyses was performed at American Crystal Sugar Quality Tare Lab, East Grand Forks, MN.

The effect of cover crop inter-seeding on yield was analyzed using PROC GLM in SAS for an RCBD design. Probabilities equal to or less than 0.05 were considered significant for main effects and interactions. A protected least significant difference (LSD) test was used to separate differences.

Table 4. Initial soil nutrient concentration and basic soil physical-chemical properties

Site	Ada, MN	Prosper, ND
Textural class	Sandy clay loam	Silty clay loam
pH	7.6	6.7
NO_3-N 0-6” (lb ac^{-1})	14.4	16
Olsen P (ppm)	19.5	40
K (ppm)	171.6	280
OM (%)	3.07	3.3

Results and discussion: Precipitation was abnormally high in 2019. There was 25% and 59% more precipitation from May to October in 2019 than in 2018 at Ada and Prosper respectively. Rainfall in 2019 at Prosper was higher than at Ada.

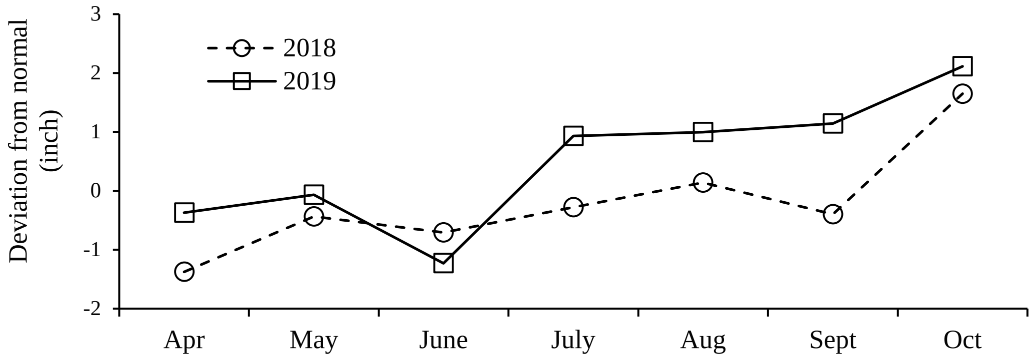


Figure 16. Deviation from normal precipitation for 2018 and 2019.

The cover crop treatment and its planting time significantly affected the sugarbeet root yield and sugar quality at Ada (Table 5).

Table 5. Effect of different inter-seeded cover crops on sugarbeet root yield, sugar quality and recoverable sugar/acre for Ada and Prosper during 2019 growing season.

Site	Planting time	Treatment	Root yield (ton acre^{-1})		Sugar %		RSA	
Ada, MN	13-Jun	No Cover Crop	30.87±4.0	AB	16.32±0.30	BCD	9219±1203	AB
		Rye	21.65±4.4	D	16.95±0.4	A	6716±1244	D
		Camelina	26.99±3.2	BC	16.82±0.4	AB	8315±774	BC
		Austrian pea	25.45±4.3	CD	16.31±0.2	BCD	7580±1201	CD
		Brown mustard	22.41±1.5	D	16.19±0.3	CD	6614±505	D
	24-Jun	Rye	30.77±0.8	AB	16.34±0.4	BCD	9186±84	AB
		Camelina	34.17±1.4	A	16.02±0.1	CD	9996±357	A
		Austrian pea	33.55±2.6	A	15.88±0.5	D	9714±368	A
		Brown mustard	32.08±1.5	A	16.54±0.3	ABC	9700±532	A
		$LSD_{0.05}$	4.33		0.54		1169	
Prosper, ND	17-Jun	No Cover Crop	35.79±3.5		14.87±0.6		9955±1024	
		Rye	34.30±5.4		14.84±0.2		9556±1543	
		Camelina	38.05±3.5		15.13±0.6		10772±745	
		Austrian pea	35.21±5.5		14.96±0.4		9803±1351	
		Brown mustard	33.61±4.2		14.83±0.7		9360±1102	
	2-Jul	Rye	37.42±4.5		14.41±0.8		10020±1215	
		Camelina	38.18±1.7		15.15±0.9		10560±963	
		Austrian pea	40.35±4.5		14.69±0.2		11071±1236	
		Brown mustard	38.30±2.9		14.65±0.5		10482±872	
		$LSD_{0.05}$	ns		ns		ns	

† Mean values for each soil followed by the standard deviation.
‡ Means within a column sharing a letter are not significantly (p=0.05) different from each other; ns= non-significant

Interseeding date and its interaction with cover crop species had a significant effect on root yield. Sugarbeet root yield was reduced if the planting date of interseeded cover crops was too early. Averaged across interseeding time at Ada, root yield for 13-June interseeded cover crop treatments was 24.1 ton acre^{-1}, lower than that of control (30 tons acre^{-1}) and 24-June interseeding (32.6 tons acre^{-1}). The rapid establishment of early interseeded cover crops caused severe competition with sugarbeet causing yield reduction. However, beet root yield for the second interseeding date was not affected. We observed that sugar beet with late interseeded cover crops had consistently higher yield than any of the treatments (Table 8). Among the treatments, 24-June interseeded camelina produced the highest root yield, 34 tons $acre^{-1}$, but was not significantly different from control.

In Prosper ND, root yield from interseeded plots was not significantly different from those of the no-cover crop control in 2019. In 2019, at Ada MN, there were no differences among treatments and the control for sugar content, except for the early-interseeded rye, where rye caused significantly higher sugar concentration than found in the control with no cover. For Prosper, there were no differences among the treatments.
Recoverable sugar per acre was affected mainly by root yield and sugar quality. The cover crop treatment and interseeding timing did not affect recoverable sugar per acre at Prosper. However, at Ada, for the second inter-seeding date the recoverable sugar per acre was higher than the first interseeding date and no cover control. Early competition between the cover crop and sugarbeet decreased the amount of recoverable sugar per acre for the first inter-seeding date, mainly due to reduced root yield in the cover crop treatments.

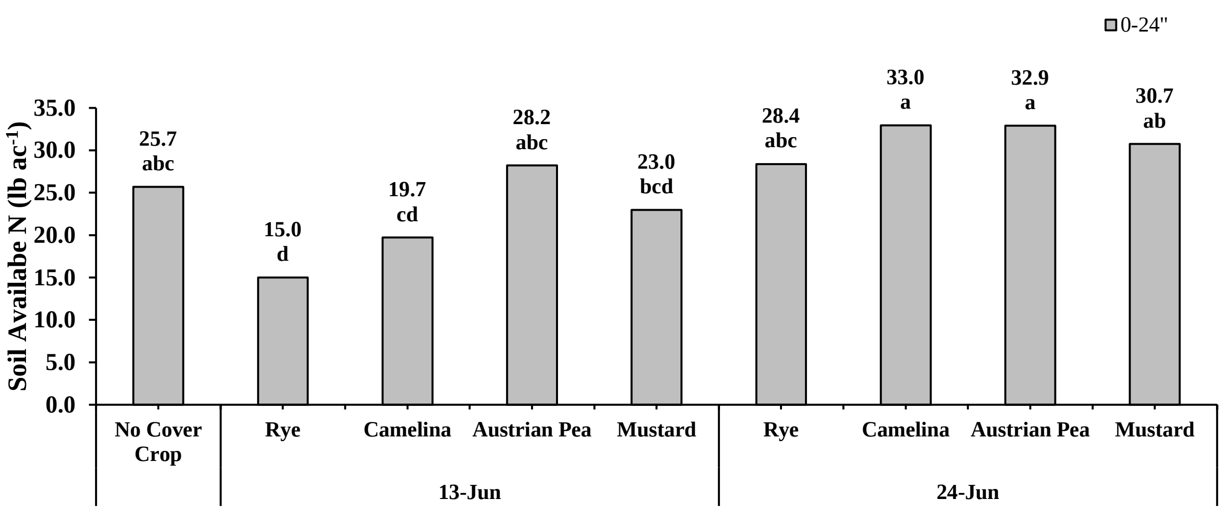


Fig. 17. Effect of cover crop interseeding on residual soil inorganic N (lb ac^{-1}) after harvest at 0-24" depth during 2019 at Ada.

Under the conditions of this experiment, root yield and sugar quality were affected by time of cover crop seeding and species type at Ada, MN. Cover crop inter-seeding at least 40-45 days after beet emergence did not affect the sugarbeet root yield. The reduction in root yield for early inter-seeding was probably the result of competition between planted cover crops and beet. However, more research is needed to identify what environmental conditions and practices would reduce the risk of yield loss following inter-seeding.

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

The goal of this research was to evaluate how soybean row spacing and soybean maturity dates affect winter camelina and cereal rye establishment, and how this affects the following spring wheat crop. The experiment was established in the 2018 growing season (interseeding cover crops into soybean) and wheat was harvested in 2019. The experiment was conducted at North Dakota State University's experiment site (46.932124° N, -96.858941° W) located near Fargo, ND. The experimental design was a randomized complete block design with a factorial arrangement with four replicates. The experimental unit size was 1.52 × 7.62 m. Treatments included soybean relative maturity, soybean row spacing, and cover crop type. Soybean relative maturities were "early" (0.5) or "late" (0.9). Plot row spacing were narrow (30.5 cm) or wide (61 cm) and soybean seeding rate was 469,300 live seeds ha^{-1}. Cover crop treatments were: none, camelina, and rye. The cereal rye cultivar 'Rymin' was sown at a rate of 67 kg live seeds ha^{-1}. The winter camelina cultivar 'Joelle' was sown at a rate of 10 kg live seeds ha^{-1}. Cover crops were sown when the soybean reached the R6 growth stage. In the wide soybean row spacing cover crops were seeded using a customized v-hoe with two blades spaced to make parallel furrows 15 cm apart. The parallel rows were sown in the center of two planted soybean rows. For the narrow soybean row spacing, a single furrow was made in the center of all rows 15 cm from each corresponding row. Furrows were made to the depth of 1.3 cm for camelina and 2.5 cm for cereal rye.

The spring wheat variety 'SY Ingmar' was seeded on May 31, 2019, after termination of the cover crop. Wheat was seeded at a rate of 2.47 million live seeds ha^{-1} with a 'Great Plains' no-till drill with 7 rows and 19 cm row spacing. The trial was harvested on September 6.

Canopy coverage, defined as a percentage of green plant matter which covers the soil, was measured using the mobile phone application 'Canopeo'~~. from the Oklahoma State University Department of Plant and Soil Sciences.~~ Canopeo measures the fractional green canopy cover through image processing and provides a green canopy coverage percentage.

Results: The wheat canopy cover percent after rye was significantly lower compared with camelina or without a cover crop (Table 6). The final crop height of the wheat plants after rye was also significantly less than after camelina or without a cover. The final result was that wheat yield after rye was significantly lower than after camelina or no cover. Wheat yield after soybean growing in narrower, 30.5-cm rows was higher than wheat grown after soybean grown in 61 cm. There was no difference in grain test weight between treatments.

Growing wheat after rye in this experiment resulted in reduced growth of the wheat and caused a lower yield and this practice is not recommended for growers. However, rye was terminated just before wheat seeding. Possibly earlier termination may reduce the negative effect of the rye on the following wheat crop. Wheat after camelina performed similar to wheat after no cover crops.

Fig. 18. Overview of NW22 wheat research area, summer 2019.

Table 6. Wheat after cover crop, 2019 NW22, Fargo ND.

Treatment		Wheat canopeo[1]	Wheat height	Wheat yield	Test weight
Row spacing (cm)		%	cm	kg ha^{-1}	lb/bu
30.5		88.6a	77.2a	4179a	57.8a
61		88.3a	76.9a	4058b	58.0a
Cover crop					
None		89.7a	77.4a	4212a	57.8a
Camelina		90.8a	78.2a	4185a	58.0a
Rye		84.9b	75.5b	3957b	57.9a
Row spacing (cm)	**Cover crop**				
30.5	None	89.3a	77.8a	4320a	57.6a
30.5	Camelina	91.3a	78.4a	4246a	57.7a
30.5	Rye	85.1a	75.4c	3957b	58.0a
61	None	90.0a	77.1ab	4105ab	57.9a
61	Camelina	90.4a	77.9a	4118ab	58.3a
61	Rye	84.6b	75.6bc	3950b	57.7a

[1]Canopeo is green canopy coverage determined on July 8 2019
Within columns and each treatment, means followed by the same letter are not significantly different at ($P \leq 0.05$).

*8) **Interseeding camelina, crambe and mustard to reduce soybean cyst nematode (SCN) (Heterodera glycines) (SCN)** (Marisol Berti, Guiping Yan, Krishna Acharya, Alan Peterson, and Angie Peltier)*

Experiment 1: Cover crop interseeded into standing soybean at V6 stage

The research was conducted at Prosper and Casselton, ND infested with SCN in 2018-2019. The experimental design was a RCBD with a split-plot arrangement with four replicates. The main plot was soybean cultivar (susceptible or resistant); subplots were winter camelina cv. Joelle (Fig. 19) and brown mustard (Mighty mustard®) cv. Kodiak interseeded at V6 stage and two check plots, one with only soybean and one without no soybean or cover crop.

Of three plots in each replicate interseeded with brown mustard at V6, one plot was terminated at R4 stage of soybean (9 August 2019), one plot was not terminated and in one soybean was removed in on 8 July. Soybean main plots were planted approximately on 29 May in Prosper and 4 June in Casselton due to wet soil conditions. Row spacing was 22 inches with a targeted established plant population of 175,000 plants/acre. Additional treatments included with only cover crop interseeded at V6 and soybean removed on July 8. This was done to determine if the presence of the susceptible soybean is what is driving SCN reproduction and to compare SCN populations for differences in population change due to soybean alone or with interseeded cover crop. The treatment with cover crop only (no soybean) was established to determine if SCN initial populations decline if soybean is not present.

<u>Results</u>: Interseeded cover crops did not reduce soybean seed yield in Prosper (Table 7). Mustard interseeded at V6 and without mid-season termination reduced soybean yield by 11 bu/acre in the susceptible soybean and by 7 bu/acre in the resistant soybean variety in Casselton. We expected a reduction

in seed yield due to the competition posed by mustard to soybean, but our objective was to see the effect of mustard terminated vs. not terminated on SCN populations.
Soybean plant height was not different among treatments (Table 7). Cover crop biomass yield across treatments was higher in the resistant variety. Camelina had the lowest biomass yield when soybean was not terminated at both locations. Upon removal of soybean both mustard and camelina increased biomass yield. Camelina is a winter crop, staying as a rosette while mustard bolted and flowered producing much more biomass.

Table 7. Soybean grain yield and plant height and cover crops dry matter biomass yield for the susceptible and resistant varieties and two cover crops (CC) planted interseeded at V6 stage in Prosper, ND.

Cover crop treatment	SCN-susceptible			SCN-resistant		
	Soybean yield	Soybean height	CC biomass yield	Soybean yield	Soybean height	CC biomass yield
	Bu/acre	inches	lbs/acre	Bu/ acre	inches	lbs/acre
Camelina V6	31.2	21.5	1947c	30.7	21.0	2484c
Mustard V6 + T	30.5	21.0	.	34.1	21.8	.
Mustard V6 no T	30.5	20.2	9495b	24.4	19.8	9688b
CamelinaV6 + R	.	.	4916bc	.	.	5433bc
Mustard V6 + R	.	.	19,183a	.	.	23,126a
Check 1-soybean no CC crop	34.3	21.2	.	35.7	21.2	.
Check 2-soybean no CC	32.3	20.8	.	34.6	21.5	.
LSD (0.05)	NS	NS	5268	NS	NS	5268
Mean variety	31.7	21.0a	8886b	31.9	21.0a	10,696a

Different small case letters indicate significant difference ($P \leq 0.05$) between susceptible and resistant variety for the same parameter evaluated.
T= termination of mustard on 9 August; R= Removal of soybean plants on 8 July.

The SCN population increased in the soil in plots with the susceptible variety from spring 2018 to Spring 2019 and decreased in the resistant variety, regardless of cover crop treatment or termination (Table 8). Interseeded cover crops did not reduce SCN on average, but cover crops seemed to contribute to the suppressing ability of the SCN-resistant soybean. In the fall of 2019, SCN samples were taking again and the results were not as expected (data not shown). SCN decreased in all plots whether they had a resistant or susceptible variety or cover crop treatment. The 2019 season was colder and wetter than average, which likely did not allow SCN to reproduce and caused high mortality to the populations present in soil in spring. Only four plots had greater than 10,000 eggs/100 cm^3 of soil and interestingly, all these four plots were in lower areas in the field that waterlogged after heavy rainfall. We speculate that SCN-eggs near the surface might had been carried by rainfall runoff to the lower spots concentrating the SCN population on those spots. One of these areas increased from 180 to 49,960 eggs/100 cm^3.

Fig. 19. Camelina interseeded at V-6 in susceptible soybean in 2019.

Table 8. SCN population change from spring 2018 to spring 2019 in the susceptible and resistant variety for three cover crops interseeded at V6 stage of soybean in Prosper and Casselton.

	SCN-susceptible variety			SCN-resistant variety		
Cover crop	S18	F18	S19	S18	F18	S19
	---------------------------------SCN eggs/100 cm^3 soil------------------------------------					
Winter camelina	6756	4590	8352	2445	1438	1005
Crambe	3678	6350	7410	3975	1660	940
Mustard	4170	7124	5410	1516	765	2590
No cover	1211	5644	8270	7598	1921	765
Mean	4229	6378	7356	4355	1509	1277

The effect of cover crop treatment was not significant.

Experiment 2: Cover crops planted in the fall after wheat and before a soybean crop

Fig. 20. Brown mustard planted after wheat harvest, fall 2018, Crookston, ND.

Soybeans were planted at Prosper, ND on 29 May 2019 and in Minnesota at the Northwest Research & Outreach Center (NWROC) in Crookston on 20 May 2019 following cover crops planted after wheat in the fall 2018 (Fig. 20).
Seed yield was lower in the susceptible variety (35.3 bu/acre) compared with the resistant variety (42.4 bu/acre), averaged across all cover crop treatments in Prosper. In Crookston, the susceptible variety had lower yield (26.6 bu/acre) than the resistant variety (39.9 bu/acre) but the difference was not significant. No differences in seed yield between the no-cover check and soybean following cover crops were observed. Soil nitrate (NO_3-N) was significantly lower after winter camelina compared with the check and brown mustard in Crookston (Table 9). This reiterates that camelina is a suitable cover crop to reduce soil leaching of NO_3-N.
Even with very low levels of SCN (< 50 eggs/100 cm^3), SCN populations can explode up to 140-fold if a SCN-susceptible variety is planted and temperature and rainfall are adequate for SCN reproduction (Table 10). Winter camelina and brown mustard had greater SCN reduction than the control with no cover crop in the resistant variety. SCN populations increased 2-4 fold even in the resistant variety, indicating that using a resistant variety does not stop SCN reproduction completely. Fall-planted cover crops reduced SCN populations in the resistant variety but not in the susceptible variety. Cover crops interseeded or preceding soybean are a potential tool to manage SCN in SCN infested soils. Cover crops interseeded or preceding soybean are a potential tool to manage SCN in infested soils.

Table 9. Soil NO_3-N in spring and fall 2019 averaged across two soybean varieties in Prosper and Crookston

	Prosper		Crookston	
Cover crop	Spring	Fall	Spring	Fall
	Soil NO_3-N (lbs/acre) (0-60-cm depth)			
Winter camelina	17.1	29.8	26.5	37.6
Brown mustard	19.9	32.9	52.4	31.0
Check	20.4	28.2	35.8	26.9
LSD(0.05)	NS	NS	21.0	NS

Table 10. SCN population change from fall 2018 to fall 2019 in Prosper and Crookston.

Cover crop	Fall 2018 S	Fall 2018 R	Spring 2019 S	Spring 2019 R	Fall 2019 S	Fall 2019 R
	--------------------------------SCN eggs/100 cm^3soil--------------------------------					
	Crookston					
Winter camelina	850	1000	850	362	4912b	1587
Brown mustard	1600	325	925	875	8412a	1212
Check	1225	875	1075	550	7387a	2087
LSD(0.05)	NS		NS		2791	
Mean variety	1225	721	950	596	6904a	1629b
	Prosper					
Winter camelina	2887	2612	2675	1800	8762a	212
Brown mustard	2175	2237	3012	2000	3900b	100
Check	3187	3787	1875	2350	4200b	1037
LSD (0.05)	NS		NS		3040	
Mean variety	2750	2879	2520	2050	5621a	450b

S= SCN-susceptible, R= SCN-resistant

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

Camelina, a member of the *Brassicaceae* family, maybe a low-input crop in the northern Great Plains, especially in double-or relay- cropping systems to provide oil for advanced biofuels or human consumption. Although winter annual biotypes of camelina can result in economic and environmental benefits for the northern Great Plains, little is known about their agronomic potential in the region. A preliminary study was established in the summer and fall of 2017, with a follow up study in the summer and fall of 2018 to determine optimum winter camelina sowing dates for achieving the greatest seed yield as well as several ecosystem services. Sowing dates ranged from the end of June to mid-October over the two growing seasons the experiment was conducted. The experimental design was a RCBD with four replicates at each location. Fall stand counts ranged from 17 to 279 plants m^2, which is less than the sowing rate of 700 pure live seeds m^{-2} used in these experiments. As observed by the data presented (Fig. 21), greater stand counts of winter camelina were associated with later fall sowing dates. Fall soil nitrate was also lower in plots with greater stands of camelina (Fig. 22). Spring stand counts ranged from 7 to 84 plants m^{-2}, with greater stand counts associated with sowing dates ranging from early- to mid-September (Fig. 23). Spring soil nitrate was lower in plots with seeding dates occurring from mid-August to mid-September (Fig. 24). Across sowing dates that survived the winter, seed yield ranged from 99 to 1317 kg ha^{-1} (Fig. 25). Results from these three environments indicate that when sown in September, and even into October, plants can successfully survive the winter and produce a harvestable crop in the northern Great Plains.

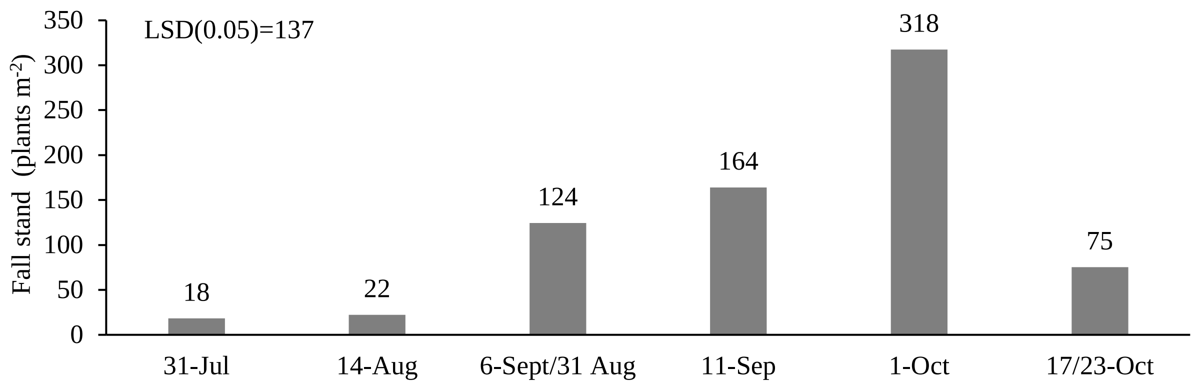
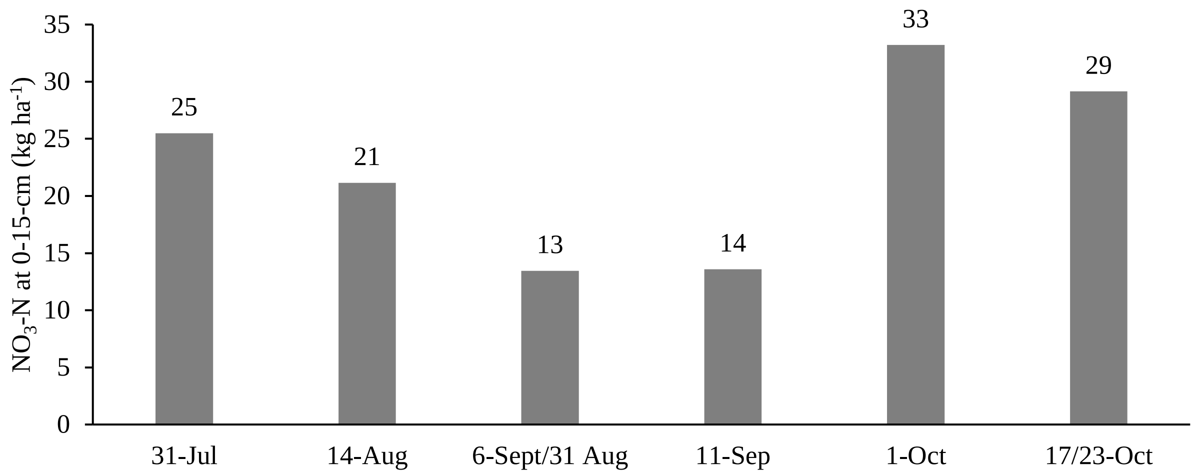


Fig. 21. Mean fall stand of winter camelina averaged across three environments, Fargo 2017 and Fargo and Prosper in 2018.



F**ig. 22. Mean fall soil nitrate at 0-15 cm for different seeding dates of winter camelina averaged across two environments, Fargo and Prosper in 2018.**

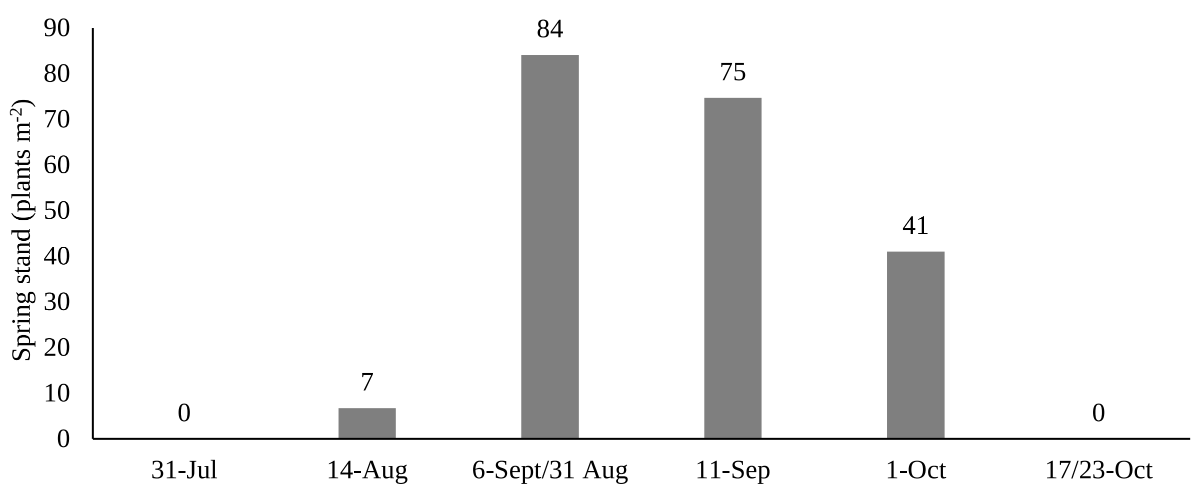


Fig. 23. Winter camelina spring stand from different fall seeding dates averaged across two environments, Fargo and Prosper in 2019.

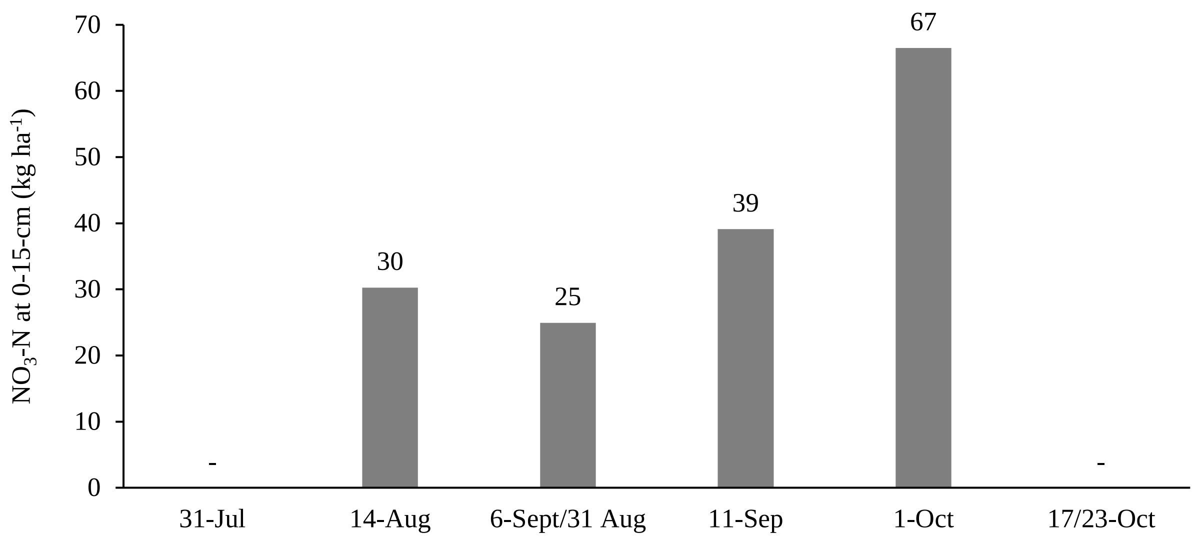


Fig. 24. Mean spring soil nitrate at 0-15 cm depth averaged across two environments, Fargo and Prosper, in 2019.

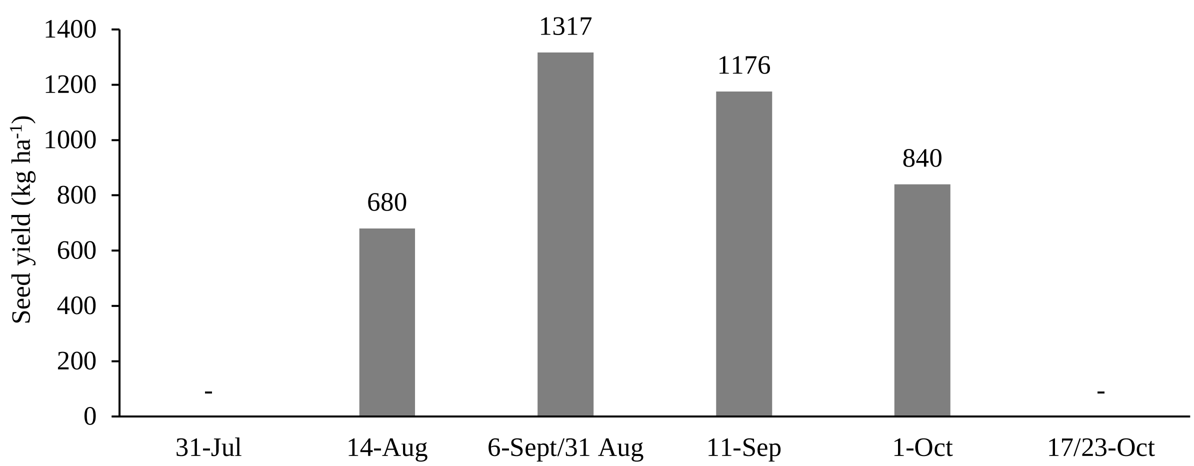


Fig. 25. Winter camelina seed yield from different fall seeding dates averaged across three environments Fargo, 2018 and Fargo and Prosper 2019.

10. ND Gardner winter rye a new release and rye variety trial for forage- (*Steve Zwinger, Carrington REC)*

Cover crop use is increasing rapidly not only in North Dakota their use is expanding across the country. Winter rye is one of the main species being used as a cover crop across the nation including ND. For northern climates with shorter growing seasons an early maturing rye variety is very important for cover cropping. This is especially true for use as a cover crop for soybean and dry bean production where rye is currently used as a cover crop to sow these cash crops into. The benefits of rye for weed and erosion control is greater when more biomass can be produced before the rye is terminated to sow these crops into. An early variety is also very important for the roller crimper system that relies on early anthesis for termination. This system is being used by farmers across the Midwest and beyond. Winter rye is also being used a forage crop in ND along with double cropping it with other forage or grain crops. An early maturing rye variety will have many advantages for uses described.

The importance of plant breeding is to develop new lines with improved traits that are desirable for the intended end use. Very little effort has gone in to improving varieties with desirable traits for cover crop use as compared to what has occurred with breeding improvements in cash crops. Releasing a variety with traits desirable for cover crop applications will insure that farmers use good quality seed of known origin to obtain the desired benefits of the cover crop.

Fig. 26. ND Gardner winter rye starting to flower

Fig.27. ND Gardner (left) alongside ND Dylan illustrating maturity differences between varieties.

The CREC agronomy program coordinates the NDSU state winter rye variety testing program along with a diverse research program using rye as a grain, forage and cover crop. The CREC has also been working on variety development focusing on winter hardiness, early season vigor, and biomass production, and early maturity. Results of this work has led to a newly released variety. ND Gardner winter rye was developed and increased at the CREC and released by the North Dakota Agricultural Experiment Station with foundation seed distributed by the ND Crop Improvement and Seed Association for the 2019 fall planting.

Fig. 28. ND Gardner foundation seed field on June 12, 2019.

ND Gardner is intended to be used mainly for the cover crop/forage market. It is intended to replace Aroostook a variety developed by USDA in 1981. Aroostook is used extensively for cover crop applications. ND Gardner is also a candidate for forage use and could be a replacement for Wheeler rye a variety released from the Michigan State University in 1971 for forage and green manure use. ND Gardner is a very early, tall variety with very good winter hardiness and good early season vigor. These attributes make it a good candidate for the rapidly growing cover crop market.

ND Gardner is named to honor the memory and contributions of Dr. John Gardner, former director at the NDSU Carrington Research Extension Center. John was a visionary leader in many aspects of agriculture including cover crop research.

Table. 11. Annual rye variety trial for forage at Carrington, ND.

Variety	Harvest date	Spring stand	Vigor	Jday of heading	Plant height	Harvest moisture	Forage DM yield
		%	1-10		inch	%	ton/ac
Rymin	17-Jun	93.3	6.5	162.8	45.3	74.5	2.18
ND Dylan	17-Jun	95.5	8.5	162.8	44.0	74.7	2.32
Dacold	20-Jun	90.0	6.5	165.5	44.2	73.8	2.16
Aroostok	10-Jun	93.0	8.5	157.5	40.7	72.8	1.91
Wheeler	20-Jun	87.5	4.0	166.8	47.9	74.8	2.00
Progas	17-Jun	93.3	7.5	163.3	38.3	73.0	2.27
ND Gardner	10-Jun	95.8	9.0	156.0	42.7	72.9	2.02
	Mean	92.6	7.2	162.1	43.3	73.8	2.12
	C.V.%	2.1	16.6	0.4	7.6	1.4	5.9
	LSD.10	2.3	1.5	0.8	4.1	1.3	0.15
	LSD.05	2.8	1.8	1.0	4.9	1.6	0.19

Trial planted, September 18

Trial harvested, June 10-20

Previous crop, wheat

11. Forage pea yield and quality. Steve Zwinger, Carrington REC

Table 12. Forage pea variety trial, Carrington, ND in 2019.

Variety	Days to bloom	Vine length	Plant canopy ht	Plant lodge	harvest moisture	Forage DM yield
		inch	inch	0-9	%	ton/ac
Flex	57.8	51.8	26.8	6.8	88.9	1.55
Max	57.5	52.6	31.2	5.8	89.1	1.61
Keystone	55.5	40.5	28.9	5.0	88.7	1.61
Fergie	53.3	51.7	31.0	5.3	88.2	1.56
PUSA FP 1701	53.5	50.9	32.5	4.8	86.6	2.08
PUSA FP 1901	57.3	57.8	29.7	7.3	87.8	1.93
Mean	55.8	50.9	30.0	5.8	88.2	1.72
C.V.%	1.2	8.5	17.4	25.3	1.6	12.5
LSD.10	0.9	5.4	NS	1.8	1.8	0.27
LSD.05	1.0	6.5	NS	2.2	2.2	0.32

Trial planted, May 10

Trial harvested, July 11

Previous crop, barley forage

Table. 13. Forage nutritive value of forage pea varieties in Carrington, ND in 2019

Variety	CP	ADF	NDF	TDN	Ash	Ca	P	Mg	K	S	RFV	RFQ
	%	%	%	%	%	%	%	%	%	%		
Flex	18.8	37.7	47.2	61.6	10.0	1.18	0.37	0.28	3.61	0.25	119	141
Max	16.9	39.1	51.7	57.5	8.9	1.01	0.32	0.26	3.01	0.23	105	121
Keystone	20.6	37.5	45.4	63.1	10.8	1.27	0.38	0.33	3.39	0.24	123	146
Fergie	17.0	39.0	48.5	58.2	8.8	1.11	0.32	0.29	2.81	0.22	112	124
PUSA FP 1701	15.8	41.7	51.5	57.4	9.1	1.20	0.32	0.30	3.04	0.23	102	113
PUSA FP 1901	17.5	38.2	51.1	59.4	9.4	1.00	0.32	0.26	2.94	0.23	108	133
Mean	17.8	38.8	49.2	59.5	9.5	1.13	0.34	0.29	3.10	0.23	112	130
C.V.%	13.0	8.2	7.9	4.4	9.5	14.4	11.1	7.3	9.7	11.5	12.2	14.6
LSD.10	3.4	NS	5.7	3.9	1.3	0.24	0.06	0.03	0.45	NS	20	28
LSD.05	4.2	NS	NS	4.8	1.6	NS	NS	0.04	0.55	NS	NS	NS

12. Cover crop research and education (March 1, 2019 - Feb 1, 2020) – *Greg Endres, Mike Ostlie*
Reports available at www.ag.ndsu.edu/CarringtonREC

a. Soybean response following winter rye cover crop, Wishek, 2019*.* (*Greg Endres, Tim Indergaard, Mike Ostlie, Sheldon Gerhardt, Crystal Schaunaman and Emily Trzpuc)*

The trial was conducted in 2019 at the NDSU Carrington Research Extension Center off-station crop research site near Wishek, with support from the ND Soybean Council, to examine the performance of soybean with winter rye grown as a preplant (PP) cover crop. Experimental design was a randomized complete block with four replications. The dryland trial was established on a reduced-till loam soil with spring soil test indicating 28 ppm P (Olsen), 208 ppm K, 4.3% organic matter, 6.7 pH (0-6" depth), and 0.19 mmho/cm soluble salts (0-6" depth). 'ND Dylan' rye was direct seeded into wheat stubble in 7-inch rows at 1.2 million PLS/A on October 26, 2018.
'PFS19B04' seed inoculated with *Rhizobium* bacteria was planted in 14-inch rows on June 3. NDAWN monthly rain (inches): May = 3.8; June = 2.8; July = 5.7; August = 3.0; September = 5.4; and October = 2.9; for a season total of 23.6 inches. Soybean seed was harvested with a plot combine on November 6.

Treatments for rye termination methods including herbicides:

1. Conventional check (no rye). PP Roundup PowerMax (32 fl oz/A) plus NIS+AMS (2.5% v/v) and Zidua Pro (4.5 fl oz/A) on June 5 (2 days after planting) to jointing ($\leq$ 12-inch tall) rye.
2. PP Roundup PowerMax plus NIS+AMS on May 10 (25 days before planting) to 1- to 1.5-leaf rye.
3. PP Roundup PowerMax plus NIS+AMS on June 5.

POST Roundup PowerMax plus NIS+AMS was applied on July 2 across all plots for general weed control with soybean at V2 growth stage. Herbicide were applied with a hand-boom sprayer delivering 14 gpa at 35-40 psi with TJ FF80015 or Turbo nozzles.

Soybean response with rye as a cover crop was similar with plant stand, late-season canopy cover, seed yield and seed quality compared to the conventional-production check (Table 14). Soil moisture also was similar among treatments. Seed yield and quality were similar among treatments.

Table 14. Soybean response, soil moisture, and weed control with rye cover crop, Wishek, 2019.											
	Plant stand	Plant canopy					Foxtail	Seed			
	(2-Jul; V2	Canopeo	Visual				control[b]		Test		
Trt no.	stage)	(5-Jun)	(25-Jul)	Soil moisture (%)[a]			(2-Jul)	Yield	weight	Oil	Protein
	plt/A			3-Jun	2-Jul	25-Jul	%	bu/A	lb/bu	%	
1	180,200	2	81	18.4	14.8	15.4	94	60.2	56.7	16.9	38.2
2	166,100	3	86	18.0	14.6	14.0	66	64.4	56.3	17.0	37.9
3	182,300	14	79	15.4	16.5	16.2	71	51.3	56.8	16.7	38.3
Mean	176,200	7	82	17.2	15.3	15.2	77	59.3	56.6	16.9	38.1
CV (%)	12.5	46.9	12.1	12.3	16.2	12.0	3.6	24.5	0.6	0.9	0.8
LSD (0.10)	NS	4	NS	NS			4	NS			

[a]Extech digital soil moisture meter (model MO750) at 4-inch soil depth.

[b]Green and yellow.

Foxtail control was greater with the check, likely due to use of the soil-applied herbicide, compared to treatments with rye. After trial maintenance application of glyphosate on July 2, weed control was adequate among treatments.

b. Winter rye cover crop seeding date and rate impact on soil, weeds and soybean, Carrington, 2019. The field study is being conducted at the NDSU Carrington Research Extension Center with support from ND Soybean Council to examine impact on soil, weeds, and soybean with winter rye seeded at two fall dates and three rates grown as a preplant cover crop. Study objective is to identify the best combination of rye seeding dates and rates for reaching goals with the cover crop including soil management and weed control while maintaining high potential for soybean seed yield. Experimental design was a randomized complete block (split-plot arrangement for rye: main plot=seeding date; subplot=seeding rate) and four replications. The dryland trial was established with corn as the previous crop on a Heimdal-Emrick loam soil with 3.9% organic matter, 7.2 pH, 22 lb N/A, 8 ppm P, 211 ppm K, and 0.16 mmho/cm soluble salts. 'ND Dylan' rye was direct seeded in 7-inch rows on October 2 and 31, 2018 at seeding rates of 25, 50, and 75 lb/A. Early seeded rye reached about 1.5 leaf stage while late-seeded rye did not emerge at close of growing season. Soil moisture was measured using an Extech digital soil moisture meter (model MO750) at 4-inch soil depth. Tillering rye at 3- to 6-inch height was terminated May 23, 2019 with an application of glyphosate (Roundup PowerMax at 32 fl oz/A) plus NIS+AMS (Class Act NG at 2.5% v/v). PFS19B04' soybean was planted into rye residue in 21-inch rows on May 30. Glyphosate plus NIS+AMS was applied on June 26 across the trial for general weed control in soybean (V1 growth stage). NDAWN monthly rain (inches): May=1.46; June=3.00; July=3.64; August=3.08; September=8.26; and October=1.85; 6-month total=21.29. Seed was harvested with a plot combine on November 5.

Averaged across seeding rates, rye ground cover was 18% with early fall seeding compared to 7% with late seeding, when visually evaluated on May 21. Averaged across fall seeding dates, rye ground cover increased from 9% at 25 lb/A seeding rate to 13% at 50 lb/A and 16% at 75 lb/A. Soybean yield with rye seeding rates averaged across dates: 25 lb/A=48.4 bu/A; 50 lb=45.4 bu/A; and 75 lb/A=44.3 bu/A (LSD 0.10=3.1 bu/A).

Table 15 indicates rye ground cover and plant density, and soil moisture with the interaction of rye fall seeding dates and rates. Plant stand ranged from 39,800 plants/A (1 plant/ft^2) to 614,700 plants/A (14 plants/ft^2) with highest density obtained with early seeding at the high rate. Stand generally was reduced with late seeding date when comparing each seeding rate. Ground cover was similar among treatments either visually estimated or measured using the Canopeo app. Soil moisture generally was similar among treatments.

Table 15. Rye ground cover and plant density, and soil moisture with winter rye cover crop fall seeding dates and rates, Carrington, 2019.

Rye seeding treatment		Rye			Soil moisture			
			Ground cover					
Date	Rate	Plant density (21-May)	Visual (21-May)	Canopeo (20-May)	20-May	31-May	10-Jun	8-Jul
	lb/A	plt/A	%		%			
	25	133,800	14	4	16.5	16.7	18.6	18.8
	50	352,900	18	7	17.2	17.1	18.9	20.7
2-Oct	75	614,700	23	7	15.8	17.3	17.7	19.3
	25	39,800	5	2	16.1	18.5	18.8	18.3
	50	167,900	8	2	17.1	17.9	18.5	19.1
31-Oct	75	233,400	10	3	17.7	17.8	20.5	21.4
CV (%)		37.0	17.6	57.0	7.8	7.2	6.1	11.2
LSD (0.10)		120,200	NS	NS	NS	NS	1.4	NS

Primary weeds in the trial were grasses: yellow and green foxtail, volunteer rye and barnyardgrass. The grass weeds were visually evaluated on June 21, with control ranging 65-74%. There was not a significant statistical difference on weed control with the interaction of rye fall seeding dates and rates.

Table 16 indicates soybean performance with the interaction of rye fall seeding dates and rates. Soybean plant stand and development generally was similar among rye treatments. Soybean seed yield under this production system ranged from 43.3 to 49.6 bu/A. Soybean yield and test weight were similar among treatments, though there was a trend of yield reduction with increasing rye seeding rates.

Table 16. Soybean response with winter rye cover crop fall seeding dates and rates, Carrington, 2019.

Rye seeding treatment		Plant						Seed	
			Emergence	Flower	Canopy closure		Physiological maturity		
Date	Rate	Stand			Visual (Jul-26)	Canopeo (Jul-29)		yield	TW
	lb/A	plt/A	Day of year		%		Day of year	bu/A	lb/bu
	25	146,600	157	199	86	93	269	47.1	60.9
	50	139,900	157	200	86	92	269	47.3	60.9
2-Oct	75	125,200	158	199	87	90	269	45.3	61.0
	25	165,500	158	199	87	91	268	49.6	61.1
	50	144,200	158	199	87	90	268	43.5	61.0
31-Oct	75	164,100	157	199	87	89	268	43.3	61.1
CV (%)		13.3	0.3	0.3	2.8	33.5	0.1	7.6	0.3
LSD (0.10)		NS	NS	1	NS	NS	NS	NS	NS

In summary, the first year of research in this multi-year study indicates minimal influence among rye fall seeding dates and rates on soil cover and moisture, and control of grass weeds. Also, performance of soybean generally was not affected by rye seeding date or rate. This likely was due to adequate soil moisture present throughout the soybean production period.

c. Pinto bean response following winter rye cover crop, Carrington, 2019.

The study is being conducted at the NDSU Carrington Research Extension Center with support from Northarvest Dry Bean Growers Association to examine soil cover and moisture, weed management, and pinto bean performance with winter rye grown as a prior cover crop. Experimental design was a randomized complete block with four replications. The dryland trial was established on a conventionally tilled Heimdal-Emrick loam soil with 4.0% organic matter, 6.5 pH, 0.41 mmho/cm salt, 70 lb/A N, 16 ppm P, 319 ppm K, and 1.5 ppm Zn. 'ND Dylan' rye was direct seeded into barley stubble in 7-inch rows at 60 lb/A on September 18, 2018. Rye plants emerged October 1 and reached the 2-leaf stage on November 15. 'ND Palomino' pinto bean was planted into tilled soil or rye residue in 21-inch rows on June 3, 2019. NDAWN monthly rain (inches): May=1.46; June=3.00; July=3.64; August=3.08; September=8.26; and 5-month total=19.4.

Rye treatments were designated by termination method and timing:

1. Conventional production check: Tillage (2x roto-till) on October 1 (13 days after seeding rye); followed by preplant (PP) Roundup PowerMax (glyphosate; 28.4 fl oz/A) plus NIS+AMS (Class Act NG; 2.5% v/v) on May 2 [31 days before bean planting (DBP)] and preemergence (PRE) Roundup PowerMax plus NIS+AMS and Spartan Elite (sulfentrazone+S-metolachlor; 20 fl oz/A) on June 5 [3 days after bean planting (DAP); 0.64 inches of rain was received during June 5-16].
2. PP Roundup PowerMax plus NIS+AMS on May 2 (tillering rye at 2- to 3-inch height).
3. PP Roundup PowerMax plus NIS+AMS on May 2 followed by PRE Roundup PowerMax plus NIS+AMS and Spartan Elite on June 5 (boot-stage rye).
4. PP Roundup PowerMax plus NIS+AMS on May 14 (20 DBP; tillering rye at 4- to 5-inch height).
5. PP Roundup PowerMax plus NIS+AMS on May 29 (5 DBP; 2-joint rye at 12-inch height).
6. PRE Roundup PowerMax plus NIS+AMS on June 10 (7 DAP; boot-stage to headed rye).

Herbicide treatments were applied with a hand-boom sprayer delivering 10 gpa through TJ 80015 flat-fan nozzles at 35 psi. Raptor (3 fl oz/A) plus SelectMax (16 fl oz/A) and Destiny HC (20 fl oz/A) were post-emergence applied at 14 gpa through TJ AIXR 110015 nozzles at 40 psi to all trial plots for general weed control on July 5.

Bean plants were hand-pulled for field drying on September 25. Seed harvested with a plot combine: treatments 1-4=September 27; treatments 5-6=October 7.

Delaying rye termination until near or after pinto bean planting extended bean plant development (emergence, flowering, and maturity) 8-14 days compared with the conventional production check and earlier rye termination treatments (Table 17). Plant stand was similar among treatments though there was a trend for the check having the highest plant density. Plant stand across treatments averaged 62,300 plants/acre, which was 67% of the 93,300 pure live seeds/A planting rate. Bean canopy closure also was reduced with the delay in rye termination (trts 5 and 6). Bean yield was similar among treatments, though there was a trend for higher yield with trts 1-4. Test weight was highest with trts 5 and 6.

Table 17. Pinto bean response to rye cover crop, Carrington 2019

Trt no.	Plant[a]						Seed	
	Emergence	Stand (3-Jul)	Flower (R1)	Canopy closure (%) 29-Jul		Maturity	Yield	Test weight
	DOY	plt/A	DOY	visual	canopeo	DOY	lb/A	lb/bu
1	163	72,100	196	89	90	256	2981	59.8
2	162	59,300	196	83	82	257	3387	60.6
3	162	63,900	196	87	87	256	3078	59.7
4	163	58,800	196	82	82	257	3204	60.1
5	174	59,300	206	66	61	264	2805	61.5
6	176	65,000	208	71	64	266	2885	61.3
Mean	167	62,300	200	80	78	259	3057	60.5
CV (%)	1.1	16.6	0.6	5.7	6.3	0.5	10.2	0.8
LSD (0.10)	2	NS	2	6	6	2	NS	0.6

[a]DOY (day of year): 167=June 16; 200=July 19; 236=Sept 17. Plant stage at stand count = V3.

Rye ground cover when measured after bean planting generally was greatest with delay of rye termination (trts 5 and 6) (Table 18). However, early season soil moisture (May 29 and June 10 measurements) was slightly higher with trts 1-4 compared to the late rye termination trts.

Table 18. Pinto bean response to rye cover crop for ground cover, soil moisture and weed control in Carrington , 2019

Trt no.	Ground cover (%)		Soil moisture[a]				Weed control[b]	
	5-Jun	6-Jun	29-May	10-Jun	8-Jul	9-Aug	3-Jul	9-Aug
	Canopeo	Line transect	%				%	
1	12	1	18.9	17.8	20.8	12.0	68	91
2	40	1	18.0	17.5	20.9	13.9	61	74
3	34	1	18.5	18.2	21.5	14.0	64	85
4	42	2	17.8	17.9	21.4	15.3	65	84
5	86	4	15.8	15.4	18.9	17.2	86	83
6	78	49	16.1	10.3	19.9	14.6	96	96
Mean	49	10	17.5	16.2	20.6	14.5	73	85
CV (%)	23.2	75.3	7.6	9	9.5	14.7	17.7	8.1
LSD (0.10)	14	9	1.6	1.8	NS	2.6	16	9

[a]Measured with Extech Instruments MO750 soil moisture meter at 4-inch soil depth.

[b]Visual evaluation of grass weeds including green and yellow foxtail, volunteer rye, and stinkgrass.

The trial contained a low density grassy weeds: green and yellow foxtail, rye (escapes), and stinkgrass. Grass control visually evaluated on July 3 (before Raptor plus SelectMax application across the trial) was good to excellent (86-96%) with the delay in rye termination until near or after bean planting (trts 5 and 6) compared to control with other treatments (61-68%). Grass control generally was good to excellent (83-91%) with all treatments on August 9 except with trt 2 (early glyphosate application without PRE herbicide). In summary, the delay in termination of rye with trts 5 and 6 provided greater (July 3 evaluation) or similar (August 9 evaluation) grass weed control compared to the check. Trial data indicates rye can be a substitute for a PRE herbicide.

In summary, lack of adequate spring rainfall and stored soil moisture during pinto bean plant establishment and delay in rye termination until near or after bean planting negatively impacted bean plant development and canopy closure but not seed yield. The delay in rye termination provided the benefits of additional ground cover and a substitute for PRE herbicide for weed control.

d. Fall-planted cover crop tolerance to soybean herbicides, Carrington, 2019.

The trial was conducted at the NDSU Carrington Research Extension Center with support from the North Dakota Soybean Council to evaluate the tolerance of six fall-planted, cool-season cover crops on ground previously treated with seven soybean herbicides that have soil residual. Experimental design was a randomized complete block with split-plot arrangement (whole plot = cover crop and subplot = herbicide) and three replicates. The field trial was established on an irrigated, conventionally-tilled, Heimdal-Emrick loam soil with 2.9% organic matter and 7.9 pH (0- to 6-inch depth). 'AG03X7' dicamba-tolerant soybean was planted at 165,000 seeds/A on May 20 in 22-inch rows. A hand-held boom sprayer was used delivering 17 gpa at 35 psi through TeeJet XR FF80015 nozzles to the center 6.7 ft of 10- by 30-ft strips. PRE herbicides [metribuzin (Sencor), sulfentrazone (Spartan), flumioxazin (Valor), pyroxasulfone (Zidua), and imazethapyr (Pursuit)] were applied at standard rates on May 21 with 59 F, 92% RH, and 5 MPH wind on dry soil; a total of 1.0 inch of rain followed during May 22-24. POST herbicides [dicamba (Engenia) and fomesafen (Flexstar)] were applied on June 18 with 53 F, 93% RH, and 5 mph wind to first- to second trifoliate (V1-2) stage soybean; a total of 0.9 inch of rain followed during June 20-21. Rainfall totaled 19.9 inches during May 21 to October 9, and supplemented with a total of 3 inches of irrigation water (overhead pivot) during June 8 to July 10. Soybean at the seed formation (R5-6) stages were terminated by mowing on August 20. Cover crops were planted August 30 into the soybean stubble with a no-till drill in 7.5-inch rows: 'Explorer' barley, 'ND Dylan' winter rye, 'Flex' field pea, 'ND Gold' flax, 'Jackhammer' radish, and 'Purple Top' turnip. Barley, rye, radish and turnip at 2- to 4-leaf stages; field pea at 5- to 6-node stages; and 1- to 3-inch tall flax were visually evaluated on September 20 [21 days after planting (DAP)] for biomass and stand reduction. A second evaluation occurred on October 9 (40 DAP) of barley at 4- to 6-inch height; rye, flax, radish and turnip at 2- to 4-inch height; and field pea at 2- to 8-inch height.

Field pea was tolerant of all herbicides. All herbicides caused injury to select cover crops. Plant injury exceeding 10%: barley = Valor; rye = Zidua; flax = Sencor; radish = Sencor, Spartan, Zidua and Flexstar; and turnip = Sencor and Zidua. (Table 19).

Table 19. Fall-planted cover crop tolerance to soybean herbicides in Carrington in 2019

Herbicide			Cover crop injury[1]											
			20-Sep						9-Oct					
Treatment	Rate	Application timing[2]	Barley	Winter rye	Field pea	Flax	Radish	Turnip	Barley	Winter rye	Field pea	Flax	Radish	Turnip
	fl oz product/A		%											
Sencor 75 DF	0.33 lb		0	0	0	0	13	20	0	0	0	15	25	22
Spartan 4F	10		0	0	0	0	22	0	0	0	0	0	22	0
Valor SX	3 oz		10	0	0	0	0	0	20	0	0	0	0	0
Zidua SC	4		0	12	0	0	20	0	0	0	0	3	22	12
Pursuit	3	PRE	0	0	0	0	0	0	0	0	0	8	0	0
Engenia + CA Ridion	12.8 + 2% v/v		0	0	0	0	0	0	0	0	0	10	0	0
Flexstar + MSO	12 + 24	POST	3	7	0	0	0	7	0	0	0	0	12	8
C.V. (%)			412						274					
LSD (0.10)			NS						NS					

[1]Biomass and/or stand reduction.

[2]PRE=May 21; POST=June 18.

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

Greta Gramig and MS student Jesse Puka-Beals, North Dakota State University

Direct seeding into strip tilled zones (STZ) of living mulches may require weed suppression tactics for soil within the STZ. Surface mulches applied in the STZ could suppress weeds and improve crop performance. We evaluated three surface mulch treatments (hydromulch, compost blanket, no mulch control) applied on STZs seeded to carrot (Daucus carota L.) within five living mulches (red clover, white clover, perennial ryegrass, weed-free control and a weedy control). Over both years and both locations, weed biomass was significantly lower in STZs where hydromulch and compost blankets were applied compared to the no mulch control (35, 48 and 155 plants m-2 respectively). No significant differences in weed response were observed between hydromulch and compost blanket. Differences in carrot emergence were location specific, with reduced carrot emergence in compost blanket treatments compared to no mulch controls (24 and 38 plants m-1 respectively) in Absaraka ND, but no differences in carrot emergence at Fargo ND. Surface mulches did not appear to alter carrot biomass, but the presence of a living mulch adjacent to the STZ significantly reduced carrot biomass by 63-79% compared to the weed free control. Carrot biomass reduction was significantly lower in the red clover and white clover treatments (65% and 63% respectively) than the weedy control (90%). Results suggest that hydromulch and compost blanket are effective at reducing weed biomass in STZs and that living mulches are effective at weed suppression in areas adjacent to the STZ. However, the presence of living mulches can significantly reduce crop yield. Competition between the living mulch and the crop may be reduced by widening the STZ. Further development of biodegradable mulches in STZs may improve crop performance and provide biodegradable alternatives to plastic mulches.


Fig. 29. Cover crops to suppress weeds in carrots, Absaraka, ND

15. Hybrid rye variety trial *Marisol Berti, Alex Wittenberg, and Alan Peterson, North Dakota State University*

Hybrid rye has gotten the attention of growers in the northern Great Plains as a potential high quality forage for silage or haylage. Cereal rye acreage, as a cover crop, has increased in North Dakota, since it fits well in the rotation before soybean, but can also be used as a forage resource in the spring. The objective of this study was to evaluate the potential forage yield of hybrid rye varieties in the Red River Valley.

The variety trials were conducted over two seasons in Fargo in 2017-2018 and 2018-2019. The experiment was a RCBD with four replicates. Seeding rate was calculated to have 800,000 live seeds/acre. The experiments were fertilized in the spring with 80 lbs/acre of nitrogen. Forage was harvested at soft dough in 2018 and milk stage in 2019.

The variety trials were conducted in heavy clay soils that waterlogged in the spring forming ice sheets reducing stands. Results indicated that although hybrid rye has a great potential in many areas, in the Red River Valley hybrid rye forage yield was similar to that of cereal rye varieties. We did not test winter triticale or winter wheat because they do not survive in the Fargo area.

Forage yield ranged between 3.04 and 3.95 tons/acre in 2018 and 3.02 to 4.73 tons/acre in 2019 and crude protein between 8 and 10% (Table 14). Reports in Wisconsin show that the yield potential for hybrid rye harvested at soft dough stage is between 5.0-6.0 tons/acre. Although the forage yields in this study were lower than what has been reported in other locations, rye is the only fall planted annual forage crop that survives the winter in Fargo environment, so getting 3.5-4.5 tons/acre of high quality forage is still a promising result for those who might need a high quality forage resource in the spring.

It is important for growers to know that location matters and hybrid rye does not perform the same in every environment. Always check on variety trials near your location and average at least three years of forage yield results to estimate the forage yield potential in your farm, since forage yield greatly varies year to year.

Table 20. Forage yield of hybrid rye and cereal rye varieties in Fargo, ND.

Variety	2018	2019
	--------------------tons/acre--------------------------	
KWS Progas	3.15	3.26
KWS Propower	3.29	3.51
KWS Bono	3.12	3.34
KWS Dolaro	3.41	3.06
Brasseto	3.95	3.02
ND Dylan	3.61	3.92
KWS Serafino	-	3.74
KWS Trebiano	-	4.73
LSD (0.05)	NS	NS

14. *Forage wheat variety trial 2019.* *Marisol Berti and Alan Peterson*

The forage wheat trial was planted on 10 May 2019 in Fargo and harvested on 24 July in Fargo, ND. The experiment was a randomized complete block design with four replicates. Evaluations included dry matter forage yield, plant height at harvest, and forage quality including (crude protein, and nitrogen content) measured with the NIR XDS analyzer. Samples were sent to the Animal Science lab for wet chemistry analysis of remaining forage quality components.

The trial had a strong incidence of bacterial leaf blight (*Pseudomonas psyringae pv. psyringae*) as shown in the figure below (Table 21, Fig. 30). Dr. Andrew Friskop, NDSU Plant Pathology, identified the disease. Disease incidence was scored from 1-5, with 5 being the highest incidence. The defoliation to plants was serious, clearly reducing potential forage yield.

Forage yield was not significantly different among varieties fluctuating between 2.95 and 3.50 tons/acre (Table 22). Although forage yield was not significant among varieties, there was a clear linear negative relationship between forage yield and disease rating (Fig. 31), with the lowest yield observed for WB-Patron and WB-9990 both with 5.0 and with 4.8 disease rating, respectively. There was also bird damage particularly severe in WB-Patron. The forage yield observed in this trial is higher of what is typically reported for annual cereal forages harvested at soft dough stage in this area (2.2-2.8 tons/acre) despite of the severe disease incidence. This indicate forage wheat has a very good forage yield potential.

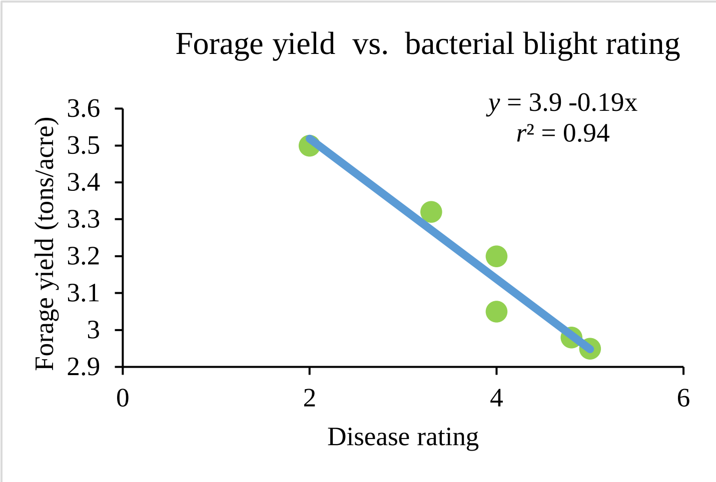


Fig. 31. Forage yield and disease incidence in forage wheat varieties, in Fargo ND 2019.

Fig. 30. Bacterial leaf blight in WB-Patron. Picture 23 July 2019.

Table 21. Disease severity (bacterial leaf blight) of five forage-wheat varieties and forage-wheat and -pea mix at Fargo, ND seeded in 2019.

Entry	Disease Rating†
WB-Patron	5.0
WB9490	4.0
WB9699	2.0
WB9590	3.3
WB9990	4.8
WB9590 + Forage pea	4.0
LSD (0.05)	0.7
CV, %	12.6

† Rating on a scale 1-5 where 5 is highest presence of disease.

Plant height was not significantly different among varieties fluctuating between 26.0 and 27.8 inches. Crude protein and nitrogen content were significantly higher for the forage wheat-pea mix as expected, although not significantly different from WB9490 and WB9699. Protein content for all varieties is above the requirement for a 1200 lbs beef cow with a calf (about 9% CP) and within the range of crude protein for an annual cereal forage harvested at soft dough stage.

Table 22. Forage yield and harvest height of five forage-wheat varieties and forage wheat-pea mix at Fargo, ND seeded in 2019.

Entry	Forage yield	Plant height
	-----tons/acre-----	-----in-----
WB-Patron	2.95	26.0
WB9490	3.05	27.5
WB9699	3.50	26.8
WB9590	3.32	27.3
WB9990	2.98	27.0
WB9590 + Forage pea	3.20	27.8
LSD (0.05)	NS	NS
CV, %	3.37	3.4

RESEARCH IN PROGRESS

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

This project was initiated in 2017 across fourcooperating farms in eastern ND that host saline soils, which interfere with crop productivity. Our goal was to assess if interseeding cereal rye into both phases of the corn-soybean rotation could improve soil health and water management and alleviate salinity-related crop stress. Each year, we monitor the sites for a suite of soil physical, chemical, and biological properties, yield and cover crop performance.

Main findings (since 2017):
In 2017 and 2018, the cereal rye broadcast at 40 lb/ac established in patchy, sparse stands. In 2019, we increased the rate to 80 lb/ac and establishment and biomass production when interseeded into corn was very good. Rye establishment in soybean was poor. We will repeat the 80 lb/ac rates in 2020.
We have not observed effects of the rye on soil properties or on the crop. For example, the soil water content has not been different for any site, for any time of year between cereal rye and no-cover plots. We have not observed a yield reduction in cereal rye strips, compared with no-cover plots. We also have not observed any differences in annual soil fertility or salt level in cereal rye strips. We will repeat intensive soil sampling to 4 ft depth in the final year of the project (2020) to assess other potential soil changes.
One objective of the project was to conduct insect surveys to identify potential pest risks associated with the cereal rye. In two years of field pit-fall trap surveys, we did not observe differences in the insect communities between cereal rye and no-cover plots. Cutworm surveys conducted in 2018 indicated that cutworm occurrence and risk was not elevated in cereal rye strips.
We have observed that the cereal rye, especially in the corn sites in 2019, produces sufficient protective cover for soil stabilization entering the winter. This is a strong benefit.

2. ***Biomass Yield And Botanical Composition Of Annual Forage Mixtures For Grazing*** *(Marisol Berti, Kenneth Mozea, and Kevin Sedivec)*

Growing annual forage mixture is a crop production technique that can be used to extend the period of grazing by ruminants, especially in the Upper Midwest region where the duration for extensive grazing is brief. Forage mixtures are sources of feed with high nutritional value for ruminant consumption. Having a mix of crops with different functionality and properties aids the ecosystem as biodiversity is improved. Forage biomass yield estimation is useful in making farm decisions regarding seeding rates, and planting

dates. The objectives of this study was to determine the biomass yield and nutritive value of annual forage mixture and to determine the botanical composition within the forage mixtures
The experiment was conducted at the North Dakota State University, Fargo research site in 2019. The experiment was a RCBD with four replicates. Treatments comprised of different forage mixtures: warm-season/cool-season, forage sorghum/brassicas mix, cool-season/forbs mix, sole sown forage pearl millet, sorghum x sudangrass and forage sorghum blends (brown mid-rib and non-brown mid-rib mix). Statistical analysis was done using standard procedures for RCBD. LSD treatment mean comparison were *F*-protected at 0.05 significance
All mixtures were planted on 3 June 2019 except for Mixture 2, which was planted on 2 July. First harvest was conducted on 1 August, 2019 and second harvest was 25 September 2019. Mixture 1 was harvested 9 October 2019. Mixture 2 was harvested only once on 25 September.

Annual ryegrass dominated Mixture 1, but was the lowest yielding mixture. Forage sorghum dominated all mixes at a seeding rate of 2 lbs/acre (Table 23).There was a difference between the botanical composition of the first and second harvest. Legumes in the mixtures were present mainly before the first cut. Forage brassicas increased in the mixture after the first cut providing forage for late-fall grazing. There was no significant difference between the biomass yield of forage mixtures and sole-seeded forage sorghum (Fig. 32).Mixtures without forage sorghum (Mixture 1, 2, 5) had lower yields than all other mixes with forage sorghum (Fig. 32).
Forage sorghum and forage pearl millet regrew fast after the first cut on all mixtures (Table 23).Crude protein value decreased during the second harvest. Mixtures 1, 2, and 4 had >15% crude protein (CP) during the first harvest which is greater than the 9-10% CP needed for a 544 kg beef cow with a calf.

Annual forage mixtures are good sources of forage. Mixes with forage sorghum produced greater biomass than mixes without forage sorghum and can provide additional forage for extended grazing.

Table 23. Seeding rate and botanical composition of two harvest times of 7 forage mixtures and 4 monocultures in Fargo, ND in 2019.

Mixture crops	Seeding rate (lbs/acre)	Botanical composition Cut 1 (% of DM)	Botanical composition Cut 2 (% of DM)
	Mixture 1		
Annual ryegrass	12	81	85
Chicory	2	5	7
Plantain	3	14	7
Red clover	3	1	0
	Mixture 2- late planting July 2		
Hybrid brassica	2		46
Turnip	2		54
	Mixture 3		
Hybrid brassica	2	1	16
Oat	5	7	17
Forage pea	5	12	0.3
Forage sorghum	2	12	59
Foxtail millet	2	69	7
	Mixture 4		
Turnip	1	2	8
Forage sorghum	2	42	44
Forage pea	5	17	0
Hybrid brassica	1	1	2
Oat	2	21	4
Faba bean	2	1	0
F. pearl millet	2	17	33
	Mixture 5		
Hybrid brassica	5	8	7
F. Pearl millet	2	92	93
	Mixture 6		
Radish	2	6	21
Sorghum x sudan	2	94	79
	Mixture 7		
Forage pea	5	6	2
Oat	5	46	18
Phacelia	1	7	1
Faba bean	5	2	0.2
BMR sorghum	3	38	80
Mixture 8-12 Sorghum sudangrass or forage pearl millet	10	100	100

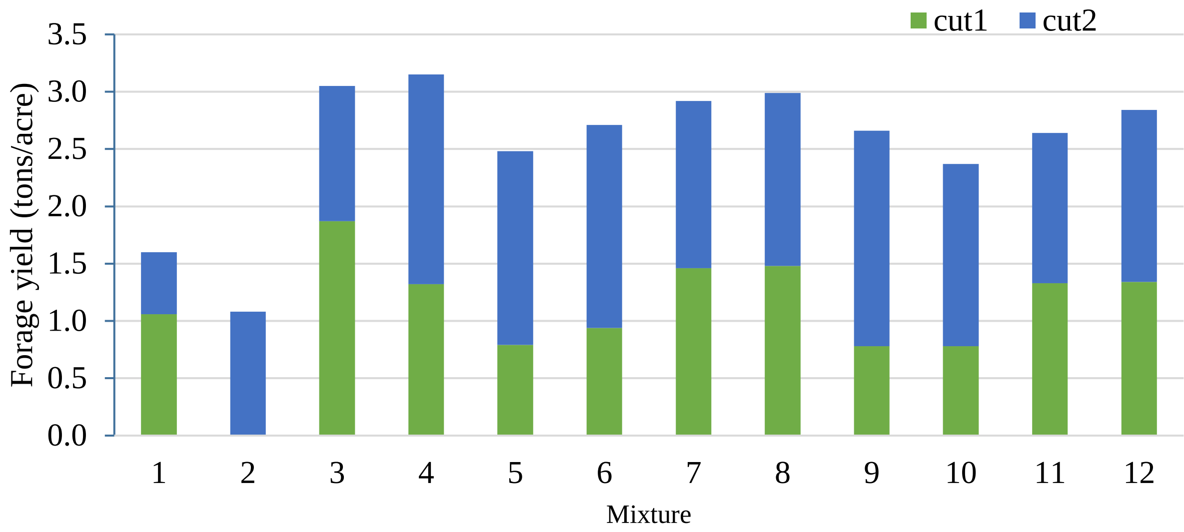


Fig. 33. Biomass yield of 12 annual forage mixtures or sole forages for grazing harvested twice in Fargo.

3. **Cover crops seeding date variety trial, Fargo, ND.** *Marisol Berti, Alan Peterson, and Alex Wittenberg*

This evaluation has been conducted every year since 2015. Twenty-one cover crops were planted on 1 August and 15 August 2019Biomass of all cover crops was harvested on 8 October 2019. The main purpose is to show farmers that planting date of cover crops in the fall really matters. Only two-weeks difference decreased biomass by half or more, especially for warm-season cover crops such as forage sorghum, foxtail millet and cowpeas (Table 24).

The highest biomass accumulation in the first seeding date was for forage sorghum, winter Austrian pea, forage pea, turnip cv. New York, and cowpea. Biomass accumulation of mustards, turnip, and Winfred hybrid did not decrease significantly with a two-week delay in planting. Forage brassicas are good cover crops for late fall and winter grazing since they can tolerate frosts of -20 F and have very high nutritive value. Hybrid brassica Winfred had 17% and 22% crude protein in seeding dates 1 and 2, respectively. Forage brassicas neutral detergent fiber digestibility (NDFD) ranged between 80 and 92%.

Table 24. Cover crops biomass yield of 21 cover crops planted on two dates in Fargo in 2019.

Cover crop	Variety/Trade Mark	1-Aug	15-Aug
		----------tons/acre-----------	
Sorghum hybrid BMR	Pampa verde Pacas	**1.42**	0.67
Foxtail millet	Siberian	0.67	0.34
Forage winter Triticale	Hy-Octane	1.02	0.58
Cereal rye (winter)	Dylan	1.16	0.47
Forage barley	Hays	1.06	0.62
Forage oat	Waldern	1.09	0.70
Turnip	Purple top	1.12	0.73
Turnip	New York	**1.46**	**1.01**
Brassica Hybrid	Winfred	0.87	**0.97**
Radish	Soilbuster	1.02	0.72
Rape	Dwarf Essex	1.28	0.78
Mighty Mustard ®	Kodiak	1.23	**1.09**
Mighty Mustard®	White Gold	1.17	**0.98**
Camelina	Joelle	1.37	0.30
Forage pea	Arvika	**1.43**	0.44
Austrian winter peas	VNS	**1.48**	0.44
Faba bean	Snowdrop	1.35	0.26
Hairy vetch	VNS	1.14	0.35
Crimsom clover	Kentucky Pride	0.96	0.26
Cowpea	VNS	**1.53**	0.57
Phacelia	VNS	0.56	0.70
Mean		1.15	0.62
LSD_1 (0.05)		0.74	
LSD_2 (0.05)		0.69	

LSD_1 is to compare means of seeding dates for a same cover crop
LSD_2 is to compare between cover crops within a same seeding date

4. On-Farm Research/Demonstration

A farmer in Rutland, ND, planted 74 acres of winter camelina after soybeans in the fall of 2018. He drilled winter camelina at 5 lbs/acre with a twin row drill at 30-inch row spacing and 6 inches between twin rows. In the spring of 2019, end of May he drilled an early maturing soybean variety into standing camelina with the same twin row drill but off-rowed to avoid running over the winter camelina plants. This is what we call relay cropping (Fig. 34, 36). On 25 July 2019, he harvested the winter camelina seed. He adapted his combine by adding pieces of drainage tile pipe (Fig. 36) so the cutting bar would not cut the soybean plants. He harvested soybean in the fall and got about 75% of the yield of a soybean without camelina. Camelina seed yield was about 700 lbs/acre. This is the first commercial field of a winter camelina-soybean relay cropping in North Dakota.

Fig. 34. Winter camelina in full bloom 26 June 2019, Rutland, ND.

A farmer in Wahpeton, ND, planted 45 acres of camelina in the fall of 2018 by aerial seeding after soybean with a seeding rate of 10 lbs/acre. Winter camelina provided a 100% cover of the soil early in the spring. He did not plant soybeans in relay. He harvested camelina seed by the end of July and had a seed yield of 1200 lbs/acre.

Fig. 35. Winter camelina in the spring (May) and near maturity in Wahpeton, ND in 2019. *Photo credits: Nick Toussaint.*

Fig. 36. Top left, interseeded soybean into standing winter camelina; Top right, winter camelina harvest (left harvested); Bottom left, combine header adapted to avoid cutting soybean plants while harvesting camelina; Bottom right, drainage tile pipe over cutter bar to protect soybean plants during camelina harvest.

5. ***Evaluation of field pennycress as a potential cover crop for suppression of weeds and other important ecosystem benefits*** *(James V. Anderson)***.**

Field pennycress (*Thlaspi arvense* L.) is another member of the *Brassicaceae* family that is also being considered as a new winter-hardy and beneficial cover crop, or as an overwintering oilseed crop for development of relay- and double-cropping systems in North Dakota. In two field strips (Fig. 37) each containing 21 blocks (1 x 1 m), native populations of field pennycress appeared as the dominant species in the early growing season of 2018. Field strips were originally set up in a RCBD with 15 blocks planted in the fall of 2017 with five accessions winter canola (*Brassica napus*, L.) replicated in, three blocks with winter camelina and three blocks as controls. An established alfalfa strip adjacent to field strip 2 (Fig. 37) was also used to evaluate 3 (0.5 x 0.5 m) blocks. Although canola did not survive the overwintering conditions of 2017-2018, the native populations of field pennycress observed as the dominant species within blocks in the spring of 2018 were allowed to grow and were evaluated for beneficial ecosystem services, including suppression of weeds and retention of soil nutrients.

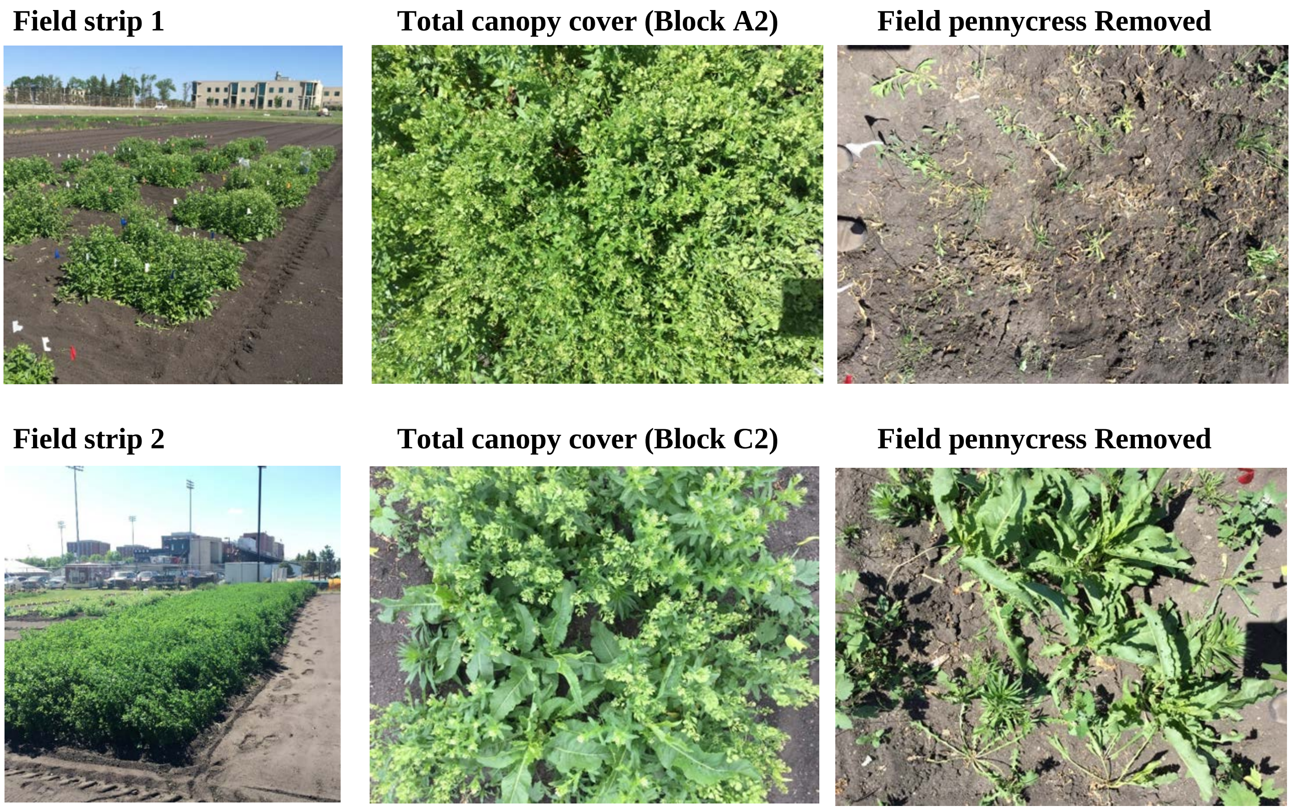


Fig. 37. Field strips (Strips 1 and 2) in Fargo, ND (latitude 46.89/longitude -96.80) in the spring of 2018. An established stand of alfalfa is also shown in Field Strip 2. A representative picture of total canopy cover before and after removal of field pennycress from Strip 1, Block A2 and Strip 2, Block C2. Field pennycress was collected from Strips between 31 May – 8 June 2018.

A simple linear regression analysis indicated field pennycress canopy cover (determined using the Canopeo App) suppressed of other weed canopy in field Strip 1 (r^2=0.82) and field Strip 2 (r^2=0.91) (Fig. 38) and increased retention of essential soil nutrients (NO_3-N, P, K, S) (Table 25). A correlation analysis (Table 26) indicated strong correlations among pennycress canopy cover, number of pennycress plants, and dry weight in relation to weed canopy and number of plants. Pennycress canopy, number, and dry weight were also strongly correlated with soil nutrient retention (Table 26).

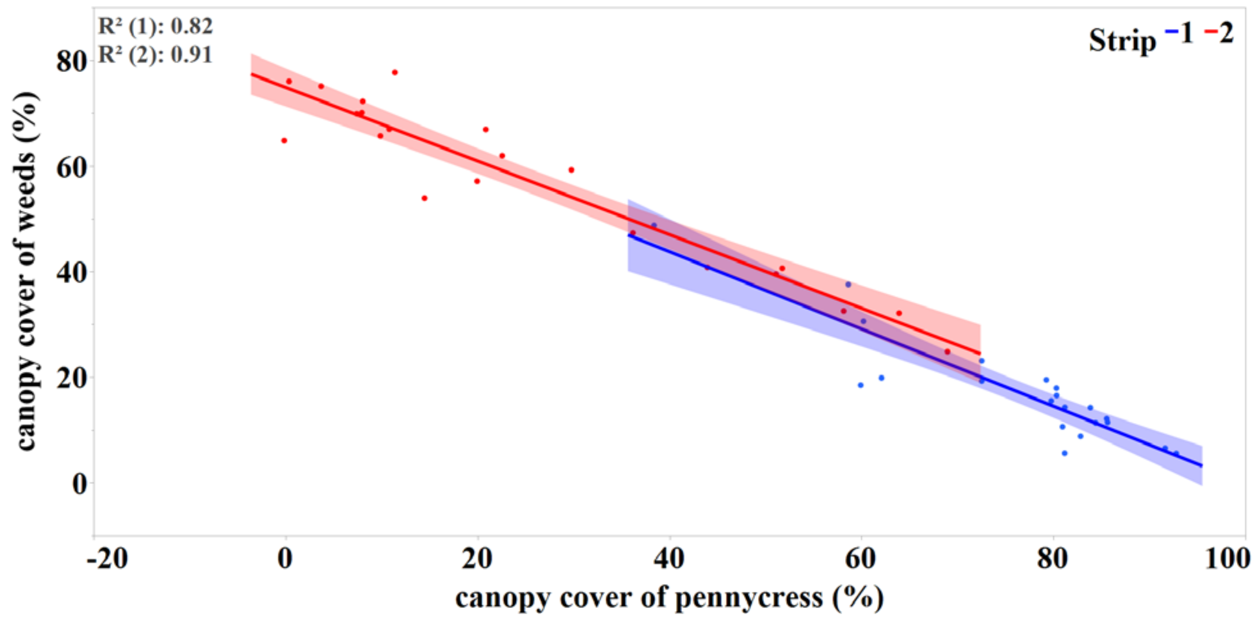


Fig. 38. Regression analysis of canopy cover (%) of weeds vs canopy cover (%) of field pennycress for each of the 21 blocks in Strip 1 (blue) and Strip 2 (red).

Table 25. Average nutrient retention of field pennycress harvested from Strip 1 (*n* = 21), Strip 2 (*n* = 21), and nutrient retention of alfalfa (*n* = 3) and extrapolated to kg ha^{-1} ± S.E.

Strip	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	S (kg ha^{-1})
1	258 ± 14	31 ± 2	330 ± 18	51 ± 3
2	73 ± 12	11 ± 2	90 ± 16	14 ± 2
Alfalfa	299 ± 20	27 ± 1	251 ± 12	22 ± 1

The lower levels of average nutrients retention by field pennycress and the overall increased average weed canopy (%) observed in Strip 2 (Fig. 39) are attributed to the fact that Strip 2 had reduced stand establishment compared with Strip 1 (Table 27). These results likely reflect the fact that Strip 1 consisted of soil that had not been tilled for over 20 years, whereas Strip 2 had been tilled and managed for three consecutive years. As a result, we hypothesize that Strip 2 had less field pennycress seed in the soil seed bank compared with Strip 1. As indicated by the soil tests conducted in the spring of 2018 (Table 28), Strip 1 generally had greater levels of NO_3-N, P, K, and S at 0-6 inches, and greater NO_3-N, P, and S at 6-24 inches compared with Strip 2. The reduced field pennycress canopy cover (%) and stand establishment (number of plants) in Strip 2 (Table 27) along with the generally lower levels of soil nutrients in Strip 2 (Table 28) likely account for the reduced nutrient retention observed in field pennycress sampled from Strip 2 compared with Strip 1 and the alfalfa strip (Table 25).

Table 26. Correlation coefficients of field pennycress canopy (%), number (no.) of plants, and dry weight (dwt) to retention of soil nutrients (N, P, K, S extrapolated to kg ha^{-1}) by field pennycress, or to weed canopy and number of plants. Analysis is represented as Strips 1 and 2 combined (*n* = 42) or Strip 1 and 2 separately (*n* = 21).

Strips 1 and 2 combined	no. pennycress	no. weeds	Canopy weeds (%)	Canopy pennycress (%)	Pennycress dwt (g)
no. weeds	-0.519				
Canopy weeds (%)	-0.677	0.719			
Canopy pennycress (%)	0.727	-0.708	-0.980		
pennycress dwt (g)	0.671	-0.660	-0.900	0.930	
N (kg ha^{-1})	0.699	-0.657	-0.907	0.932	0.989
P (kg ha^{-1})	0.766	-0.657	-0.907	0.939	0.970
K (kg ha^{-1})	0.719	-0.626	-0.915	0.937	0.971
S (kg ha^{-1})	0.702	-0.641	-0.904	0.928	0.982
Strip 1					
no. weeds	-0.053				
Canopy weeds (%)	-0.268	0.487			
Canopy pennycress (%)	0.387	-0.515	-0.908		
Pennycress dwt (g)	0.663	-0.485	-0.473	0.689	
N (kg ha^{-1})	0.709	-0.446	-0.527	0.681	0.938
P (kg ha^{-1})	0.690	-0.336	-0.473	0.628	0.892
K (kg ha^{-1})	0.817	-0.289	-0.586	0.710	0.825
S (kg ha^{-1})	0.684	-0.357	-0.506	0.646	0.891
Strip 2					
no. weeds	-0.548				
Canopy weeds (%)	-0.840	0.681			
Canopy pennycress (%)	0.895	-0.623	-0.953		
pennycress dwt (g)	0.933	-0.555	-0.844	0.911	
N (kg ha^{-1})	0.915	-0.545	-0.854	0.920	0.995
P (kg ha^{-1})	0.929	-0.570	-0.863	0.929	0.997
K (kg ha^{-1})	0.928	-0.556	-0.864	0.929	0.993
S (kg ha^{-1})	0.938	-0.556	-0.847	0.917	0.998

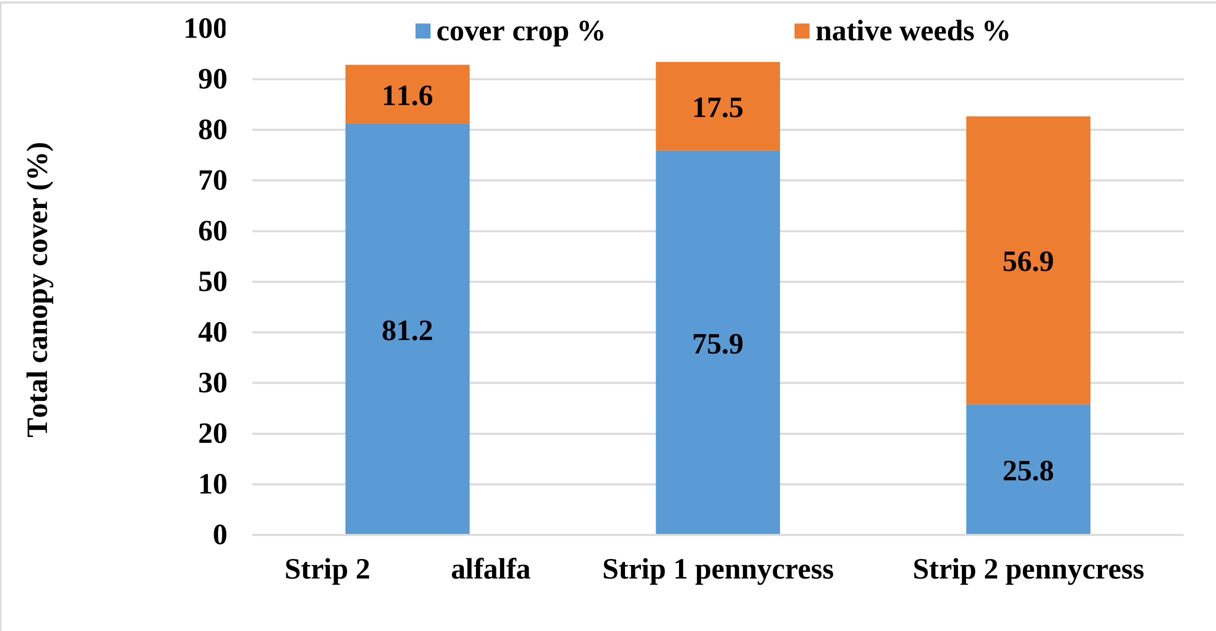


Fig. 39. Average canopy cover of field pennycress and alfalfa in relation to canopy cover (%) of weeds in either Strip 1 or 2 in Fargo, ND. Strip 1 (*n* = 21), Strip 2 Pennycress (*n* = 21), Strip 2 alfalfa (*n* =3).

Table 27. Mean and standard error of canopy cover (%) or number (no.) of plants for weeds and field pennycress in Strip 1 or Strip 2.

% Canopy	**Strip**	**Number**	**Mean**	**Std Err**	**Lower 95%**	**Upper 95%**
Weeds	1	21	17.49	2.99	11.45	23.53
	2	21	56.93	2.99	50.89	62.97
Field pennycress	1	21	75.89	3.97	67.86	83.93
	2	21	25.76	3.97	17.73	33.79
no. plants	**Strip**	**Number**	**Mean**	**Std Err**	**Lower 95%**	**Upper 95%**
Weeds	1	21	87.67	9.14	69.18	106.15
	2	21	136.33	9.14	117.85	154.82
Field pennycress	1	21	34.86	3.88	27.00	42.70
	2	21	20.71	3.88	12.86	28.56

Table 28. Average soil nutrient analyses (N, P, K, S) from soil collected in the spring of 2018 in Strips 1 (*n* = 2) and 2 (*n* = 2) at the Biosciences Research Laboratory in Fargo, ND.

Strip	**Depth (cm)**	**N (kg ha^{-1})**	**P (kg ha^{-1})**	**K (kg ha^{-1})**	**S (kg ha^{-1})**
1	0 - 15	220	69	728	269
	15 - 60	491	153	1800	911
2	0 - 15	61	62	540	27
	15 - 60	188	99	1958	646

The results of this study demonstrate the potential for field pennycress to be developed into a useful winter-hardy oilseed crop or cover crop for managing weeds and reducing nutrient runoff in northern agroecosystems.

EXTENSION EVALUATION AND IMPACT

Jean Haley Consulting LLC

The survey conducted of farmers attending the 2019 DIRT workshop indicated that 40% were considering use of cover crops to manage problematic areas as a result of attending this DIRT workshop. Farmers are already doing most of cover crops practices or considering them. However, 29% of farmers were not considering to graze cover crops. This is not surprising because many farmers in the audience did not have cattle (Fig. 40).

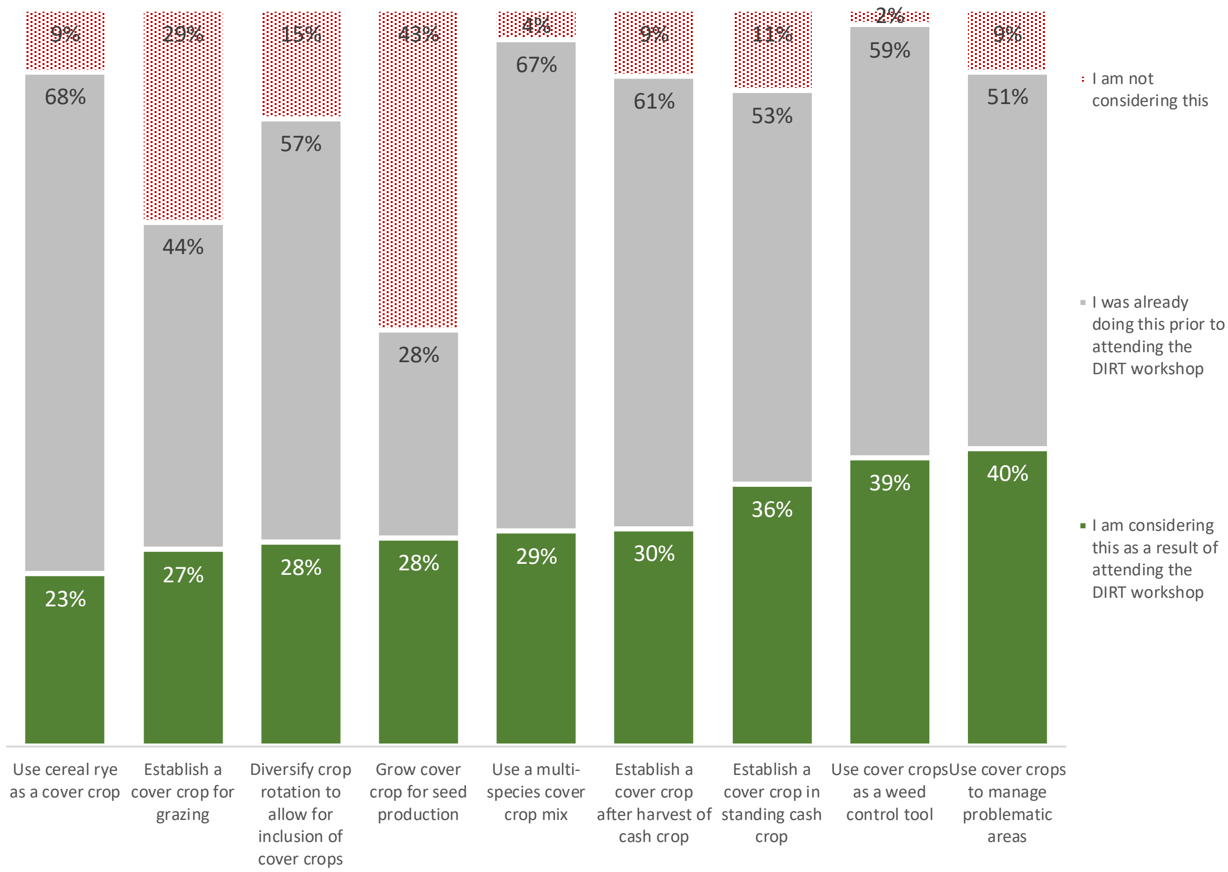


Fig. 40. Survey to farmers attending 2019 DIRT Workshop (n=44-48). Cover Crops Practices

The total acres farmed by respondents in 2019 increased by over 100,000 acres, from 52,400 acres in 2016 to 157,298 acres in 2019. Two-thirds of 2019 farmer respondents lease their land; 79% of leased land is farmed without livestock. Likewise, the majority of those who own their land farm without livestock (64% yellow side of Fig. 41).

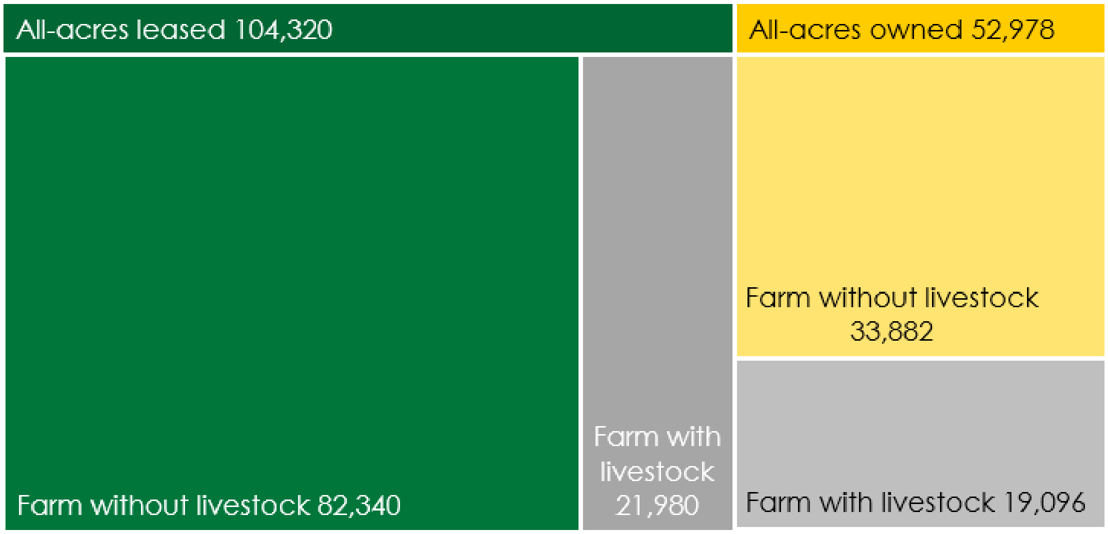


Fig. 41. 2019 acres farmed in ND from farmers attending Café Talks.

Farmer respondents show much more progress in cover crops practices. This likely reflects the amount of effort the Café Talks and other NDSU Extension programs have put into this topic in recent years. The greatest impacts among respondents include using cereal rye as a cover crop (26% adoption) and establishing a cover crop after harvest of a cash crop (20% adoption) (Fig. 42. The greatest potential for future adoption include establishing a cover crop in standing soybean and using a multi-species cover crop mix (51% considering adoption).

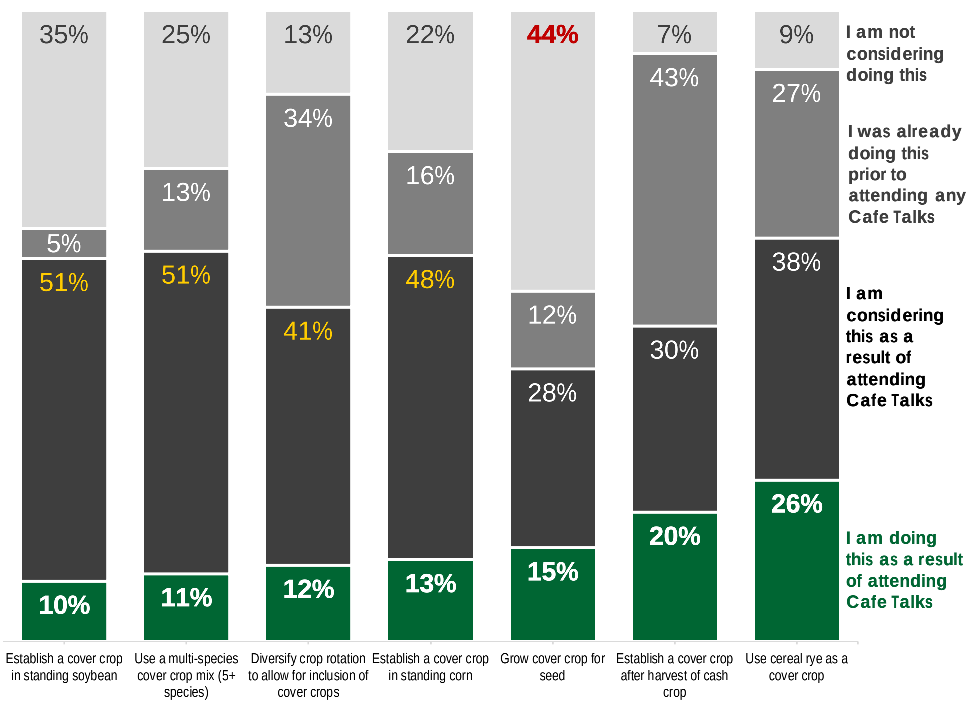


Fig. 42. Cover crops adoption practices as a result of farmers attending one or more Café Talks

Cover crops have been a common topic at Café Talks since they began in 2014. The increase in adoption among respondents illustrates the success of this approach. Establishing a cover crop after a cash crop saw the most dramatic increase (9%). Establishing a cover crop in standing corn saw the most dramatic decrease (15%).

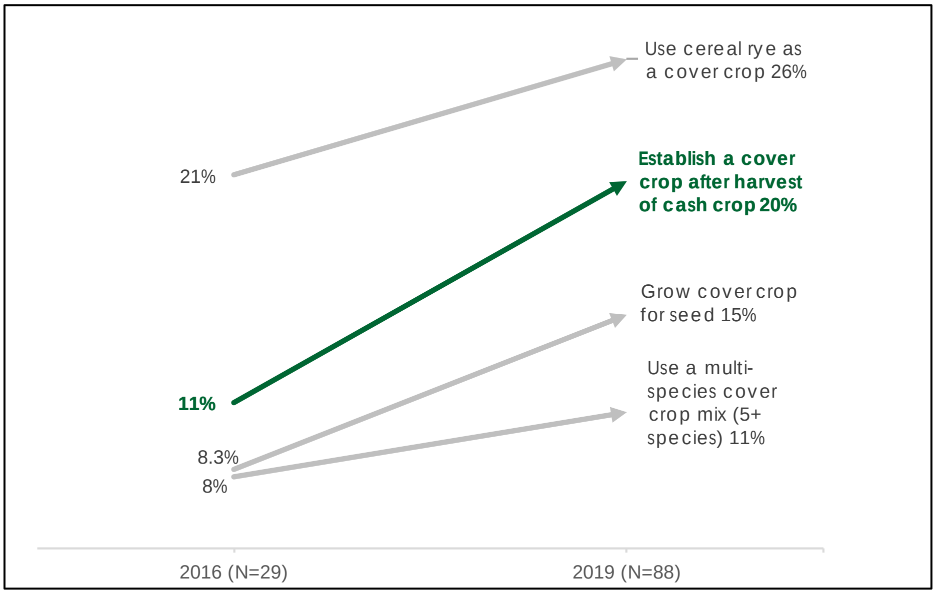


Fig 42. Increased adoption of practices, as result, of farmers attending one or more Café Talks.

PUBLICATIONS

Peer-reviewed journal publications

1. Andersen, B., D.P. Samarappuli, A. Wick and M.T. Berti*. 2020. Faba bean and pea can provide late-fall forage grazing without affecting maize yield the following season. Agronomy, 10:80.
2. Delavarpour, N., S. Eshkabilov, T. Bon, J. Nowatzki, and S. Bajwa. 2020. Performance comparison of two guidance systems for agricultural equipment navigation. DSMIE, 541-551. https://doi.org/10.1007/978-3-030-22365-6_54
3. Mohammed, Y.A., H.L. Matthees, R.W. Gesch, S. Patel, F. Forcella, K. Aasand, N. Steffl, B.L. Johnson, M.S. Wells, and A.W. Lenssen. 2019. Establishing winter annual cover crops by interseeding into maize and soybean. Agron. J. doi: 10.2134/agronj2019.06.0415.
4. Delavarpour, N., S. Eshkabilov, T. Bon, J. Nowatzki, and S. Bajwa. 2019. The performance analysis of tactile and ultrasonic sensors for planting, fertilizing, and cultivating cover crops. ASABE.doi: https://doi.org/10.13031/aim.201901247
5. Peterson, A., D. Samarappuli, and M.T. Berti*. 2019. Intersowing cover crops into standing soybean in the US Upper Midwest. Agronomy 9: 264 http://dx.doi.org/10.3390/agronomy9050264
6. Wittenberg, A., J.V. Anderson, and M.T. Berti*. 2019. Winter and summer annual biotypes of camelina have different morphology and seed characteristics Ind. Crops Prod. 135:230-237
7. Anderson, J.V., A. Wittenberg, H. Li., and M.T. Berti. 2019. High throughput phenotyping of *Camelina sativa* seeds for crude protein, total oil and fatty acids profile by near infrared spectroscopy. Ind. Crops Prod. 137:501-507.
8. Acharya, K., G. Yan, and M.T. Berti. 2019. Can camelina, crambe, and brown mustard reduce soybean cyst nematode populations? Ind. Crops. Prod. 140:111637.

Abstracts and Presentations at conferences, workshops, symposiums

1. Sigdel, S., M. Berti, S.C. Leiva, and A. Chatterjee. 2020. Cover crop inter-seeding under sugarbeet production. Presented at the 50th Annual Sugarbeet Research Reporting Session of SREB, Fargo, ND, 14 January 2020.
2. Berti, M.T. 2020. Cover crop seed regulations and crop variety v. selection. Cover Crops In-Service, An in-person training for NDSU Extension agents, NRCS, and SCD personnel. Carrington, ND, 13 January 2020. *Invited.*
3. Berti, M.T. 2020. Selecting cover crops by function. An in-person training for NDSU Extension agents, NRCS, and SCD personnel. Carrington, ND, 13 January 2020. *Invited.*
4. Keena, M. Cover crop identifications. An in-person training for NDSU Extension agents, NRCS, and SCD personnel. Carrington, ND, 13 January 2020
5. Meehan, M. Cover crops cost calculator debut. 2020. An in-person training for NDSU Extension agents, NRCS, and SCD personnel. Carrington, ND, 13 January 2020
6. Ostlie, M. 2020. Herbicide considerations prior to and after planting cover crops. An in-person training for NDSU Extension agents, NRCS, and SCD personnel. Carrington, ND, 13 January 2020.
7. Sedivec, K. 2020. Selecting appropriate mixes when integrating livestock. An in-person training for NDSU Extension agents, NRCS, and SCD personnel. Carrington, ND, 13 January 2020
8. Mozea, K. M.T. Berti, K. Sedivec, A. Peterson, A. Wittenberg, S. Cabello, and A. Greenberg. 2020. Biomass yield and botanical composition of annual forage mixtures for grazing. American Forage and Grassland Council Conference Greenville, SC, 5-8 January 2020.
9. Berti, M.T. 2019. Managing soybean cyst nematode with cover crops. Prairie Grains Conference Grand Forks, 11-12 December 2019. *Invited*
10. Berti, M.T. 2019.Timing and establishment of cover crops. Dakota Innovation Research and Technology Workshop Fargo, ND, 9-11 December 2019. *Invited*
11. Berti, M.T. and Y. Lawley 2019. High protein forage options and interseeding alfalfa in corn. Dakota Innovation Research and Technology Workshop Fargo, ND, 9-11 December 2019. *Invited*
12. Cabello, S., S. Podder, M.T. Berti, D. Samarappuli, B. Andersen, A. Wittenberg, and A. Peterson. 2019. Cover crops decrease initial water content, sugarbeet root yield, and residual NO_3-N in the northern Great Plains. ASA-CSSA-SSSA International Annual Meetings, San Antonio, TX, 10-13 November 2019.
13. Cabello, S., S. Podder, M.T. Berti, D. Samarappuli, B. Andersen, A. Wittenberg, and A. Peterson. 2019. Legume fall-planted cover crops slightly increased corn yield in the northern Great Plains. ASA-CSSA-SSSA International Annual Meetings, San Antonio, TX, 10-13 November 2019.
14. Gasch, C., and A. Wick. 2019. Filling the fallow: Adventures in on-farm cover crop research and demonstration in North Dakota. Invited oral presentation in a cover crop symposium, ASA-CSSA-SSSA Annual Meeting, San Antonio, TX, 10-13 November 2019.
15. Patel, S., A.W. Lenssen, K.J. Moore, and M.T. Berti. 2019. Increasing overall productivity by intercropping corn and alfalfa. ASA-CSSA-SSSA International Annual Meetings, San Antonio, TX, 10-13 November 2019.
16. Puka-Beals, J. and G.G. Gramig. 2019. Combining cover crops, strip tillage, and novel mulches to manage weeds in carrot. SA-CSSA-SSSA International Annual Meetings, San Antonio, TX, 10-13 November 2019.
17. Wittenberg, A., M.T. Berti, A. Peterson, D.P. Samarappuli, A. Greenberg, K. Mozea, S. Cabello, S. Podder, and J.V. Anderson. 2019. Sowing date affects winter camelina stand. ASA-CSSA-SSSA International Annual Meetings, San Antonio, TX, 10-13 November 2019.
18. Sigdel, S. M.T. Berti, S. Cabello-Leiva, and A. Chatterjee. 2019. Interseeding cover crops under sugarbeet production. ASA-CSSA-SSSA International Annual Meetings, San Antonio, TX, 10-13 November 2019.

19. Franzen, D.W., M.T. Berti, S. Matthews, and A. Wick. 2019. Increase in non-exchangeable ammonium after cover crop rye and forage radish. ASA-CSSA-SSSA International Annual Meetings, San Antonio, TX, 10-13 November 2019.
20. Berti, M.T., 2019. Importance of integrating cover crops into cropping systems. First International Cover Crops Conference, Lanzhou, China 20-26 September 2019. *Invited speaker.*
21. Anderson, J.V., W. Chao, D.P. Horvath, M.T. Berti and R.W. Gesch. 2019. Evaluation of winter hardy oilseed cover crops suitable for developing multi-cropping systems in cold and growth-limiting climates. First International Cover Crops Conference, Lanzhou, China 20-26 September 2019.
22. Wittenberg, A., M.T. Berti, A. Peterson, D.P. Samarappuli, A. Greenberg, K. Mozea, S. Cabello, S. Podder, and J.V. Anderson. 2019. Fall sowing dates in camelina affected plant density. 31th Annual Meeting of the Association for the Advancement of Industrial Crops (AAIC). Tucson, AZ, 8-11 September 2019.
23. Berti, M.T. 2019. Forages, biomass, and cover crops production research. Annual meeting regional committee NCCC31 "Ecophysiological Aspects of Forage Management". Madison, WI, 17-18 July 2019.
24. 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. Poster presentation, Soil Ecology Society Biennial Meeting, Toledo, OH. June.
25. Berti, M.T., G. Yan, D. Samarappuli, A. Peterson, A. Wittenberg, and J.V. Anderson. 2019. Potential benefits to the environment by integrating winter camelina in current cropping systems of the northern Great Plains of the USA. In European Biomass Conference and Exhibition. 27-30 May 2019, Lisbon, Portugal. Available at http://www.etaflorence.it/proceedings/index.asp
26. Wittenberg, A. M.T. Berti, A. Peterson, S. Cabello, B. Andersen, and S. Podder. 2019. Industrial applications of processed camelina [*Camelina sativa* (L.) Crantz] seed oil and meal. Annual EpsCor Conference, Fargo, ND. 27 March 2019.
27. Berti, M.T. 2019. Interseeding, nutrient cycling, alfalfa-corn intercropping, and winter camelina studies. Annual Coordinated Agricultural Program (CAP) project. Fargo, ND, 26-27 March, 2019.
28. Cabello-Leiva, S. and M.T. Berti, 2019. Cover crops decrease initial water content, sugarbeet yield, and residual $N\text{-}NO_3$ in the northern Great Plains. 35th Annual Plant Science Graduate Student Symposium. Fargo, ND, 16-15 March, 2019.
29. Berti, M.T. 2019. Alfalfa management and production. Grazing Cover Crops Workshop, Dickinson, ND, 4 March 2019.
30. Berti, M.T. 2019. Cover crops North Dakota report. Midwest Cover Crops Annual Conference. Springfield, IL. 20-21 February 2019.
31. Anderson, J.V., A. Nobriga, B. Bigger, M. Berhow and S. Vaughn. Evaluation of field pennycress as a useful oilseed cover crop for suppression of weeds in the Northern Great Plains. 59th Annual Meeting of the Weed Science Society of America, New Orleans, LA, 11-14 Feb. 2019.

Proceedings publications

1. **Berti, M.T.***, G. Yan, D. Samarappuli, A. Peterson, A. Wittenberg, and J.V. Anderson. 2019. Potential benefits to the environment by integrating winter camelina in current cropping systems of the northern Great Plains of the USA. p. 131 *In* European Biomass Conference and Exhibition. 27-30 May 2019, Lisbon, Portugal. Available at http://www.etaflorence.it/proceedings/index.asp (verified 10 June 2019).
2. Zanetti, F., M. Christou, E. Alexopoulou, **M.T. Berti,** A. Vecchi, A. Borghesi, and A. Monti. 2019. Innovative double cropping systems including camelina [*Camelina sativa* (L.) Crantz] a valuable oilseed crop for bio-based applications. p. 127-130 *In* European Biomass Conference and Exhibition. 27-30 May 2019, Lisbon, Portugal. Available at http://www.etaflorence.it/proceedings/index.asp (verified 10 June 2019).

3. **Berti, M.T.*,** D. Samarappuli, and G. Pourhashem. 2019. Environmental impact of crops and agricultural residues as feedstocks for bio-based product development. *In* 5th Latin-American Biorefineries Congress, Concepcion, Chile 7-9 January, 2019. Available at www.biorrefinerias.cl

Grants

1.1. USDA-NIFA- 3/2020-02/2024. Managing disturbance for multi-functional rangelands: livestock, plant, and pollinator responses to management strategies that differentially use fire and grazing, $499,242, Harmon, McGranahan, Berti

1.2. USDA-NIFA- ASAFS. 10/2019-9/2021.Alfalfa management practices and their effect on arbuscular mycorrhizal fungi (AMF) populations- towards improving health, productivity, and sustainability of alfalfa production, $429,011 Berti

1.3. USDA-NACA 7/1/2019-6/30/2020, Evaluation of ecosystem services provided by *Camelina sativa* as a cover crop for northern climates, $22,000, Berti , Anderson

1.4. ND Soybean Council. Research and Extension Efforts at the Soil Health and Agriculture Research Extension (SHARE) Farm (year 7), $82,075, Wick, Gasch, Daigh, Berti,

1.5. ND Soybean Council. SHARE Farm North: Expanding Soil Health Building Research and Extension Efforts. $23,622, Wick, Gasch, Daigh, Berti

1.6. ND Wheat Commission. Soil Health and Agriculture Research Extension (SHARE) Farm in Mooreton and Larimore, ND. $80,471 Wick, Gasch, Daigh, Berti,

1.7. NC-SARE. 10-1/2017-9/30/2019 Combining cover crops, strip tillage, and novel mulches to manage weeds in vegetable cropping systems. $96,695 Gramig

1.8. NC-SARE. 11-1/2020-12/31/2022 Grazing Management Practices to Enhance Soil Health in the Northern Great Plains. $198,168 Meehan, Sedivec, Keena

Variety release

North Dakota State University released a new winter rye variety – ND Gardner (see report for details)

***Graduate students** (advisor in parentheses)*

1. Jesse J. Puka-Beals, MS Combining cover crops, strip tillage, and novel mulches to manage weeds in carrot. North Dakota State University. (Gramig) 2018-2020
2. 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.
3. Nadia Delarvarpour, PhD., North Dakota State University, Improving the twin-row interseeder guidance system. (Bajwa and Nowatzki) January 2017-May 2019.
4. Alan Peterson, MS, Interseeding camelina on standing soybean. North Dakota State University. (Berti) June 2016-May 2019.
5. 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.
6. Kyle Aasand, MS, Corn and soybean relay cropping with winter rye, field pennycress, and winter Camelina. North Dakota State University (Johnson) June 2016- May 2020.
7. 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.
8. Kory Johnson, MS. Interseeding camelina into narrow row spacing soybean of different maturity groups. North Dakota State University (Kandel) January 2017-May 2020.
9. Alex Wittenberg, MS. Morphological differences between spring and winter camelina types. North Dakota State University (Berti) May 2018-May 2020.
10. 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.

11. Kenneth Mozea, MS. Biomass and botanical composition of annual forage mixtures for grazing. North Dakota State University (Berti), May 2019-May2021.
12. Sailesh Sigdel, MS Cover crop inter-seeding under sugarbeet production. North Dakota State University (Chatterjee) May 2018-December 2020
13. Marcus Mack, MS Rye termination timing study in relation to soybean planting date. North Dakota State University (Ransom) May 2018-May 2020.
14. Brooke Rockentine, MS, Entomology (Gasch) (Summer 2017 – present)
15. Mackenzie Ries, MS Soil Science (Gasch) (January 2018 – present)
16. Alec Deschene, MS Soil Science (Gasch) (August 2018 – present)
17. Jeremy Wirtz, MS Soil Science (Goos) 2017- May 2019.
18. 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

Extension publications, material, news, videos

1. Ruark, M. and D. Franzen. 2020. Nitrogen availability from cover crops: Is it always about the C:N ratio? Crop & Soils Magazine. DOI: 10.1002/crso.20003
2. Berti, M.T. 2019 Full-season cover crops mixtures for grazing. Forage Focus, March 2019. p. 6
3. Wick, A., M.T. Berti, and L. Briese. 2019. Starting with cover crops in North Dakota. Midwest Cover Crops Council cover crop recipe. Bull MCCC-102. Available at mccc.msu.edu.statesprovince/north-dakota/
4. Wick, A., F. Casey, C. Gasch, A. Daigh, D. Ripplinger, B. Nelson, J. Harmon, D. Ritchison, T. DeSutter, A. Chatterjee, 2019 (In Review). Soil Health and Agriculture Research Extension (SHARE) Farm, NDSU Soil Health Booklet.
5. Kandel, H. NDSU Extension Sets Cover Crop Field Day http://www.ag.ndsu.edu/news/newsreleases/2019/aug-19-2019/ndsu-extension-sets-cover-crop-field-day.
6. Kandel, H. and M. Berti NDSU Extension Cover Crop Field Day. Crop and Pest Report, Aug. 29. No 15:1-2. https://www.ag.ndsu.edu/cpr/news-events-updates/ndsu-extension-cover-crop-field-day-08-29-19. https://www.ag.ndsu.edu/cpr/plant-science/cover-crop-tour-ndsu-campus-fargo-09-12-19.
7. Sedivec, K., M. Meehan and J. Block. Grazing/Harvesting Rule Change to Benefit Producers
8. https://www.ag.ndsu.edu/news/newsreleases/2019/july-8-2019/grazing-harvesting-rule-change-to-benefit-producers/view
9. Meehan, M. Four Keys for Grazing Cover Crops. Progressive Cattleman. September 2019.
10. Meehan, M. Tips for Fall Grazing Cover Crops. North Dakota Stockmen. September 2019.
11. Meehan, M. and K. Sedivec. Keys for Fall Grazing Cover Crops
12. https://www.ag.ndsu.edu/news/newsreleases/2019/sept-9-2019/ndsu-extension-offers-tips-for-fall-grazing-cover-crops

Videos

1. Wick, A.F, 2019, DIRT Workshop Coverage. AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=aDrjXG3k0Iw
2. Wick, A.F, 2019, DIRT Workshop Preview with Lee Briese. AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=CHF9z3nCNrY
3. Wick, A.F, 2019, Winter Camelina. AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=B1J83URX3OQ
4. Wick, A.F, 2019, Comparing Warm and Cool Season Grasses. AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=a1X6DvjB8KQ
5. Wick, A.F, 2019, Cover Crops on Prevented Plant. AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=vkciX3Pu-mw
6. Wick, A.F, 2019. Soil Sense Podcast Release. AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=VR739G95tFs

7. Wick, A.F, 2019, Nitrogen Release Study. AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=pJfY9WD6PSM
8. Wick, A.F, 2019, Cover Crops for Prevent Plant and Grazing. AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=Z2BACUDQUqM
9. Wick, A.F, 2019, What's to Come in the Soil Health Minute. AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=fm_d-GnzWo8
10. Wick, A.F. 2019. Soil Health Café Talks Cover a Wide range of Topics, AgWeek TV Soil Health Minute, Fargo Communications Production, https://www.youtube.com/watch?v=9fpkps3Skq0

Field days

1. Cover crops in the farming system. 7th Annual on-farm research summit, Panel Discussion, Alerus, Grand Forks, ND, December 11, (Kandel, 110 participants).
2. Soil Health Tour for NDSCS college students, October 29, 2019, Wahpeton, ND (Wick, Hoffman, 20 attendees)
3. Leonard Soil Health Tour, September 26, 2019, Leonard, ND (Zimmerman, Walberg, Wick, 15 attendees)
4. Cover Crops Field Day, September 17, 2019, Fargo, ND (Kandel, Berti, Wick, Ransom, Schmitt, Peterson, Wittenberg, Franzen, Cabello, 75 attendees).
5. Cover crop plants were on display and handout about cover crops. Big Iron Farm Show, September 10-12. West Fargo, ND. (Kandel)
6. Interseeding corn and soybean with cover crops Ransom County plot tour. Included planted demonstration with rye and camelina seeded into corn and soybean, Lisbon, ND, Sept. 5, 2019 (Ransom, Kandel, 15 attendees)
7. Interseeding corn with cover crops Steele County plot tour. Included planted demonstration with rye and camelina seeded into corn and soybean. Sept 3, 2019. (Ransom, Kandel, 17 attendees).
8. Farm to Table Tour, Breker Farm, August 29, 2019, Rutland, ND (Breker, Wick, Gesch, 100 attendees).
9. Interseeding corn and soybean with cover crops Sargent County plot tour, Gwinner. Included planted demonstration with rye and camelina seeded into corn and soybean. August 26, (Ransom, Kandel, 17 attendees).
10. Soil Health in North Dakota Tour for Canadian Farmers and Educators – Wagner and Trautman, August 15, 2019, Wahpeton and Mooreton, ND (Wick, 20 attendees)
11. Absaraka Field Day at Horticulture Research Farm: August 15, 2018, Absaraka, ND. (60 attendees).
12. Fargo Organic Field Day at North Dakota State University: August 10, 2018. Fargo, ND (Gramig, 40 attendees)
13. Soil Health in North Dakota Tour for Canadian Farmers and Educators – Breker, August 14, 2019, Wahpeton and Mooreton, ND (Wick, 20 attendees)
14. Soil Health in North Dakota Tour for Canadian Farmers and Educators – SHARE Farm and Toussaints, August 13, 2019, Wahpeton and Mooreton, ND (Wick, 20 attendees).

Workshops and professional training

1. Cover crops for grazing workshop in Dickinson, ND , March 4 2019 (60 attendees)
2. An in-person training for NDSU Extension agents, NRCS, and SCD personnel. Carrington, ND, 13 January 2020. (50 attendees)

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.

Websites

1. CropSys CAP website www.cropsyscap.org: 18,598 visits and 42,116 pages viewed in 2019
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. 929 subscribers to YouTube Channel (February 2019).
   Extension events for the CAP and extension materials are published on this site as well as in the CropSys CAP website.

Podcasts

Wick, A.F. 2019. Soil Sense Podcast Series, 16 Episodes with different guests, Host: Tim Hammerich (12,026 plays as of 2/12/20).

Decades of Building Soil Health, Joe Breker, October 31
SHARE Farm Reflections and Insights, Ken Johnson, Jean Henning, October 24
Managing Salts, Allie Slykerman, October 17
Integrating Cattle and Cover Crops, Luke Ressler, October 10
Soil Physics and Soil Biology, Aaron Daigh, October 3
Building Soil Health on your Toughest Field, Doug Toussaint, September 26
Salinity and Sodicity Issues, Naeem Kalwar, September 19
Improving Soil Health Over Generations, Lee Trautman, September 12
Cover Crops, Marisol Berti, September 5
Taking Off with Soil Health, Matt Nelson, August 29
Lessons Learned form 20 Years of Crop Consulting, Lee Briese, August 22
Challenges of Building Soil Health in Cool Wet Climates, Sam Landman, August 15
Precision Ag for Healthier Soils, Dave Franzen and Anthony Thilmony, August 4
Soil Fertility, Dave Franzen and Anthony Thilmony, August 1
Soil Health Systems on the Farm, Tony Wagner, August 1
Setting the Stage for Soil Health in North Dakota, Abbey Wick, July 29

Wick, A.F. 2019. Shark Farmer Radio Show Guest, XM Rural radio 147, September 24.

Wick, A.F. 2019. Importance of Aggregation for Soil Health. March 13, Webinar, No-Till Farmer Magazine, sponsored by Illinois Soybean Association, ND Corn Council, ND Soybean Council (337 pre-registered attendees; 531 views since posting on-line).

Wick, A.F., J. Fuhrer. 2019. Ideas for Working Alongside Farmers to Improve Soil Health. March 12, Webinar, SSSA/ASA Webinar Series for CCA's, sponsored by General Mills (over 1,000 pre-registered attendees).

Wick, A.F. 2018. Nerding Out about Soil Health with Dr. Abbey Wick. Future of Ag Podcast, Host: Tim Hammerich.

IMPACT STATEMENT

Cover crops adoption in North Dakota is increasing edramatically thanks to the many researchers and graduate students (18) involved in cover crops research and extension in the state. Researchers were able to secure $1,431,184 in new funding for cover crops research in 2019, in addition to the NIFA CropSys CAP project for 3.7 million, which is in its fourth year of execution. Cover crops researchers published eight peer-reviewed articles, 3 proceedings publications, 31 presentation in conferences, workshops and symposiums. Fourteen field days were organized during the season and numerous other extension publications, podcasts, videos and interviews.

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 2019 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.

The survey conducted of farmers attending the 2019 DIRT workshop indicated that 40% were considering use of cover crops to manage problematic areas as a result of attending this DIRT workshop. Farmers are already doing most of cover crops practices or considering them. However, 29% of farmers were not considering to graze cover crops.

Noteworthy is that two farmers planted winter camelina in the fall of 2018 to increase seed for the cover crops market (75 and 45 acres fields). One of the farmers relayed soybean into winter camelina in May 2019 obtaining two crops in one season. Winter camelina provides a 100% cover in the spring protecting the soil of erosion and removing excess water.