North Dakota – MCCC State Report 2014

Cover crops in grain crops (corn-soybean-wheat), forage for hay and fall grazing, salinity management, and prevented planting.

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COMPLETED RESEARCH

1. Performance and production of forage brassica cover crops in North Dakota
Marisol Berti, Osvaldo Teuber, Alfredo Aponte, and Dulan Samarappuli

In North Dakota, some forage brassicas such as radishes and turnips are used as cover crops after cereal crops, but usually in mixture with other cover crops. In 2012, the estimated acreage planted to forage brassicas in North Dakota was 213,810 acres which was 2.1% of the total acreage of cover crops in the USA.

North Dakota growers could extend the grazing season with forage brassica cover crops reducing their costs, improving profitability of farming operations by providing high quality feed for late-season use. As well those growers that do not have cattle in their farming system can benefit of using forage brassica as cover crops to improve soil health by reducing soil erosion, increasing water infiltration, reducing soil compaction, suppressing weed seeds germination, and diseases in the soil. The objectives of this study were i) to evaluate different cultivars of brassicas species as full-season forages and as cover crops in different environments in North Dakota; and ii) to determine their adaptability, yield potential, and nutritional quality for animal production.

Two forage brassica cultivar trials, a full-season and a cover crops, were established in Carrington, Fargo, and Prosper, ND, in 2013. The first experiment included six brassica species: kale (*Brassica oleracea* L.), swede or rutabaga [*Brassica napus var. napobrassica* (L.) Mill], forage rape (*Brassica napus* L.), turnip (*Brassica rapa* L.), winter canola (*Brassica napus*), and some hybrids (crossing between two different brassica species). Several cultivars of each one of the crops were planted, totaling 20 different cultivars.
The cover crops study was seeded in Prosper and Fargo in 2013 on oat (*Avena sativa* L.) stubble. This experiment included five brassica species such as radish (*Raphanus sativus* L.), forage rape, hybrids, Ethiopian cabbage (*Brassica carinata* A. Braun.), and turnip. Several cultivars of each specie were tested totaling 17 cultivars.

The kale cv. Maris Kestrel had the highest total yield (leaves + roots/stems), 10 Mg dry matter/ha. The forage quality of all full season grown brassicas was very high with RFQ values of greater than 300 and very high crude protein (20-32%). Forage brassicas are highly digestible feed and a great source of forage for grazing in the fall. Two main problems to grow full-season forage brassicas are: 1) the lack of good herbicides for weed control and 2) the need of several application of insecticide to control flea beetles (*Phyllotetra cruciferae*).

Cover crop forage brassicas had yields of up to 5 Mg/ha in only 80 days of growth. Forage quality was also very high in digestibility and crude protein content. Forage brassicas are frost tolerant and can survive well into November providing a high quality forage resource late in the fall. Weeds and insects pressure in the fall are much less than in the spring and summer reducing the need of pesticides applications.

Forage brassicas planted as cover crops in August following a cereal crop have a lot of potential in North Dakota.

Objectives

The specific objectives of this study were: 1) To evaluate different cultivars of brassicas species as forage and cover crops in different environments of North Dakota; ii) To determine their adaptability, yield potential, and nutritional quality for animal production.

Materials and Methods

All research was conducted during 2013 in North Dakota State University (NDSU) research site in Fargo, Prosper, and Carrington, ND. Two experiments were planted, 1) a full-season and a cover crops forage brassica cultivar trial.

Forage brassicas cultivars trials:

The experiment included six brassica species: kale, swede or rutabaga, forage rape, turnip, hybrids, winter canola, and several cultivars of each one of the crops, totaling 20 different cultivars (Table 2). The experimental design was a randomized complete block (RCBD), with three replicates. Seeding was done with a plot seeder (Plot seeder XL Wintersteiger, City Country), at 1- to 1.5-cm depth.

The plots had 8 rows spaced at 15 cm and were 6 m in length. Seeding date was 16 May in Carrington in 2013. The 2013 Fargo seeding was lost. The study was fertilized with 100-80-100-20 kg ha^{-1} of N-P-K-S if soil test indicated need (Table 1). Weed control was done by hand and all plots were sprayed at least three times with bifenthrin (Sniper) for flea beetles control. All plots was harvested at the same time in fall. Harvest in Carrington was 26 October 2013 (Fig. 1).

Evaluations included biomass production of roots/stems and leaves. The biomass was harvested from $1m^2$ in each plot at the end of the season. In the laboratory, the plants harvested were divided in its different components such as leaves, stems, and roots to evaluate botanical composition.

Fig. 1. Cultivar trial full-season forage brassicas, Carrington, ND, 2013

Cover crops brassicas cultivars trials:

The cover crops study was seeded in Fargo and Prosper in 2013 on oat stubble. This experiment included five brassica species such as radish, forage rape, Ethiopian cabbage, hybrids, (crossing between two different brassica species), and turnip. Several cultivars of each species were tested totaling 17 cultivars (Table 4).

Forage brassicas as cover crops were planted in 8 and 9 August 2013 at Fargo and Prosper, respectively. The statistical design was a randomized complete block (RCBD), with three replicates. The plots had 8 rows separated 15 cm each other. The seeding was done with a plot seeder (Plot seeder XL Wintersteiger) at 1- to 1.5-cm depth. Crops were harvested on 15 and 21 November 2013 in Prosper and Fargo, respectively. Soil samples were taken in each experiment. Soil test for the experimental sites are indicated in Table 1.

Table 1. Soil analysis of experimental sites in Carrington, Fargo and Prosper.

Site/year/trial	$N\text{-}NO_3$[a]	$N\text{-}NO_3$[b]	P	K	S[a]	S[b]	pH	OM
	kg/ha		mg/kg		kg/ha			%
Carrington 2013, Full crops	44	47	7.0	125	4.5	24.0	7.1	2.7
Fargo 2013, Cover crops	10	92	7.3	253.3	8.6	51.5	7.9	3.5
Prosper 2013 Cover crops	22	17	27	160	-	-	6.4	4.0

[a] $N\text{-}NO_3$ at 0- to15-cm depth

[b] $N\text{-}NO_3$ and S at 15 to 60 cm depth

Forage quality analysis:
Forage samples of all cultivar trials, full season and cover crops, were taken right before harvest. These samples were placed in bags and transported to Plant Sciences forage lab to separate the plants in its different botanical parts (leaves, stems/roots), and then dried. Dry samples were ground to 1-mm in size and sent to the University of Wisconsin, Animal Sciences laboratory to determine nutritional quality; ash, crude protein (CP), neutral detergent fiber (NDF), Acid detergent fiber (ADF), acid detergent lignin (ADL), in vitro dry matter digestibility (IVDMD), total digestible nutrients (TDN), dry matter intake (DMI), and neutral detergent fiber digestibility (NDFD). With these quality components both Relative Feed Value (RFV) and Relative Forage Quality (RFQ) were calculated. Only Ash, CP, ADF, NDF and RFQ are presented in this report.

Results

Forage brassicas cultivars trials
At the Carrington site in 2013, the kale 'Maris Kestrel' had the greatest total yield including both leaves and roots/stems (Table 2, Fig.2). The kale cv. Sovereign, the swede cv. Major Plus, the hybrid Winfred and the forage rape 'Barsica' were among the highest yielding full-season forage brassica crops.
Maris Kestrel had over 10 Mg/ha of dry matter yield in Carrington in 2013 and it was also the highest yielding in Fargo in 2014. The yield of Maris Kestrel is probably greater than many other forages grown full season.
Although the above-mentioned cultivars have great yield potential as full-season forage crops, brassica crops as forages have several agronomic limitations that will hinder their future development.

Fig. 2. Maris Kestrel kale grown in Carrington, ND, 2013.

Forage brassicas establishment in the spring is slow and the small seedlings are not very good competitors with broadleaved cool-season weeds. Unfortunately, there are not herbicides labeled for forage brassicas and they tolerate very few herbicides, none with a wide spectrum of weed control.

Also, brassicas are very susceptible to flea beetles in early stages of development and throughout the season up to three insecticide applications are needed which would not be economic in a large scale production.

Table 2. Full-season forage brassicas leaves, roots/stalks and total dry matter yield in Carrington, ND, in 2013 and in Fargo, ND, in 2014.

Crop	Cultivar	Carrington, 2013			Fargo, 2014		
		Total leaves	Total roots/stalks	Total yield	Total leaves	Total roots/stalks	Total yield
		------------- Dry matter yield (Mg/ha)-------------------					
Kale	Siberian	3.74	0.68	4.43	1.80	0.91	2.72
Kale	Maris Kestrel	6.25	4.56	**10.81**	3.91	3.96	**7.87**
Kale	Dwarf Blue Vates	5.53	1.06	6.59	4.36	1.75	6.11
Kale	Sovereign	4.44	2.87	7.30	3.63	3.26	6.89
Kale	Bayou	-	-	-	1.62	2.77	4.38
Swede	Major Plus	2.86	3.17	6.03	2.22	4.25	6.48
Swede	American Purple Top	2.23	3.64	5.87	1.44	3.16	4.60
Swede	Dominion	2.45	2.37	4.81	1.19	3.60	4.79
Turnip	Purple Top	2.36	2.53	4.88	0.86	1.95	2.81
Turnip	Rack	2.96	1.80	4.76	0.77	1.64	2.41
Turnip	Pointer	2.77	1.91	4.68	1.10	2.14	3.24
Hybrid	Winfred	3.97	2.24	6.21	1.66	3.13	4.78
Hybrid	Pacer	2.37	3.50	2.72	1.32	0.00	1.33
Forage rape	Rangi	3.36	1.57	4.93	1.47	3.34	4.82
Forage rape	Barsica	4.50	1.89	6.39	3.40	3.35	6.75
Forage rape	Dwarf Essex	3.49	1.15	4.64	1.37	1.50	2.87
Forage rape	Bonar	3.32	1.19	4.51	1.88	1.59	3.46
Winter canola	Riley	3.04	0.95	3.99	1.25	1.39	2.65
Winter canola	Griffin	3.19	0.87	4.06	1.17	0.84	2.01
Winter canola	Athena	3.17	0.82	3.99	1.57	1.31	2.88
Winter canola	Summer	2.80	1.38	4.18	0.75	1.35	2.10
LSD (0.05)		1.09	1.06	1.85	1.07	1.25	1.93
CV%		19	35	21	35	34	28

Seeding date 16 May 2013; harvest date 26 October, 2013.

Forage brassicas were very high quality digestible forage as expected. Crude protein content was very high (20-32%), even higher than CP content typical of legume forages such as alfalfa (*Medicago sativa* L.) (Table 3). Swedes leaves had the highest CP content. Forage quality of full season grown brassica leaves was really high with RFQ values greater than 300. The RFQ includes the NDFD value, this really high values occur because all these brassicas have NDFD of 90% or greater.

Table 3. Full-season forage brassicas forage quality of leaves in Carrington, ND, in 2013.

Crop	Cultivar	Ash	CP	ADF	NDF	RFQ
		----------------------	%	-----------------------		
Kale	Siberian	14.2	26.3	13.4	20.0	373
Kale	Maris Kestrel	13.1	20.1	15.3	20.1	394
Kale	Dwarf Bue Vates	13.3	23.2	14.3	19.4	406
Kale	Sovereign	13.3	23.3	15.2	19.9	394
Swede	Major Plus	15.0	28.8	15.4	21.9	339
Swede	American Purple Top	14.2	32.1	18.7	23.7	305
Swede	Dominion	15.4	27.9	16.1	22.0	335
Turnip	Purple Top	17.8	28.5	14.7	22.1	321
Turnip	Rack	17.3	27.2	14.1	21.1	346
Turnip	Pointer	17.8	26.1	14.3	22.2	326
Hybrid	Winfred	13.3	25.4	13.6	20.2	394
Hybrid	Pacer	18.6	27.5	13.8	22.2	322
Forage rape	Rangi	12.7	25.3	13.6	20.5	389
Forage rape	Barsica	13.4	24.8	12.7	17.6	441
Forage rape	Dwarf Essex	13.0	26.8	13.3	20.5	383
Forage rape	Bonar	13.4	27.7	13.9	20.5	379
Winter canola	Riley	12.7	27.3	13.0	20.6	374
Winter canola	Griffin	13.5	27.2	12.3	19.8	390
Winter canola	Athena	12.0	26.6	13.3	19.1	406
Winter canola	Summer	13.1	27.6	13.1	20.7	372
LSD (0.05)		2.2	2.2	1.6	2.0	42
CV%		9.5	5.1	6.8	5.8	6.0

Seeding date 16 May 2013; harvest date 26 October, 2013.

Cover crops brassicas cultivars trials

Although the month of August was dry in 2013 also, above average rainfall fell in September and cover crops had excellent yields at both locations, Fargo and Prosper. The turnip cultivars Appin and Pointer had the greatest total yield at both locations, Fargo and Prosper (Table 4).

Fig. 3. Forage brassica cover crops in Prosper, ND, October, 2013.

In about 80 days from planting to killing frost, some cover crops accumulated up to 5 Mg/ha of dry matter. Forage brassicas can grow at much lower temperatures than other crops and they are very frost tolerant tolerating down to -8 to -10˚C.

Using forage brassica as cover crops in North Dakota have a lot of potential. The weed and flea beetles pressure in the fall is much lower, brassicas provide excellent soil cover and protection, and can be used as forage for grazing.

Fig. 4 Turnip 'Appin' in Prosper, ND, October 2013.

Forage quality of leaves was evaluated for the cover crops cultivar trial in both locations (Table 5). Forage quality was much higher in Prosper than Fargo for all brassicas tested. These results were due to the greater available moisture in Prosper where plants produced much greater biomass and leaves.

Even though there was about a 100 RFQ points difference between both locations, the RFQ values ranking was similar. The quality analysis indicated that rapes, hybrids, and Ethiopian cabbage had the highest RFQ values or best quality in both locations. Crude protein was highest in the turnip cv. Appin in Fargo. Several brassicas approached 20% CP in Prosper.

Forage brassicas in general are a very high quality forage, highly digestible, and a very high CP content which is only a few percentages point below the CP content in legumes. Because of their high water content and highly digestible material, grazing must be supplemented with high fiber forage such as wheat straw or low quality grass hay.

Table 4. Fall-planted cover crops leaves, roots/stems and total dry matter yield in Fargo and Prosper, ND, in 2013.

Crop	Cultivar	Fargo			Prosper		
		Leaves	Roots/Stems	Total	Leaves	Roots/Stems	Total
		------------------------Dry matter yield (Mg/ha)----------------------					
Turnip	Appin	1.57	0.27	1.84	**4.17**	0.96	**5.14**
Turnip	New York	1.46	0.21	1.67	2.24	0.61	2.85
Turnip	Rack	0.96	0.23	1.19	2.39	0.39	2.78
Turnip	Pointer	1.49	0.18	1.67	**4.04**	0.97	**5.00**
Turnip	Purple Top	1.33	0.24	1.57	2.55	0.88	3.43
Turnip	Barkant	1.38	0.22	1.60	2.56	1.19	3.75
Rape	Barnapoli	0.90	0.18	1.08	2.74	0.30	3.04
Rape	Dwarf Essex	0.85	0.19	1.03	2.60	0.39	2.99
Hybrid	Winfred	0.92	0.20	1.12	2.75	0.37	3.12
Hybrid	Pasja	1.57	0.20	1.77	2.71	0.28	2.99
Hybrid	Hunter	1.44	0.16	1.61	2.80	0.31	3.11
Hybrid	T-Raptor	1.49	0.18	1.67	3.00	0.32	3.33
Hybrid	Vivant	1.76	0.17	1.93	2.63	0.28	2.91
Radish	Daikon	0.90	0.28	1.17	2.12	1.13	3.25
Radish	Graza	0.81	0.24	1.05	2.17	0.73	2.90
Radish	Groundhog	0.74	0.30	1.04	2.43	1.46	3.89
Eth. Cabb.	Corinne	0.70	0.09	0.78	1.97	0.29	2.26
LSD (0.05)		0.34	0.06	0.36	1.24	0.55	1.69

Seeding date 8-9 August, 2013; harvest date 21-15 October, 2013, Fargo and Prosper respectively.

Table 5. Fall-planted cover crops forage quality in Fargo and Prosper, ND, in 2013.

		Fargo					Prosper				
Crop	Cultivar	Ash	CP	ADF	NDF	RFQ	Ash	CP	ADF	NDF	RFQ
		--------------%--------------					--------------%--------------				
Turnip	Appin	20.4	21.3	19.1	27.4	258	14.5	18.6	16.1	20.1	383
Turnip	New York	19.6	17.6	17.2	26.9	265	15.1	17.4	15.0	19.8	383
Turnip	Rack	19.3	17.6	18.9	30.2	241	13.7	17.8	14.8	19.9	392
Turnip	Pointer	19.1	14.2	16.2	26.8	273	15.6	17.5	14.2	19.3	398
Turnip	Purple Top	18.9	16.3	17.3	27.4	264	14.4	17.0	14.7	19.6	396
Turnip	Barkant	20.4	15.3	17.3	28.1	255	15.1	16.0	14.3	20.0	386
Rape	Barnapoli	14.7	13.5	16.4	22.8	329	10.7	20.1	15.5	19.2	425
Rape	Dwarf Essex	14.2	14.8	18.1	25.2	298	11.0	17.8	14.5	18.0	450
Hybrid	Winfred	14.8	14.6	18.1	25.2	301	10.5	17.0	14.9	18.3	449
Hybrid	Pasja	20.8	14.7	18.7	29.6	246	15.8	16.4	14.7	19.5	391
Hybrid	Hunter	19.7	15.5	17.1	26.1	276	14.8	17.8	14.4	19.1	405
Hybrid	T-Raptor	19.5	14.8	17.1	28.0	260	14.8	15.0	15.3	20.4	379
Hybrid	Vivant	20.4	15.0	16.4	26.4	271	14.8	19.2	13.9	18.6	415
Radish	Daikon	20.7	17.7	22.8	31.5	224	16.2	19.3	17.8	23.6	320
Radish	Graza	20.4	18.3	19.3	28.5	243	13.9	20.7	15.6	21.1	366
Radish	Groundhog	20.4	15.0	24.1	33.6	213	15.4	18.5	17.7	23.5	320
Eth. Cabb.	Corinne	15.6	19.5	18.2	25.9	286	10.4	21.1	16.8	20.2	400
LSD		2.6	3.5	2.3	3.7	39	1.3	2.4	1.6	1.9	37
CV%		8.4	13.1	8.1	7.6	8.9	5.6	7.9	6.2	5.8	5.7

Seeding date 8-9 August, 2013; harvest date 21-15 October, 2013, Fargo and Prosper respectively.

In 2014, the cultivars Appin, Pointer and Barkant were the highest yielding in Fargo (Table 6). In Prosper, the turnips Appin, Rack, and Purple Top were the highest yielding cover crops. The cultivar Appin was the highest yielding at both locations both years. The forage yield of all cover crops were greater in Fargo and Prosper compared with yield in 2013. The rainfall in August of September of 2014 was excellent for the establishment and growth of cover crops.

The rape cultivar Dwarf Essex that has many growers excited as a cheap cover crop actually was one of the lowest yielding cover crops at both locations and years.

Table 6. Fall-planted cover crops leaves, roots/stems and total dry matter yield in Fargo and Prosper, ND, in 2014.

		Fargo			Prosper		
Crop	Cultivar	Leaves	Roots/Stems	Total	Leaves	Roots/Stems	Total
		------------------------Dry matter yield (Mg/ha)----------------------					
Turnip	Appin	3.99	1.67	**5.66**	2.81	1.51	**4.32**
Turnip	New York	2.93	1.87	4.80	2.12	1.20	3.32
Turnip	Rack	2.34	1.61	3.95	2.42	1.91	**4.33**
Turnip	Pointer	3.90	1.93	**5.82**	2.01	1.19	3.21
Turnip	Purple Top	2.57	0.99	3.56	3.80	2.05	**5.85**
Turnip	Barkant	4.81	1.60	**6.41**	1.73	1.30	3.04
Rape	Barnapoli	2.47	0.51	2.98	2.96	0.73	3.69
Rape	Dwarf Essex	2.50	0.69	3.18	1.76	0.90	2.66
Hybrid	Winfred	3.34	0.97	4.31	3.17	1.06	4.23
Hybrid	Pasja	3.83	0.81	4.64	3.13	0.79	3.91
Hybrid	Hunter	4.00	0.93	4.93	2.35	1.04	3.40
Hybrid	T-Raptor	3.20	0.62	3.82	2.41	1.03	3.44
Hybrid	Vivant	2.36	0.59	2.95	3.44	1.27	4.71
Radish	Daikon	2.78	1.72	4.50	1.39	1.79	3.18
Radish	Graza	1.50	1.27	2.77	1.29	1.44	2.74
Radish	Groundhog	2.35	2.16	4.51	1.43	1.73	3.15
Eth. Cabb.	Corinne	3.62	0.67	4.29	2.44	0.62	3.06
LSD (0.05)		1.77	0.68	2.08	1.84	0.94	2.62
CV%		36	36	31	49	47	45

Conclusions

Forage brassicas seeded in the spring can produce up to 10 Mg/ha with very high quality. Unfortunately, their future development as a crop in North Dakota is limited by the lack of herbicides available and also for the need of up to three applications of insecticide to control flea beetles.

Forage brassicas seeded in August as cover crop following a cereal crop have a much greater potential in the state. Forage yield of up to 5 Mg/ha of really high forage quality was produced in only 80 days of growth. Also, the weed and insect pressure this time of the year is much lower.

Further research to determine the benefits to the soil health and the following cash crop is needed to further advance the introduction of these crops.

Swede "Major plus" Carrington 2013

Hybrid "Winfred" Carrington 2013

Kale "Maris Kestrel", November, Fargo 2012

Kale "Sovereign" Carrington 2013

Turnip "Pointer" Prosper 2013

Radish "Groundhog" Prosper 2013


Flea beetle damage in August 2013 **Flea beetle damage in August 2013**

2. **Utilizing annual forages for late-fall and early winter grazing: Impacts on soil health, forage production, and cattle performance**
   E.M. Gaugler, K.K. Sedivec, D.L. Whitted, and B.W. Neville

Annual forages planted in late summer can provide an early winter grazing option to complement rangeland and serve as an alternative to dry lot feeding. From 2012 to 2014, three grazing treatments were tested on two cropping systems. A single-crop (annual cocktail forage crop) and dual-crop (cereal crop/annual cocktail forage crop) system were subjected to the following treatments: 1) full use, 2) 50 percent degree of disappearance, and 3) no use. Mid-gestation beef heifers were assigned to paddocks for a grazing period that began in mid-October and was projected to last 60 d. The objective was to identify which treatment would best maintain soil health while also serving the nutrient demands of beef cattle. Cattle fed in a dry lot system served as the control. In 2012 and 2014, barley served as the cereal crop and yielded an average of 1681.25 and 2152 kg/ha; respectively. The cereal crop in 2013, oats and peas, was deemed as a production failure. In 2012 and 2013, all systems provided neutral or increased final body condition score (BCS) and average daily gain (ADG). On average, cattle performance was greatest on 50 percent use of the cocktail crop, resulting in an ADG of 1.87 lb/d. A decrease in soil bulk density (g/cm^3), at a depth of 0-3 cm, was experienced in all years and in all treatment types.

RESEARCH IN PROGRESS

1. Nutrient cycling ability of forage radish and turnip previous to corn and soybean
Marisol Berti, Osvaldo Teuber, and Dulan Samarappuli

An experiment was established in Fargo and Prosper, ND, to determine the ability of forage radish and turnip to recycle nutrients. For this turnip and radish were planted in the fall of 2014, and in the spring of 2015 corn and soybean will be planted no till into the residue of the cover crops. Treatments will also include four nitrogen rates in the corn experiment. Cover crops and cash crops yield will be evaluated. Also, the N, P, and K content in the cover crops and cash crops biomass will be determined.

2. . Aerial seeding of cover crops in standing corn and soybean
Marisol Berti and David Ripplinger

The season in North Dakota is too short to plant a cover crop after corn or soybean harvest, but this can be done with aerial seeding of cover crops before harvest. Replicated experiments to optimize aerial seeding of cover crops will be established in standing corn and soybean. A check plot with no cover crop will be included. Cover crop seed will be broadcasted by hand on top the crop canopy at different growth stages. Initial and final stand count and phenological stages in corn and soybean, and the cover crops will be recorded. Total plant biomass and grain yield of both cash crops will be harvested. Nitrogen uptake by the cash crop and the cover crop will be calculated. Other evaluations will include light under the canopy, cover crop emergence, and soil moisture (soil volumetric water). Costs of production will consider the production input expenses including seed, fertility, and pest management costs.

3. **Corn-alfalfa intercropping: alfalfa as a cover crop in corn**
Marisol Berti, Johanna Lukascheswky, and David Ripplinger

An experiment designed as randomized complete block, with a split-plot arrangement with four replicates, was started in Fargo and Prosper in 2014 with the objective of optimizing productivity and economic feasibility of alfalfa by establishing it as an intercrop into the previous year's corn crop. Treatments include 1) corn at 61-cm row spacing, 2) corn at 76-cm row spacing 3) corn (61-cm)–alfalfa intercropped, 4) corn (76-cm)–alfalfa intercropped, 5) corn (61-cm)–alfalfa intercropped + prohexadione calcium (PHX), 6) corn (72-cm)–alfalfa intercropped + PHX, 7) Year 2, alfalfa alone on Treatments 1 and 2, 8) Year 2, corn at 61-cm, and 9) Year 2, corn at (76-cm). Alfalfa in Treatments 3, 4, 5, and 6 will continue to grow in Year 2. Plant height and forage yield of corn and alfalfa will be evaluated for each cut in alfalfa and for one cut in the fall in corn both years. Forage quality and corn N uptake will be evaluated. An economic analysis will be conducted to determine the economic benefits of intercropping.

4. **Dwight, ND (Richland County) Cover crops demonstration site**
Chandra M. Heglund and Abbey F. Wick

The objectives of this demonstration plot were to: i) identify mixes of cover crop species that most efficiently utilize water and scavenge Nitrogen (N) in a full season scenario and ii) working one-on-one with producers to test and answer local questions on the use of cover crops. The strip of plots was established on the south end of a quarter near Dwight, ND on July 15, 2014. Large portions of this quarter have historically been too wet to plant due to a high clay content (60%), compaction and reduced drainage. This is a fairly common problem for soils in the Red River Valley region. Cover crops plots were used to evaluate the effectiveness of different cover crop mixes to utilize water and scavenge N for following cash crop productivity. Each of the six mixes was replicated three times in 70 x 70 foot (21x21 m) plots and three "bare" plots were also established as control plots. Plots were broadcast seeded on July 15, 2014 and lightly incorporated into the soil using a grass drill. After the July 15, 2014 planting date, there were no precipitation events for four weeks. Table 1 depicts the six cover crop mixes used.

Table 1. Cover crop mixes used at the Dwight, ND Cover Crop Demonstration Site.

	Crops included
Mix 1	Annual Rye, Cereal Rye, Radish and Turnip
Mix 2	Annual Rye, Cereal Rye, Dwarf Essex and Sugarbeet
Mix 3	Oats, Triticale, Radish and Turnip
Mix 4	Oats, Triticale, Dwarf Essex and Sugarbeet
Mix 5	Annual Rye, Cereal Rye, Radish, Turnip, Sunflower, Winter Pea and Flax
Mix 6	Annual Rye, Cereal Rye, Dwarf Essex, Sugarbeet, Sunflower, Winter Pea and Flax

Plant and soil sampling was completed October 22, 2014. Cover crop establishment was similar across all plots; dominant species were Radish, Turnip and Dwarf Essex Rapeseed. Mix 6

(Annual Rye, Cereal Rye, Dwarf Essex, Sugarbeet, Sunflower, Winter Pea and Flax) had the highest biomass and Mix 3 (Oats, Triticale, Radish and Turnip) had the lowest at 2.54 ton ac $^{-1}$ and 1.16 ton ac $^{-1}$, respectively. Composite soil cores to three feet were collected from each replicated plot, and separated into 0-6", 6-12", 12-24" and 24-36" sections. Soil samples were analyzed for: N, P, K, % Organic Matter, % Water Content, pH and Soluble Salts (EC) on all depths collected. The top six inches were analyzed for aggregate size distribution and respiration via Solvita analysis.

Based on one year of data, soil N content and % soil moisture content showed differences among cover crop mixes. The "bare" plots had an average Nitrate-N concentration of 9.83 ppm in the 0-6" depth of soil, whereas the cover crop mixes ranged from 2.83 to 1.67 ppm Nitrate-N for this depth under Mix 2 and Mix 3, respectively. Percent soil moisture was also much higher in the "bare" plot than the mixes, throughout the entire soil core. The 0-6" depth of the bare check had a soil moisture content of 22.7%. Mix 6 was the most efficient water user, with moisture content of 9.61% for that same depth. The preliminary data indicate that cover crop mixes are effective for water usage and nutrient scavenging. All mixes preformed efficiently in scavenging N from the soil. Mixes 2, 4 and 6 were most efficient at water usage, with all mixes performing better than the bare check. Cover crop plots will be established at this site over the next several years and used for Extension programming to help answer local cover crop questions.

5. DeLamere, ND (Sargent County) Cover crops and salinity demonstration site
Chandra M. Heglund and Abbey F. Wick

The objectives of this demonstration site include: i) using cover crops to manage prevented plant and also soil salinity and ii) working one-on-one with producers to test and answer local questions on the use of cover crops. Due to wet spring conditions, the entire quarter was prevented plant. Additionally, about 20 acres of the field has high salinity levels (aka salt-affected) as a result of water upwelling into the field from ditches permanently filled with water for duck habitat. With salinity, we talk about dividing the quarter into separate "fields" based on conditions – i.e. if the soil is not salt-affected, manage it for soil health in general and if it is salt-affected, manage it with more salt-tolerant species that generally use more water. This field is the perfect example of this scenario where the 20 acres of saline soil along the north edge should be managed differently from the interior of the field that is not salt-affected. Thus, one cover crop mix (Dwarf Essex Rapeseed, Radish, Turnip, Barley, Sunflower and Sorghum Sudangrass) was used

to manage the salt-affected area on the north part of the field and the remaining interior of the field was seeded to (Dwarf Essex Rapeseed, Radish, Turnip, Barley) to provide cover, use water and build soil health in general. We also sectioned out a third area in the field by the approach and used Cereal Rye plus a straw mulch in response to several producers being interested in using Cereal Rye as a cover crop. Cover crops were seeded on August 3, 2014 and successful establishment was generally observed across the field, with the exception of a few very saline, high compaction areas near the field entrance where the rye was seeded.
This site serves as a demonstration resource for local producers interested in implementing cover crops on their fields. On September 17, 2014 a field day was held at this site, drawing over 120 local producers and agricultural industry interested in both use of cover crops and salinity management. Cover crops planted on this site were evaluated and discussed as one tool to manage soil salinity and improve overall soil health. Additionally, we used three soil pits to talk about rooting depth and water use of cover crops. Future objective for this site will be to continue to demonstrate the effectiveness of cover crops to manage salinity through extension events.

6. Long-term Organic Tillage Systems (LOTS) Study, Dickinson, ND.
Patrick M. Carr and Greta G. Gramig

There is considerable interest in reducing tillage among organic farmers in the Great Plains. A long-term study was established in 2009 to determine if continuous organic zero-till (OZ) systems could be developed and implemented successfully in western North Dakota. A 5-yr crop rotation that includes four grain crops (winter wheat, field pea, navy bean, and proso millet) along with two cover crops (winter rye and hairy vetch) was established under conventional- or clean-till (CT), reduced-till (RT), and OZ management in a randomized complete block with each crop phase by tillage combination replicated five times. Wheat and pea grain yields in the continuous OZ system have been < 60% of those produced under CT. Harvestable grain has not been produced during the navy bean and millet phases under OZ. Weed pressure has been severe and is worsening in the OZ system, in part because of the failure of fall-seeded rye and vetch cover crops to overwinter and produce adequate amounts of above-ground, rolled-crimped biomass to suppress weeds the following growing season. Use of sheep (*Ovis aries*) and acetic acid prior to seeding and after harvesting grain crops have failed to control perennial and several annual weed species. Lack of weed control currently prevents continuous OZ from being a viable option for most organic

farmers in the Great Plains and similar climatic regions.

7. Double-Cropping Annual Forages

Steve Zwinger and Steve Schaubert

Winter cereals have been evaluated as forage/cover crop at the CREC with the database demonstrating their value as reliable forage crop that provides cover and extends the haying/grazing season. The use of winter cereals as forage is a method of integrating cropland into a livestock system along with producing quality forage with dependable yields. One of the advantages of using winter cereals as a forage crop is the early spring growth along with an associated early harvest. When harvesting winter cereals as a forage crop there is a period of time where no crop is growing leaving an opportunity to sown a second crop of forage for haying, grazing or cover crop. Taking the forage crop off early allow the option of double cropping annual forages if adequate moisture and fertility levels are present along with variety selection and adapted crop choices.

The CREC evaluated winter cereals as a forage crop during the 2014 growing season with the goal of double cropping Piper sudangrass into each treatment after harvest. Winter cereals used in the trial were rye, triticale, wheat, and spelt. Rye varieties include Hazlet, a recent release from Ag Canada and ND exp., an experimental rye variety being developed by NDSU as a potential new variety. Both rye varieties were developed as a grain type variety. Thunder Cale and Metzger are private winter triticale varieties developed for forage use. Jerry winter wheat is an adapted winter grain variety developed by NDSU while Willow Creek is a winter wheat variety developed by MSU as a forage type. Oberkulmer spelt is a Swiss variety that is used for both grain and forage while Frank was developed by MSU as a grain variety. The trial was sown on September 24, 2013 into undisturbed flax stubble. Fall soil test results indicated 80 lbs /acre soil N with no additional fertilizer used. No herbicides were used on this trial. Rye, triticale and wheat were sown at 1.2 million PLS/ac with spelt sown in the hull at 110 lbs. PLS/acre All winter cereal treatments were harvested (Table 1) 7-10 days after heading in the anthesis stage. Double crop treatments (Table 3) of Piper sudangrass were sown on the same day the winter cereal was harvested to keep all treatments uniform. All sudangrass treatments were direct seeded into the harvested winter cereal stubble.

Results (Table 1) illustrate differences not only in yield and quality also the differences that exist in maturity or harvest date which is an important factor to consider if double cropping is a goal. Data is consistence with past performance with rye the earliest to harvest and spelt the last. The harvest period for the treatments in this trial was spread out over 15 days, June 23-July 7. Generally the order of harvest by maturity has been rye, triticale, wheat then spelt. This year maturity was similar with the exception of varieties selected for triticale and wheat which differed. Willow Creek wheat and Metzger triticale were later in maturity when compared to Thunder Cale and Jerry.

Forage yields (Table 1) gathered illustrate significant differences between the types of winter cereals and differences among varieties within types. Yield data gathered show a strong relationship in yield by harvest date. Yields significantly increased with later harvest dates in this trial. Lowest yields were from rye and triticale which was harvested on 23 June compared with the highest yields of spelt harvested on 7 July. Varietal differences within triticale and wheat demonstrate a significant yield increase as harvest dates were delayed. Metzger triticale had a 0.5

DM ton/ac increase when compared to the earlier variety Thunder Cale. A similar yield increase of 0.6 DM ton/ac occurred with Willow Creek wheat when compared to Jerry.

Quality data (Table 2) is consistent with past data illustrating slight differences among the crops used in this trial. Rye tends to be lower in quality when compared to wheat or other crops used. Although significant quality differences exist they are minor comparing the treatments. Jerry winter wheat had the highest crude protein and TDN along with the lowest fiber values. Relative Feed Value (RFV) use multiple quality parameters to measure the forage show Jerry the highest at 103 and Willow Creek the lowest at 80.

Results from the double crop of Piper sudangrass are presented in Table 3. Planting dates ranged from 23 June to 7 July depending on the previous harvest. Data gathered show the tallest plant heights were achieved from the earliest planting dates. The highest yields were also associated with the earliest planting dates of the sudangrass. Planting dates on 23 June averaged 1.75 DM tons/acre while the 7 July planting averaged 0.7 DM ton/acres totaling the first and second yield show minimal differences among the treatments. Total yields (data not presented) range from 3.7 DM ton/ac to 4.0 DM ton/ac.

The CREC will continue to evaluate double cropping annual forages as a forage management system. This trial will be continued in 2015 to gather multiyear performance of this strategy. Research trials will be expanded to add additional species to test how they will perform in a double crop forage system.

Figure 1. Willow Creek in boot stage and heading Metzger triticale on June 26.

Figure 2. Piper sudangrass on September 25 illustrating differences in growth by planting date.

Table 1. Forage yield of small grains in Carrington, ND.

Variety	Crop	Harvest date	Harvest stage	DM Forage yield
				tons/acre
DR02	rye	23-Jun	late anthesis	2.15
Hazlet	rye	23-Jun	late anthesis	2.02
Thunder Cale	triticale	23-Jun	late anthesis	2.05
Metzger	triticale	2-Jul	late anthesis	2.57
Jerry	wheat	26-Jun	mid anthesis	2.46
Willow Creek	wheat	7-Jul	mid anthesis	3.10
Oberkulmer	spelt	7-Jul	end anthesis	3.18
Frank	spelt	7-Jul	early anthesis	3.17
Mean				2.58
C.V.%				7.6
LSD (0.10)				0.24

DM = Dry matter.

Table 2. Forage quality of small grains in Carrington, ND.

Variety	CP	ADF	NDF	TDN	Ca	P	Mg	K	S	RFQ	RFV
			------------------------------			%		-------------------------------------			
DR02	10.4	42.1	66.6	51.8	0.40	0.28	0.15	2.43	0.11	78.40	90.37
Hazlet	11.3	41.4	65.6	52.2	0.40	0.29	0.16	2.30	0.12	80.29	91.57
Thunder Cale	11.0	40.2	64.2	53.1	0.41	0.27	0.16	2.25	0.13	83.45	96.99
Metzger	11.2	41.5	65.1	52.0	0.42	0.28	0.14	2.45	0.13	80.86	90.09
Jerry	11.4	38.8	62.6	54.3	0.40	0.28	0.16	1.92	0.12	87.08	103.21
Willow Creek	10.7	43.4	64.6	50.6	0.52	0.26	0.12	2.41	0.12	79.29	80.27
Oberkulmer	10.8	40.9	63.1	53.3	0.43	0.26	0.14	1.94	0.13	84.05	92.72
Frank	10.9	42.2	64.4	51.6	0.45	0.26	0.13	2.24	0.13	80.82	86.45
Mean	11	41.3	64.5	52.40	0.43	0.27	0.14	2.24	0.12	81.80	91.50
C.V.%	8.2	3.0	1.6	1.5	15.4	6.2	10.9	9.1	11.8	2.8	4.6
LSD (0.10)	NS	1.5	1.3	1.0	0.08	0.02	0.02	0.25	0.02	2.8	5.1

Table 3. Forage yield of sudangrass varieties planted as a double-crop after a winter cereal crop.

Variety	Crop	Planting date	DM Forage yield
			tons/acre
DR02	rye	23-Jun	1.71
Hazlet	rye	23-Jun	2.01
Thunder Cale	triticale	23-Jun	1.62
Metzger	triticale	2-Jul	1.31
Jerry	wheat	26-Jun	1.47
Willow Creek	wheat	7-Jul	0.64
Oberkulmer	spelt	7-Jul	0.78
Frank	spelt	7-Jul	0.76
Mean			1.29
C.V.%			22.9
LSD (0.10)			0.36

PUBLICATIONS (list within each category)

Peer-reviewed journal publications

Samarappuli, D., B.L. Johnson, H. Kandel, and M.T. Berti. 2014. Biomass yield and nitrogen content of annual energy/forage crops preceded by cover crops. Field Crops Res. 167:31-39.

Gesch, R., D. Archer, and M.T. Berti. 2014. Dual cropping winter camelina with soybean in the Northern Corn Belt. Agron. J. 106: 1735-1745.

Abstracts/ Presentations

Aponte, A., E. Deckard, R.W. Gesch, B.L. Johnson, D. Samarappuli, O. Teuber, and M.T. Berti. 2014. Double- and relay-cropping systems of oilseed and biomass crops for sustainable energy production. ASA-CSSA-SSSA International Annual Meetings. 2-6 November 2014, Long Beach, CA.

Carr, P.M., and G.G. Gramig. Continous organic zero-till: Elusive or illusory. In 2014 Annual Meeting Abstracts [CD-ROM computer disk]. ASA, CSSA, and SSSA, Madison, WI.

Gesch, R.W., D.W. Archer, M.T. Berti, and A. Aponte. 2014. Dual purpose oilseed cover crops for sustainable bioenergy production. ASA-CSSA-SSSA International Annual Meetings. 2-6 November 2014, Long Beach, CA.

Teuber, O., A. Aponte, L.J. Cihacek, E.L. Deckard, B.L. Johnson, D. Samarappuli, K. Sedivec, and M.T. Berti. 2014. Performance and production of brassicas cover crops in North Dakota. ASA-CSSA-SSSA International Annual Meetings. 2-6 November 2014, Long Beach, CA.

Berti, M.T., B.L. Johnson, R. Gesch, Y. Ji, K. Alisala, S. Menon, A. Aponte, S.R. Kamireddy, J. Lukascheswky, and W. Seames. 2014. Double-and relay-cropping systems for oil and biomass feedstock production in the North Central Region. 2014 North Central Regional SunGrant Center Annual Meeting. 27-28 March, 2014, Minneapolis, MN.

Proceedings publications

Berti, M.T., B.L. Johnson, R. Gesch, A. Aponte, J. Lukaschewsky, Y. Ji, and W. Seames. 2014. Energy balance of relay- and double-cropping systems for food, feed, and fuel in the North Central Region, USA. p. 103-107 *In* 21st European Biomass Conference and Exhibition. 23-27 June, 2014, Hamburg, Germany Available at http://www.etaflorence.it/proceedings/index.asp (verified 10 July 2014).

Extension publications/ field days

Berti, M.T., H. Kandel, D. Samarappuli, and B.L. Johnson. 2014. Cover crops for fall grazing or as a source of nutrients for subsequent crops. Crop and Pest Report No. 14, North Dakota State Univ. Ext. Serv. 6 August 2014. Available at http://www.ag.ndsu.edu/cpr

Gaugler, E.M., B.W. Neville, A.F. Wick, D.L. Whitted, and K.K. Sedivec. 2014. Utilizing annual forages in single- and dual-crop systems for late-fall and early winter grazing: Impacts on cattle performance and economics. p. 31. *In* 2014 North Dakota Beef report, North Dakota State University, Fargo.

Wick, A.F., D. Franzen, H. Kandel. 2014. Considering Cover Crops on Prevented Plant Ground. NDSU Crop and Pest Report, June 26. Available at: http://www.ag.ndsu.edu/cpr

Wick, A.F., H. Weiser, T. DeSutter. 2014. Managing Saline Soils. Progressive Forage Grower Magazine. (focus on use of cover crops for salinity management) available at: http://www.progressiveforage.com/forage-production/management/divide-and-conquer-managing-saline-soils

Scheve, A., A.F. Wick. 2014. Bringing Cover Crops and Soil Health to Traill County, Impact Report, NDSU Extension Service. Available at: http://www.ag.ndsu.edu/impactreports/reports/2014-impact-reports

Blawat, M., A.F. Wick. 2014. Cover Crops used as a Viable Tool for Soil Health, Impact Report, NDSU Extension Service. Available at: http://www.ag.ndsu.edu/impactreports/reports/2014-impact-reports

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Wick, A.F. 2014. Cover Crop Programs in the Red River Valley, Impact Report, NDSU Extension Service. Available at: http://www.ag.ndsu.edu/impactreports/reports/2014-impact-reports

Cover Crops Could Help Farmers Prep Wet Ground for Spring, July 29, 2014, Wick featured in Farm and Ranch Guide, article by: Ryan Crossingham. Available at: http://www.farmandranchguide.com/news/crop/cover-crops-could-help-farmers-prep-wet-ground-for-next/article_2e78772e-142d-11e4-b78d-001a4bcf887a.html

Wick, A.F. 2014. Cover Crops 101, Extension Education Video, InHouse Productions, available at: https://www.youtube.com/watch?v=nTXEj5CNBik

Annual Soil Health Field Day, August 15, 2014, Shawna Olson, KFGO Radio, Tour to Mooreton and Delamere, ND. (visited cover crop plots and had radio coverage during stops)

Cover Crops and Conservation Tillage Conference, November 19, Mick Kjar, Farm Talk 890.

Cover Crops and the Conservation Tillage Conference, October 16, 2014, Ken Morgan, IFN.

Cover Crop Use, October 16, 2014, Mick Kjar, Farm Talk 890.

Extension Field Days and Workshops

Soil Health Café Talk, special guest: Marisol Berti (cover crops); February 5, 2015, Wahpeton (15 attendees).

Soil Health Café Talk, special guest: Marisol Berti (cover crops); February 5, 2015, Milnor (15 attendees)

Cover Crop Plot Tour, October 21, 2014, Dwight, ND (Wick; 15 attendees).

Salinity Field Day, September 19, 2014, Grand Forks, ND (DeSutter, Wick, Knudson; 40 attendees)

Management Tools for Saline and Sodic Soils, September 17, 2014, Delamere, ND (Wick, Blawat, 120 attendees)

2nd Annual Soil Health Field Day: Tools to Take Home, August 21, 2014, Mooreton, ND (Wick; 135 attendees)

No-till Tour with Producers at Hoenhause Farm, July 21, 2014, Lisbon (Wick, Weiser; 21 attendees)

Cover Crops 101, July 9, 2014, Hillsboro, ND. Funded by ND SARE (Wick, Scheve; 35 attendees)

Cover Crops 101, June 30, 2014, Wahpeton, ND. Funded by ND Corn Growers (Wick; 65 attendees).

National Conference on Cover Crops and Soil Health Broadcast Summit. February 18, 2014, Fargo, ND (Wick, Gustafson; 15 attendees)

Grants

Eastern North Dakota Soil Salinity Specialist – Years Three Four and Five. 2012-2015, EPA-319, $191,921 (Franzen and Wick). (heavy emphasis on use of cover crops for saline soil management).

IMPACT STATEMENT (no more than 4 sentences)
Cover crops will impact North Dakota's economy by improving soil health, nutrient cycling, productivity of grain and energy crops, reducing expensive nitrogen inputs, and as a source of supplemental summer and fall forage.