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Evaluation of Cool Season Cover Crops in the Northern Great Plains

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ABSTRACT

Cool season annuals provide multiple benefits to production agriculture when planted as a cover crop. Benefits include weed suppression, controlling soil erosion, adding nitrogen, water management, increasing soil organic matter and other soil health improvement. Cover crops can also enhance wildlife habitat and provide food sources for pollinators and forage for grazing. Success of the cover crop planting depends on selection of the best adapted cultivar or variety that meets the planting objective. The purpose of this study was to evaluate fifty-nine commercially available cultivars and varieties of eight common annual, coo1 season species for their adaptation to the Northern Great Plains. Oats (*Avena sativa* L. and *Avena strigosa* Schreb.), cereal rye (*Secale cereal* L.), Austrian winter pea (*Pisum sativum* L.), daikon radish (*Raphanus sativus* L.), crimson clover (*Trifolium incarnatum* L.), red clover (*Trifolium pratense* L.), balansa clover (*Trifolium michelianum* Savi), and hairy vetch ((*Vicia villosa* Roth) and [*Vicia villosa* Roth ssp. *varia* (Host) Corb]) were evaluated for field emergence, winter hardiness, plant height, days after planting (DAP) to 50% bloom, and disease and insect resistance at the Bismarck, North Dakota Plant Materials Center in 2017 and 2018. The cover crops were planted in the spring and terminated in the fall by frost. Overall, field emergence was good for all species. The only species to exhibit winter hardiness was red clover, with all cultivars of the species showing excellent regrowth the following spring. All Austrian winterpea cultivars became severely diseased at or prior to flowering. Balansa clover remained small and was not vigorous. Most of the cereal rye cultivars had abundant leaves but very few seedheads. The exceptions were Merced and FL401. They had early and abundant flowering but very few leaves. Crimson clover was variable in size and exhibited some moisture stress in 2018. Hairy vetch had good establishment and plants had abundant horizontal spread. The hairy vetch cultivars ‘Villana’ and ‘TNT produced few or no flowers. The daikon radishes were vigorous, flowered and produced seeds, except for ‘Graza’, which remained vegetative. Additional information such as biomass production, forage quality, and salinity tolerance of best performing cover crop cultivars would be useful to maximize their use as a cover crop in the Northern Great Plains.

INTRODUCTION

Utilizing annual, cool season grasses and legumes as cover crops improves soil health, conserves energy, builds resilience, and manages climate risk (Lal, 2004; Reicosky and Forcella, 1998; Hargrove, 1986; Reeves, 1994). Cool season, annual legumes such as hairy vetch and crimson clover reduce nitrogen inputs of subsequent commodity crops (Singh et al., 2004; Smith et al., 1987), while non-leguminous cover crops, such as small grains, effectively limit nitrate leaching and soil erosion (Meisinger et al., 1991). However, multiple benefits are not achieved unless the best adapted cultivar(s) are planted that meet the planting objectives (i.e. weed suppression, nitrogen scavenging, reduce soil erosion) and the end-user’s expectations. The purpose of this study is to evaluate growth characteristics of annual, cool season grass, legume, and forb cultivars to determine their adaptation for cover cropping in the Northern Great Plains.

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MATERIALS AND METHODS

The study was conducted at the USDA-Natural Resources Conservation Service Plant Materials Center, Bismarck, North Dakota in 2017 and 2018. Annual, cool seasons were planted on a pure live seed (PLS) basis (Table 1). Legumes were not inoculated with rhizobia before seeding. Plots were planted 5 June 2017 and 16 May 2018 with a Truax/Kincaid small plot cone seeder into a tilled seedbed. Rye and Austrian winterpea had to be reseeded on 6 June 2018 due to drill issues. Soils were a Mandan silt loam. Each plot was a single row measuring 20 feet long. Rows were spaced 56 inches apart. Fertility was adequate at the site, so no fertilizer was applied. The 2018 plots were planted adjacent to the 2017 plots so that growing conditions were similar but contamination from the previous year was avoided. Plots received approximately one-inch of supplemental irrigation a few days after planting in 2017 to germinate the seed. No irrigation was applied in 2018.

Approximately every 7 days field emergence was estimated in each plot for four weeks after planting using the following rating scale: 0 = poor (<25% germination), 1 = moderate (30-60%), 2 = good (65–85%), 3 = excellent 90-100%). Entries were evaluated for disease and pest damage (rated from 0–5, where 0 = no damage and 5 = severe damage) at 50% bloom (varied by species and cultivar).

Results from preliminary plots grown for the full season in 2016 indicated red clover was the only species in the study that was winter hardy. Therefore, only the red clover was counted by estimating plants in a 3-ft section of row in each plot in October and in April of 2017 and 2018. The other species were observed for winter hardiness, but no counts were made in the fall before overwintering. Bloom period was monitored by noting the date of 50% bloom. Average plant height was determined at 50% bloom on the vegetative growth.

The experimental design was a randomized complete block with 4 replications. To determine variation among cultivars within a species, a mean and standard deviation were reported.

RESULTS AND DISCUSSION

Monthly rainfall totals and temperatures were from US Climate Data reports for Bismarck, North Dakota. The weather station for Bismarck is located at the National Weather Service which is directly across the road from the Bismarck Plant Materials Center. The total rainfall for April through October 2017 was 11.29 inches. The total rainfall for April through October 2018 was 14.38 inches. The average rainfall is 14.83. Rainfall amounts for each month can be found in Fig. 1. The first killing frost occurred early in October of 2017 and 2018. Low average temperatures in February averaged below 0º F both years (Fig. 2).

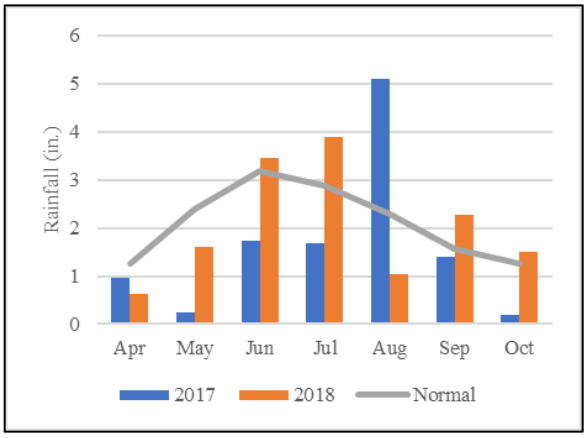

Fig 1. Monthly and normal rainfall in Apr.-Oct. 2017 and 2018, Bismarck, ND.

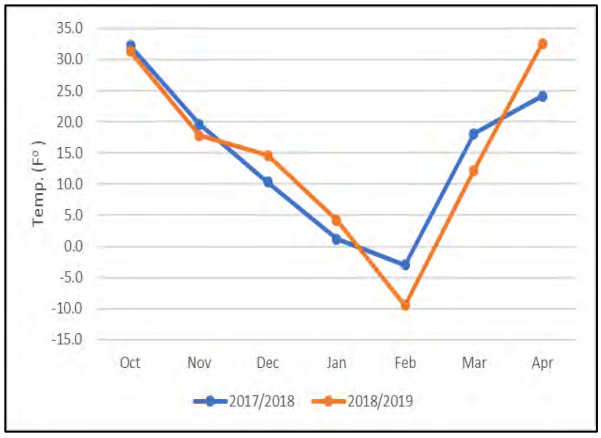

Fig 2. Monthly average low temperature in Oct.-Apr in 2017-2018 and 2018-2019, Bismarck, ND.

Table 1. Species, cultivars and seeding rates of annual cool seasons planted in 2017 and 2018 at the USDA NRCS Plant Materials Center, Bismarck, ND.

Common name	Species	Cultivar	PLS lb/acre	% PLS	Seeding rate lb/acre
Austrian winter pea	*Pisum sativum*	Arvica 4010	70	94	74
Austrian winter pea	*Pisum sativum*	Dunn	70	85	82
Austrian winter pea	*Pisum sativum*	Frost Master	70	85	82
Austrian winter pea	*Pisum sativum*	Lynx	70	96	71
Austrian winter pea	*Pisum sativum*	Maxum	70	91	76
Austrian winter pea	*Pisum sativum*	Survivor 15	70	80	88
Austrian winter pea	*Pisum sativum*	Whistler	70	90	78
Austrian winter pea	*Pisum sativum*	Windham	70	80	88
Balansa clover	*Trifolium michelianum*	Fixation	5	47	11
Balansa clover	*Trifolium michelianum*	Frontier	5	58	9
Black oats	*Avena sativa*	Cosaque	60	83	72
Black seeded oats	*Avena strigosa*	Soil Saver	60	98	61
Cereal Rye	*Secale cereale*	Aroostook	100	90	111
Cereal Rye	*Secale cereale*	Bates	100	88	113
Cereal Rye	*Secale cereale*	Brasetto	100	92	109
Cereal Rye	*Secale cereale*	Elbon	100	88	114
Cereal Rye	*Secale cereale*	FL 401	100	80	126
Cereal Rye	*Secale cereale*	Guardian	100	93	108
Cereal Rye	*Secale cereale*	Hazlet	100	84	119
Cereal Rye	*Secale cereale*	Maton	100	90	111
Cereal Rye	*Secale cereale*	Maton II	100	91	110
Cereal Rye	*Secale cereale*	Merced	100	84	119
Cereal Rye	*Secale cereale*	Oklon	100	90	112
Cereal Rye	*Secale cereale*	Rymin	100		
Cereal Rye	*Secale cereale*	Wheeler	100	82	122
Cereal Rye	*Secale cereale*	WinterGrazer 70	100	78	128
Cereal Rye	*Secale cereale*	Wren’s Abruzzi	100	84	119
Crimson clover	*Trifolium incarnatum*	AU Robin	18	50	32
Crimson clover	*Trifolium incarnatum*	AU Sunrise	18	46	43
Crimson clover	*Trifolium incarnatum*	AU Sunup	18	92	20
Crimson clover	*Trifolium incarnatum*	Contea	18	60	30
Crimson clover	*Trifolium incarnatum*	Dixie	18	53	34
Crimson clover	*Trifolium incarnatum*	KY Pride	18	56	18
Hairy vetch	*Vicia villosa*	CCS Groff	18	90	20
Hairy vetch	*Vicia villosa*	Purple Bounty	18	78	23
Hairy vetch	*Vicia villosa*	Purple Prosperity	18	90	20
Hairy vetch	*Vicia villosa*	Villana	18	94	20
Hairy vetch	*Vicia villosa*	TNT	18	75	20
Woollypod vetch	*Vicia villosa* subsp. *varia*	Lana	18	98	18

Table 1 (cont.). Species, cultivars and seeding rates of annual, cool seasons planted in 2017 and 2018 at the USDA NRCS Plant Materials Center, Bismarck, ND.

Common name	Species	Cultivar	PLS lb/acre	% PLS	Seeding rate lb/acre
Oilseed radish	*Raphanus sativus*	Big Dog	9	93	10
Oilseed radish	*Raphanus sativus*	Concorde	9	88	10
Oilseed radish	*Raphanus sativus*	Control	9	88	10
Oilseed radish	*Raphanus sativus*	Defender	9	97	9
Oilseed radish	*Raphanus sativus*	Driller	9	97	9
Oilseed radish	*Raphanus sativus*	Eco-till	9	88	10
Oilseed radish	*Raphanus sativus*	Graza	9	93	10
Oilseed radish	*Raphanus sativus*	Groundhog	9	85	11
Oilseed radish	*Raphanus sativus*	Lunch	9	93	10
Oilseed radish	*Raphanus sativus*	Nitro	9	98	9
Oilseed radish	*Raphanus sativus*	Sodbuster Blend	9	94	10
Oilseed radish	*Raphanus sativus*	Tillage	9	90	10
Red clover	*Trifolium pratense*	Cinnamon Plus	9	61	15
Red clover	*Trifolium pratense*	Cyclone II	9	59	15
Red clover	*Trifolium pratense*	Dynamite	9	62	15
Red clover	*Trifolium pratense*	Freedom	9	61	15
Red clover	*Trifolium pratense*	Kenland	9	82	11
Red clover	*Trifolium pratense*	Mammoth	9	88	10
Red clover	*Trifolium pratense*	Starfire	9	49	15
Red clover	*Trifolium pratense*	Wildcat	9	89	15

Balansa Clover

Both balansa clover cultivars emerged within 21 days. Emergence for 'Fixation' was slightly quicker than for 'Frontier' (Table 2). 'Frontier' had very little foliage and had a very short stature. 'Fixation' was taller (Table 3) and had more leaf material than 'Frontier', but neither produced abundant forage. Horizontal spread was good. In 2017 'Fixation' averaged 35 inches and 'Frontier' averaged 23 inches horizontal growth. Vigor was fair for both cultivars. Both cultivars exhibited stress, likely related to heat and/or drought by the end of the growing season. Some mature seed was produced before frost both years. When planted in the spring as a full season cover crop, the species exhibited no winter hardiness.

Table 2. Mean values and standard deviations of emergence groups (see below) of balansa clover at 7, 14, 21 and 28 days after planting in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Days after planting/Year							
	7		14		21		28	
	2017	2018	2017	2018	2017	2018	2017	2018
Fixation	0.5	1.8	0.5	2.8	3.0	3.0	3.0	3.0
Frontier	0.0	1.3	0.0	2.0	3.0	3.0	3.0	3.0
Mean	0.3	1.5	0.3	2.4	3.0	3.0	3.0	3.0
SD[2/]	0.5	0.5	0.5	0.5				

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence). [2/] Standard deviation.

Table 3. Mean values and standard deviations for plant height and days after planting to 50% bloom for balansa clover cultivars in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018
Fixation	11.3	15.0	63.0	60.0
Frontier	2.8	2.0	43.0	42.0
Mean	7.0	8.5	53.0	51.0
SD[1/]	4.6	7.0	10.7	10.0

Black Oats

Black oats and black seeded oats emergence were good. 'Cosaque' emergence was slightly quicker than 'Soil Saver' (Table 4). Dry field conditions at planting in 2017 likely slowed emergence. 'Soil Saver' was at 50% bloom approximately 71 days after planting in 2017 and 60 days after planting in 2018 (Table5). 'Cosaque' produced no seed heads in 2017. In 2018, less than 50% of the 'Cosaque' plants produced seed heads. Flowering was at least 30 days later than 'Soil Saver'. The exact flowering date was not captured, but 'Cosaque' had not yet developed seed heads when 'Soil Saver' was flowering. Disease was noted in 2017 and 2018 for both cultivars. Disease was severe for 'Cosaque' in 2017. When planted in the spring as a full season cover crop, the species had no winter hardiness.

Table 4. Mean values and standard deviations of emergence groups (see below) of black seeded oats and black oats at 7, 14, 21 and 28 days after planting in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Days after planting							
	7		14		21		28	
	2017	2018	2017	2018	2017	2018	2017	2018
Cosaque	2.0	2.5	2.3	3.0	3.0	3.0	3.0	3.0
Soil Saver	1.5	1.5	1.5	3.0	3.0	3.0	3.0	3.0
Mean	1.8	2.0	1.9	3.0	3.0	3.0	3.0	3.0
SD[2/]	0.5	1.1	0.6					

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence). [2/] Standard deviation.

Table 5. Mean values and standard deviations for plant height and days after planting to 50% bloom for black oats cultivars in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018
Cosaque	17.5	30.8	n/a	n/a
Soil saver	21.3	28.0	71.0	60.0
Mean	19.4	29.0	71.0	60.0
SD[1/]	2.6	2.1		

SD[1/] Standard deviation.

Cereal Rye

Emergence of all rye cultivars was within 14 days in 2018, with most emerging within 7 days (Table 6). Dry conditions at planting in 2017 slowed emergence. The only cultivars to produce heads on the entire row were 'Merced' and 'FL401'. Both cultivars were at 50% flowering within approximately 42 days after planting. 'Merced' and 'FL401' plants grew to a height of approximately 40 inches (head height) but produced very few leaves, making them poor cultivar choices when forage production is a goal of the cover crop. 'Bates' produced heads on approximately 50% of the plants in the stand in 2018. 'Wrens Abruzzi', 'Maton II', and 'Wintergrazer 70' produced heads on about 25-30% of plants within a stand in 2018. Far fewer heads were produced in 2017 on all cultivars except FL401 and Merced. All cultivars were severely diseased when observed on August 30, 2017. On August 8, 2018 disease was moderate for most cultivars. All cultivars lacked winter hardiness. Lack of seed production may be a desirable trait when planting cereal rye as a full season cover crop. Further evaluation would be needed to find a leafy cultivar that would not produce seed and would have disease resistance. When planted in the spring as a full season cover crop, the species had no winter hardiness.

Table 6. Mean values and standard deviations for field emergence of emergence groups (see below) of cereal rye cultivars at 7, 14, 21 and 28 days after planting in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Days after planting							
	7		14		21		28	
	2017	2018	2017	2018	2017	2018	2017	2018
Aroostock	1.0	2.8	3.0	3.0	3.0	3.0	3.0	3.0
Bates	1.0	2.8	3.0	3.0	3.0	3.0	3.0	3.0
Brasetto	1.0	2.8	3.0	3.0	3.0	3.0	3.0	3.0
Elbon	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
FL 101	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Guardian	n/a	2.3	n/a	3.0	n/a	3.0	n/a	3.0
Hazlet	1.0	2.8	3.0	3.0	3.0	3.0	3.0	3.0
Maton	1.0	2.5	3.0	3.0	3.0	3.0	3.0	3.0
Maton II	0.8	3.0	2.3	3.0	3.0	3.0	3.0	3.0
Merced	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Oklon	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Rymin	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Wheeler	0.8	3.0	2.3	3.0	3.0	3.0	3.0	3.0
Wintergrazer 70	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Wren Abruzzi	1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
Mean	1.0	2.9	2.9	3.0	3.0	3.0	3.0	3.0
SD[/2]	0.3	0.4	0.6					

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence). SD[2/] standard deviation.

Crimson Clover

Generally, emergence was within 14 days for all cultivars (Table 7). Plants were taller and bloomed earlier in 2018 compared to 2017. 'AU Sunup' had the shortest height and was the earliest blooming cultivar, with seed setting noted on July 19, 2018. 'KY Pride' was the slowest to reach 50% bloom (Table 8). The reason for the wide variation in DAP to 50% bloom between 2017 and 2018 is not known. Ponding of irrigation water and below normal, precipitation from May-July in 2017 may have been contributing factors. Height was variable within cultivars. Drought, heat and rabbit/deer predation

stressed crimson clover. No cultivar consistently expressed symptoms. When planted in the spring as a full season cover crop, crimson clover had no winterhardiness. However, some reseeding occurred.

Table 7. Mean values and standard deviations of emergence groups (see below) of crimson clover cultivars at 7, 14, 21 and 28 days after planting in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Days after planting							
	7		14		21		28	
	2017	2018	2017	2018	2017	2018	2017	2018
AU Robin	2.0	2.5	3.0	3.0	3.0	3.0	3.0	3.0
AU Sunrise	2.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
AU Sunup	2.0	1.3	3.0	2.3	3.0	3.0	3.0	3.0
Contea	2.0	1.8	3.0	2.8	3.0	3.0	3.0	3.0
Dixie	2.0	2.5	3.0	3.0	3.0	3.0	3.0	3.0
Kentucky Pride	2.0	2.5	3.0	3.0	3.0	3.0	3.0	3.0
Mean	2.0	2.3	3.0	2.8	3.0	3.0	3.0	3.0
SD[/2]		0.8		0.4				

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence; 2 = good (65-85% emergence); 3 = excellent (90-100% emergence). SD[2/] standard deviation.

Table 8. Mean values and standard deviations for plant height and days after planting to 50% bloom for crimson clover cultivars in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Plant height (in.)		DAP to 50% bloom	
	2017	2018		
AU Robin	17.5	19.3	86.3	63.0
AU Sunrise	17.8	19.8	85.0	62.0
AU Sunup	13.0	16.3	64.5	50.0
Contea	14.3	18.3	93.5	70.0
Dixie	17.8	18.0	93.5	68.5
Kentucky Pride	15.5	18.3	101.0	76.5
Mean	16.0	18.3	85.3	65.0
SD[1/]	3.0	2.1	14.3	9.2

Hairy Vetch

Most hairy vetch cultivars emerged within 14 days in 2018 (Table 9). Emergence was slower in 2017, likely due to dry soil conditions at the time of seeding. Purple Bounty had slightly slower emergence both years. 'Lana' woollypod vetch was the tallest cultivar and bloomed the earliest (Table10). 'Villana' produced no flowers and 'TNT' produced very few flowers in 2017 and 2018. To reduce contamination in a grain crop following hairy vetch, cultivars lacking seed production potential may be desirable. Horizontal vine growth of all cultivars was excellent. When planted in the spring as a full season cover crop, the species had no winter hardiness.

Table 9. Mean values and standard deviations of emergence groups (see below) of hairy vetch cultivars at 7, 14, 21 and 28 days after planting in 2017 and-2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Days after planting							
	7		14		21		28	
	2017	2018	2017	2018	2017	2018	2017	2018
CCS Groff	1.0	0.0	2.0	3.0	3.0	3.0	3.0	3.0
Lana	0.8	2.3	1.5	3.0	3.0	3.0	3.0	3.0
Purple Bounty	0.5	0.5	1.5	2.8	3.0	3.0	3.0	3.0
Purple Prosperity	0.8	1.3	1.8	3.0	3.0	3.0	3.0	3.0
TNT	1.0	3.0	2.0	3.0	3.0	3.0	3.0	3.0
Villana	0.8	2.8	1.5	3.0	3.0	3.0	3.0	3.0
Mean	0.8	1.6	1.7	3.0	3.0	3.0	3.0	3.0
SD[/2]	0.4	1.2	0.6	0.2				

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence). SD[2/] standard deviation.

Table 10. Mean values and standard deviations for plant height and days after planting to 50% bloom for hairy vetch cultivars in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018
CCS Groff	17.5	16.8	53.0	56.3
Lana	19.8	17.3	49.5	51.0
Purple Bounty	16.3	17.3	53.0	54.8
Purple Prosperity	16.3	15.5	53.0	53.8
TNT	9.8	n/a	n/a	n/a
Villana	11.0	n/a	n/a	n/a
Mean	15.1	16.7	52.1	53.9
SD[1/]	4.5	1.5	2.4	3.1

[1/]SD - Standard deviation.

Daikon Radish

Radish emergence was within 7 days in 2018 for most cultivars (Table 11). Emergence was slower in 2017 due to dry seedbed conditions. 'Graza' was the slowest to emerge both years. 'Concorde' was the earliest blooming cultivar (Table 12). Vegetative heights at 50% bloom were similar for most cultivars. 'Lunch' was slightly shorter and slower to flower in 2017. 'Graza' was the only cultivar that did not flower, so would not reseed. Its leaves were large and abundant and grew to a height of approximately 30 inches by the end of the 2018 growing season. Observations also indicated that 'Graza; had abundant tuber growth. Leaf holes, likely caused by flea beetles, were noted in August 2018 for all cultivars. Cultivars were mostly done flowering and had produced seed pods, so plant growth was not greatly

impacted. Damage was not noticed at 50% bloom. 'Graza' leaves had less predation. Additional data on tuber growth may be beneficial in selecting a radish cultivar for improving water infiltration and reducing soil compaction.

Table 11. Mean values and standard deviations of emergence groups (see below) of daikon radish sources at 7, 14, 21 and 28 days after planting in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Days after planting							
	7		14		21		28	
	2017	2018	2017	2018	2017	2018	2017	2018
Big Dog	2.0	3.0	2.8	3.0	3.0	3.0	3.0	3.0
Concorde	2.0	3.0	2.8	3.0	3.0	3.0	3.0	3.0
Control	2.0	3.0	2.8	3.0	3.0	3.0	3.0	3.0
Defender	1.0	2.5	1.5	3.0	3.0	3.0	3.0	3.0
Driller	1.5	3.0	2.5	3.0	3.0	3.0	3.0	3.0
EcoTill	1.8	3.0	2.3	3.0	3.0	3.0	3.0	3.0
Graza	0.0	1.3	0.0	2.8	3.0	3.0	3.0	3.0
Groundhog	2.0	2.8	2.8	3.0	3.0	3.0	3.0	3.0
Lunch	1.3	2.0	2.0	3.0	3.0	3.0	3.0	3.0
Nitro	1.8	3.0	2.0	3.0	3.0	3.0	3.0	3.0
Sodbuster	1.0	2.0	1.5	3.0	3.0	3.0	3.0	3.0
Tillage	1.5	2.5	1.8	3.0	3.0	3.0	3.0	3.0
Mean	1.5	2.6	2.0	3.0	3.0	3.0	3.0	3.0
SD[2/]	0.7	0.6	1.0	0.1				

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence). SD[2/] standard deviation.

Table 12. Mean values and standard deviations for plant height and days after planting to 50% bloom for daikon radish cultivars in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018
Big Dog	21.5	14.3	54.0	47.0
Concorde	27.5	19.8	47.5	42.8
Control	25.8	16.3	57.3	54.8
Defender	25.0	18.3	55.0	55.0
Driller	23.5	14.3	52.3	48.5
EcoTill	21.8	15.0	52.0	49.3
Graza	n/a	n/a	n/a	n/a
Groundhog	22.3	15.5	56.5	49.3
Lunch	17.3	12.0	61.5	53.8
Nitro	22.3	15.3	58.5	48.5
Sodbuster	21.0	14.5	57.0	53.0
Tillage	22.8	15.3	53.3	45.3
Mean	22.1	15.5	55.0	49.8
SD[1/]	3.8	3.1	5.2	4.4

[1/]SD - Standard deviation.

Red Clover

Emergence was within 21 days for all cultivars (Table14). Bloom was later in 2017 compared to 2018 (Table 15). 'Mammoth' had some flowers but less than 50% of the plants bloomed either year. Red clover flowering was indeterminate and extended for a long period of time. It was noted on 9/26/2018 that plants continued to bloom. Red clover was grazed by rabbit and deer throughout the growing season and gophers destroyed some plants, making it difficult to accurately measure height. Plants in 2018 became stressed by the middle of August, with leaf tips drying, likely due to heat. All red clover cultivars overwintered and produced full stands both years. On 6/12/2018, all cultivars that had been planted in 2017 had blooms except for 'Mammoth'. Plants from the 2018 planting emerged in April 2019. On 5/29/2019 plants were approximately 1 foot tall and severely grazed. Red clover also showed winter hardiness in preliminary plots planted in 2016.

Table 13. Mean values and standard deviations of emergence groups (see below) of red clover cultivars at 7, 14, 21 and 28 days after planting in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Days after planting							
	7		14		21		28	
	2017	2018	2017	2018	2017	2018	2017	2018
Cinnamon Plus	1.5	1.5	1.8	2.3	3.0	3.0	3.0	3.0
Cyclone II	2.0	1.5	2.3	2.5	3.0	3.0	3.0	3.0
Dynamite	2.0	2.3	2.5	2.8	3.0	3.0	3.0	3.0
Freedom	2.0	1.8	2.5	2.5	3.0	3.0	3.0	3.0
Kenland	2.0	1.3	1.8	2.0	3.0	3.0	3.0	3.0
Mammoth	2.0	2.3	2.3	2.8	3.0	3.0	3.0	3.0
Starfire II	2.0	1.0	2.0	2.0	3.0	3.0	3.0	3.0
Wildcat	2.0	2.3	2.5	3.0	3.0	3.0	3.0	3.0
Mean	1.9	1.7	2.2	2.5	3.0	3.0	3.0	3.0
SD[/2]	0.4	0.6	0.6	0.5				

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence; 2 = good (65-85% emergence); 3 = excellent (90-100% emergence). SD[2/] standard deviation.

Table 14. Mean values and standard deviations for plant height and days after planting to 50% bloom for red clover cultivars in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018
Cinnamon Plus	20.3	16.3	83.8	69.0
Cyclone II	19.3	17.0	80.3	66.0
Dynamite	15.5	13.3	82.5	72.0
Freedom	19.8	16.3	80.3	66.0
Kenland	19.8	17.8	77.0	64.0
Mammoth	13.5	11.5	n/a	n/a
Starfire II	20.0	15.8	82.5	73.5
Wildcat	18.5	17.8	83.5	66.0
Mean	18.3	16.0	81.4	68.0
SD[1/]	3.1	2.2	4.1	4.4

[1/]SD - Standard deviation.

Austrian Winter Pea

Emergence was within 14 day for all cultivars in 2018 (Table 15). In 2017, emergence was slower due to dry seedbed conditions. 'Windham' was at 50% bloom sooner than the other cultivars, at 51 and 46 days after planting in 2017 and 2018, respectively. Plants began to develop disease when plants began to set pod and were still flowering, killing all plants before they had completely matured. In 2018, 'Survivor 15' became diseased before reaching 50% bloom. Disease may not be as severe if peas were planted in a mix where the concentration of pea plants was less. When planted in the spring as a full season cover crop, the species had no winter hardiness.

Table 15. Mean values and standard deviations of emergence groups (see below) of winter pea cultivars at 7, 14, 21 and 28 days after planting in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Days after planting							
	7		14		21		28	
	2017	2018	2017	2018	2017	2018	2017	2018
Arvica 4010	0.8	1.5	1.8	3.0	3.0	3.0	3.0	3.0
Dunn	0.5	0.3	1.5	3.0	3.0	3.0	3.0	3.0
Frost Master	0.0	0.3	1.0	3.0	3.0	3.0	3.0	3.0
Lynx	0.0	0.3	1.0	3.0	3.0	3.0	3.0	3.0
Maxum	0.3	0.5	1.3	3.0	3.0	3.0	3.0	3.0
Survivor 15	1.0	2.0	2.0	3.0	3.0	3.0	3.0	3.0
Whistler	0.0	0.8	1.0	3.0	3.0	3.0	3.0	3.0
Windham	0.0	1.0	1.0	3.0	3.0	3.0	3.0	3.0
Mean	0.3	0.8	1.3	3.0	3.0	3.0	3.0	3.0
SD[/2]	0.5	0.8	0.7					

[1/] 0 = poor (<25% emergence); 1 = moderate (30-60% emergence); 2 = good (65-85% emergence); 3 = excellent (90-100% emergence). SD[2/] standard deviation.

Table 16. Mean values for plant height and days after planting to 50% bloom for winter pea cultivars in 2017 and 2018 at the USDA-NRCS Plant Materials Center, Bismarck, ND.

Cultivar	Plant height (in.)		DAP to 50% bloom	
	2017	2018	2017	2018
Arvica 4010	32.5	25.8	58.5	51.7
Dunn	29.3	21.3	63.3	51.0
Frost Master	23.8	23.8	63.0	53.0
Lynx	13.8	12.5	61.5	51.0
Maxum	30.0	23.8	58.3	49.0
Survivor 15	31.0	n/a	n/a	n/a
Whistler	16.5	16.5	61.5	55.0
Windham	15.0	14.3	51.0	46.0
Mean	24.0	19.6	59.6	50.7
SD[1/]	8.0	5.7	5.0	4.0

[1/]SD - Standard deviation.

CONCLUSIONS

Choosing the best adapted cover crop is the first step to a successful cover crop planting. The 2-year evaluation of commercially available cereal rye, crimson clover, hairy vetch, red clover, Austrian winter pea, balansa clover, and black oats and black seeded oats provided beneficial information on best adapted cultivars and varieties for the Northern Great Plains. Most of the species and cultivars exhibited good adaptation based on field emergence and DAP to 50% bloom. Red clover was the only species in the trial that was winter hardy when planted as a full season cover crop. Additional trials are needed to determine winter hardiness and plant performance when planted after grain harvest or inter-seeded into a crop. Additional information is also needed on biomass production of best performing cultivars to maximize cover crop benefits and to further describe their productivity and adaptation in the region.

REFERENCE

Hargrove, W.L. 1986. Winter legumes as a nitrogen source for no-till grain sorghum. Agron. J, 78:70-74.

Lal, R. 2004. Soil carbon sequestration impacts on global climate change and food security. Sci.: 304 no. 5677 pp. 1623-1627.

Meisinger, J.L., W.L. Hargrove, R.L. Mikkelsen, J.R. Williams, and V.W. Benson. 1991. Effects of cover crops on groundwater quality. *In* Cover Crops for Clean Water; W.L. Hargrove: Soil Water Conserv. Soc., Ankeny, IA p 9-11.

Reeves, D.W. 1994. Cover crops and rotations. pp 125-172. *In* J.L. Hatfield and B.A. Stewart (eds). Advances in Soil Science; Crops and Residue Management. Lewis Publishers, CRC Press Inc., Boca Raton, FL.

Reicosky, D.C. and F. Forcella. 1998. Cover crop and soil quality interactions in agroecosystems. J. Soil and Water Conserv. p. 224-229.

Singh, Y., B. Singh, J.K. Ladha, C.S. Khind, R.K. Gupta, O.P. Meelu, and E. Pasuquin. 2004. Long-term effects of organics inputs on yield and soil fertility in the rice-wheat rotation. Soil Sci. Soc. of Amer. J. 68: 845-853.

Smith, M.S., W.W. Frye, and J.J. Varco. 1987. Legume winter cover crops. Advances in Soil Sci., 7:95-139.

Statistix 10. 2013. Analytical software, Tallahassee, FL.

USDA Agriculture Research Service. 2012. USDA plant hardiness zone map. URL: https://planthardiness.ars.usda.gov/PHZMWeb/ (accessed 20 June 2019).

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