RDAR Project 2022D007R: Utilizing Winter Cereals for Forage, Grain and Improving Soil Health Under Conditions of Drought Stress

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Project Objectives:

1. Evaluation of the establishment of fall seeded annual crops under different stubble heights and/or seeding dates.
2. Evaluation of forage and grain yield production from fall and spring seeded winter annual crops.
3. Evaluation of the establishment, forage yield and quality of an annual crop mix.
4. Evaluation of specific soil parameters under various fall and spring crop treatments.
5. Evaluation of the impact on subsequent (spring) crops from fall seeded cocktail mixes of annual crops.

Project Overview

The use of fall and winter cereal crops for both forage and grain production was evaluated at four sites (Oyen, Forestburg, Fort Kent and Westlock) under a range of growing conditions between the fall of 2021 and harvest of 2022. The project verified that fall and winter crops have good potential for forage production and can be competitive for grain production with spring annuals. Data from one production year, however, must be used with caution.

Spring triticale provided the highest grain yield from both the fall seedings on canola stubble in the brown soil zone. Prima fall rye and the annual crop mixes yielded above the trial mean. Seeding dates and/or stubble heights did not appear to have had significant impact on yield or crop heights. Spring crops seeded into annual crop mix stubble tended to produce less than the trial mean.

Spring barley was the highest yielding grain and spring seeded fall crops provided the most biomass yield at the GRO site which was less impacted by drought conditions than the brown soil zone sites. Metzger winter triticale and Hazlet fall rye provided the highest forage yield at LARA. Hazlet fall rye was the higher yielding grain.

Soil bio-physical parameters including wet aggregation stability, water infiltration, active carbon and compaction, were positively affected by various combinations of fall and spring seeded crops.

The treatment combinations of fall and spring seeded crops tested in this project need further evaluation before recommendations for forage and grain use can be made with confidence. It was observed that fall and winter cereals do have strong potential as a forage source even under dry conditions which gives producers options during drought stress.

Background

The challenging growing conditions in 2021 and 2022 in east central Alberta created a severe shortage of feed for cattle operations in much of Alberta and western Canada. Native range,

re-seeded pasture and hay land as well as annual crop acreage used for forage were impacted. No component of the annual feeding program is at normal production levels except perhaps the acres under irrigation.

One option for forage and grazing in stressful times is the use of annual forage crops. Fall or winter annuals can play a significant role as a forage source, seeded either in the fall or in the spring. Fall seeded annuals have the potential to provide not only early season forage, but can be managed for silage, greenfeed or grain. Seeded in the spring, the winter annuals remain vegetative during the growing season, offering a high quality forage that will continue to grow when moisture and fertility requirements are met.

Three winter crops are options for Alberta growers (fall rye, winter wheat and winter triticale) all offering differing levels of winter hardiness and productivity. Annual crop mixes ("cocktail crop mixes') can also provide a valuable source of forage material for livestock. Benefits may extend to improvements in specific soil health parameters as well. Successful crop establishment can be dependent on the previous crop, seeding date, soil moisture, snow cover in the winter and early spring weather. Target seeding dates range from late summer/early fall in northern areas of the province to late September in the south.

This one year project focused on the use of fall and spring seeded winter annuals as well as a multi-mix of crops as a source of both forage and feed grain. Various management practices such as seeding date and stubble height were monitored. Results will complement information generated within the CAP funded *Yield and Quality of Cereal and Alternative Annual Crops for Forage Production in Alber*ta (2020 N029X) by looking at winter crops as solo stands.

Project Design and Methodology

All treatments (Table 1) were replicated within specific blocks in a randomized completed block design. Small plot equipment was used for seeding, herbicide application and harvest. Plots sizes ranged between 8.63 and 11.7 m2, depending on the equipment used by each association.

Table 1 **Winter Cereal Treatments**

Crop	**Variety**
Winter Wheat	Wildfire
	Pintail
Fall Rye	Prima
	Hazlet
Winter Triticale	Luoma
	Metzger
Spring Wheat	AAC Brandon
Spring Rye	Gazelle
Spring Triticale	Taza
CCC Mix	Oats, Japanese millet, brassica, peas, hairy vetch, phacelia
Seeding Date	Early fall (no later than Sept 24)
	Late fall (at least 2 weeks later than first seeding)

	Spring (mid to late May)
Stubble Height	Tall (at least 8 inches tall)
	Short (as short as possible)

Fall seeded treatments were planted into standing stubble or chem fallow. Spring seeded treatments were planted into the same stubble or the stubble from the fall seeded cocktail mix. Biomass yield and quality were determined in 2022 from both the fall and spring seeded winter annuals and the cocktail mix treatments. Grain yield and quality were collected from the fall seeded winter annuals as well as the spring seeded crops. Soil samples for evaluation of bio-physical parameters were taken post harvest at the CARA and LARA sites. In-field compaction and infiltration measurements were also made.

Results and Discussion

Establishment of the various treatments was evaluated by plant counts within each treatment block. Observations from each site indicated a trend towards better establishment with early (September) versus later (October seeding). Stubble height did not influence spring plant counts, even though it was assumed the taller stubble may have trapped more snow which would have protected the fall seedlings. Plant counts made in May 2022 from spring seeded crops were typically higher than those within the fall seeded crops. All counts were less than the target population of 70 plants per meter of row for wheat, 72 plants for rye and 86 for the triticale. Overall establishment was best in the forage block at the Westlock site managed by GRO, with counts ranging between 58 and 87 per m of row. Establishment of the plants for grain harvest was better in the tall stubble.

Average dry matter biomass/forage **yield** at the BRRG site was approximately 7% higher from the late fall seeded (2239 lb/A) versus the early seeded cereals at 2100 lb/A. Highest yielding was the early seeded Luoma triticale at 4364 lb/A. Lowest yielding was the early seeded fall CCC/spring Wildfire combination. Highest protein levels were measured in the early seeded fall cocktail and spring seeded Prima fall rye at 14.22%. Lowest protein was measured in the fall seeded Prima. Treatments including a fall cocktail mix trended higher in protein than the other treatments, both in the early and late seeded blocks. The Hazlet fall rye yielded significantly higher among the spring seeded fall and winter crops at 2436 lb/A.

Grain yield was not available from the BRRG early seeded block while the fall crops seeded in October yielded an average of 23.8 bu/A, Highest yielding was the spring rye on cocktail stubble treatment at 37.1 bu/A. Gazelle spring rye was the highest yielding grain at 76.6 bu/A.

There was no significant difference in dry matter yield in CARA's early short stubble forage block. Average yield among the 19 treatments was 1697 lb/A, ranging from 3685 lb/A in the fall seeded Metzger to a low of 520 lb/A from the spring seeded prima fall rye. Forage yield from the taller stubble block averaged 1464 lb/A. Highest yielding was the fall seeded Pintail winter wheat at 3125 lb/A. Lowest yielding was the spring seeded Metzger winter triticale on cocktail stubble at 592 lb/A. The cocktail treatment yielded well above the trial average at 2648 lb/A and had the highest protein level.

Grain yields averaged just over 14 bu/A in CARA's early seeded fall crops in short stubble. Hazlet fall rye yielded significantly higher at 30 bu/A, Prima fall rye yielded significantly higher in

CARA's late seeded tall stubble block at 23 bu/A. Average yields in the early seeded tall stubble block were 6 bu/A higher than the early seeded short stubble and 10 bu/A higher than the late seeded tall stubble block. Fall rye yielded the highest in each of the tall stubble blocks, with Hazlet at 24.8 in the early seeded group and Prima in the late seeded group.

Forage yield in GRO's short stubble block was led by spring seeded Hazlet fall rye, spring seeded Luoma winter triticale, the cocktail mixes and spring seeded Metzger winter triticale. Average yield for the forage block on short stubble was 8835 lb/A. The spring seeded crops were generally much higher yielding than the fall seeded cereals. The spring seeded fall ryes on cocktail stubble contained the highest level of protein at 15%.

GRO's grain yield on tall stubble was led by spring barley at 125 bu/A. Lowest yielding was spring wheat and winter triticale on cocktail stubble. Spring barley was the highest yielder on the short stubble while spring wheat on the cocktail stubble had the lowest bushels per acre yield.

Fall seeded Louma and Metzger winter triticales yielded significantly higher at the LARA site at 12,167 lb/A of biomass. Protein levels were lower and fibre levels were higher than the average for the site, indicating a poorer overall nutritional quality. Lowest yielding was the spring seeded Metzger triticale. Highest protein level was observed in the spring seeded wildfire winter wheat.

LARA's grain trial averaged 90 bu/A overall. Luoma winter triticale and Hazlet fall rye broke the 100 bu/A mark with 102 and 101 bu/A respectively. Yield of spring seeded crops ranged between 76 and 92 bu/A.

Performance of the **annual crop mixes** was not consistent between the sites. At the BRRG site, establishment of the fall seeded mix was well below the target plant population and also lower than all the fall seeded mono-crops. The spring seeded plot was higher at 80 plants per square meter but the dry matter yield was below the trial average. Feed quality parameters of the spring seeded mixes were above the trial average at 13.42% versus 11.96%. Results were similar for the BRRG trial seeded October 2021. Grain yield on the annual mix stubble for the spring rye was above the site average at 37.1 bu/A, but much lower for the spring wheat and spring triticale.

At the location managed by CARA, plant counts of the annual mixes were lower than the target rate from both stubble height blocks. Dry matter yields from spring cereals seeded into the annual mix stubble within the short stubble block were lower than the site average. The spring seeded mix produced 2431 lb/A which was above the site average, however the yield was less than all the fall seeded winter cereals. A similar pattern was observed in the tall stubble block, where the spring seeded mixes yielded above the trial average and was comparable to the yield from the fall seeded annuals.

The fall seeded annual crop mixes did not establish well at the GRO trials, however the spring seeded mixes established well and led the trial in yield which was similar to the spring seeded fall or winter crops.

Similar to the other locations, establishment of the fall seeded annual crop mixes in the LARA forage block was poor. Dry matter yield of the mixes was 36% higher than the trial average.

Bio-physical soil parameters were measured within one forage block (early seeded short stubble) and one crop block (early seeded tall stubble) of the CARA trials. In the forage block, there were no significant differences in depth to 200 psi. Differences were significant in the depths to 300 psi with the deepest found in the annual mix/spring seeded Metzger treatment and the shallowest in the spring seeded Pintail winter wheat on the mix stubble. Water infiltration levels were significantly quicker in the Pintail and Wildfire winter wheats on cocktail stubble as well as the spring seeded Wildfire and fall seeded Metzger. Differences in soil microbial respiration and active carbon were not significant. Bulk density levels were significantly higher in the fall seeded wildfire winter wheat and lower in the spring seeded Hazlet fall rye on annual mix stubble.

In CARA's early seeded tall grain stubble block, depth to 200 psi was deepest in the spring wheat treatment and shallowest in the spring rye seeded into the cocktail mix stubble. Depth to 300 psi showed a similar trend, but with both the spring seeded winter triticale and rye having significantly deeper depths. Water infiltration was significantly quicker in the spring wheat on cocktail stubble, spring wheat and the fall seeded Metzger and Hazlet treatments. There were no significant differences in the soil microbial respiration levels. Active carbon was higher in the spring triticale on the cocktail stubble treatment and lowest in the fall seeded Metzger and Prima plots. Wet aggregation stability was significantly higher in the spring triticale seeded into annual mix stubble.

Soil samples submitted by LARA could not be analyzed for statistical significance, but in-field compaction measurements showed the depth to both 200 and 300 psi was deepest in the fall seeded Hazlet followed closely by the cocktail mix treatment. Infiltration was quickest in the fall seeded pintail winter wheat and spring seeded fall rye treatments into cocktail stubble.

The impact of the fall seeded annual crop mixes was not consistent between site locations, but results indicate the mixes can have a role in forage production at points in Alberta. 2022 yields within the early and late BRRG forage trials appeared to be negatively impacted by the mix stubble at both seeding dates, but protein and total digestible nutrients tended to be higher. Grain yield was much lower in the spring wheat and fall rye treatments but higher in the spring triticale on cocktail stubble.

CARA's forage trial yields also trended lower from crops seeded into the mix stubble, although the 2022 seeded annual mix yield was much higher than the trial average. Feed quality from the cocktails mix were slightly above average in most feed components. Spring seeded crops into annual mix stubble were lower than the site average in the early seeded short stubble, similar in the late seeded short stubble, but all were slightly higher in protein.

The spring seeded cocktail mixes on cocktail stubble was the highest yielding forage at the GRO site. Quality parameters were generally below the site average. Protein levels and total digestible nutrients from the Hazlet and Prima fall rye and Metzger triticale on the mix stubble were higher than the site average. Grain yields at the GRO site were not positively influenced by the fall seeded cocktail mixes.

Within LARA's forage trial, the cocktail mix yielded above the site average by over 2600 lb/A. Other spring seeded crops into the annual mix stubble tended to be lower yielding. The

influence on feed quality was mixed between the cocktail stubble treatments, ie. some spring seeded crops contained higher protein while others were less, for example.

The annual crop mixes influenced some of the soil health parameters monitored at the CARA and LARA sites. The depth to 300 psi was significantly deeper in the spring seeded Prima on annual mix stubble in the CARA early seeded short forage block. The water infiltration rate was significantly higher in the annual mix/Metzger treatment and wet aggregation stability also tended to be higher in the treatments including the annual mixes. In CARA's early seeded tall grain block, both the active carbon and wet aggregation stability were significantly higher in the cocktail/spring triticale treatment.

Project results must be utilized with caution, as only one site year of data from each site was collected. The project did generate interest in the use of fall and winter crops for forage as well as grain. At the BRRG site, for example, Louma winter triticale yielded the highest in both grain and forage yield. Hazlet fall rye was also a high yielding forage. Pintail winter wheat was a high yielding grain. BRRG yields were slightly less from the second seeding date, although results are not significant.

Spring triticale provided the highest grain yield from both the short seedings on cereal stubble. Drought tolerant Prima fall rye provided the highest biomass yield. Seeding dates and stubble heights do not appear to have had significant impact on yield or crop heights.

Spring barley was the highest yielding grain at the GRO site. Metzger winter triticale and Hazlet fall rye provided the highest forage yield at LARA. Hazlet fall rye was the higher yielding grain.

Soil bio-physical parameters were evaluated at the CARA site on early seeded crops into tall stubble within the blocks targeted for both forage and crop production. The only parameter which generated significant differences was water infiltration, which was led by the Metzger winter triticale treatment.

The various treatments intended for both forage and grain need further evaluation before recommendations can be made. It was observed that fall and winter cereals do have strong potential as a forage source even under dry conditions. The fall and winter crops may be competitive at some locations for grain yield, although spring crops were stronger at the other sites.

Benefits to Industry

Feed is the largest component in the annual cost for maintaining a breeding cow. Having options to fill gaps when growing conditions are challenging can mean the difference between maintaining a genetic herd base or selling and having to replace that base herd at a higher cost in the future. Specific characteristics of the base herd may have taken decades of development and cannot be easily replicated.

At times when production of traditional feeds is challenged, winter cereals can be easy to establish and may be more responsive to early season or periodic precipitation than perennials or other annual crops. Fall seeded crops provide several options for use, including late fall grazing, early spring grazing, silage, greenfeed and even grain. Spring seeded winter crops will remain vegetative, are quick to grow and stand up well to good grazing management.

In addition to the versatility of the winter cereals, the physiology of winter cereals, ie. abundant basal leaves and early spring growth, can also make the stand more competitive against annual weeds thus potentially reducing herbicide costs. Use of home (or locally) grown winter cereals for forage may replace the need for importing costly feed from outside the region. Ranches run the risk of importing invasive weeds along with the feed they bring in, resulting in an investment both in time and herbicides for control.

Winter annuals may also be less impacted by fusarium head blight due to earlier maturity or harvest as forage.

Cocktail mixes can provide many of the same benefits as using winter annuals for feed. The mixes are easy to establish and can provide forage within weeks after seeding. Studies with CARA have shown a mix of crops can produce more biomass than individual crop stands. The annual crop mixes also provided improvements in some soil health parameters during one production year.

Maintaining Alberta's cow herd is very important for the sustainability of the beef industry. Beef cow herd numbers have already dropped during the past few years and recovery from a sell off due to prolonged feed shortages may be a blow that some operations can't recovery from.

Appendix – Data Tables

Table 1 **BRRG Forage Seeded September 21, 2021**

		Plant count/m2		Avg	Dry	Nutritional Analysis					
		Fall	June	Ht	Matter						
Trt	Variety	m2	m2	cm	lb/A	CP	TDN	CA	P	K	Mg
1	Wildfire	77.5	0.0	68	3556	10.95	57.50	0.26	0.28	2.02	0.14
2	Pintail	58.5	39.5	67	2825	10.95	57.06	0.21	0.28	1.96	0.15
3	Prima	51.0	0.5	105	2454	8.34	54.61	0.18	0.24	1.70	0.11
4	Hazlet	24.0	11.5	97	2414	8.77	55.78	0.20	0.24	1.77	0.11
5	Metzger	33.5	8.8	92	2723	10.69	55.29	0.25	0.31	2.23	0.11
6	Luoma	59.8	12.5	111	4364	8.94	51.42	0.22	0.24	1.92	0.10
7	CCC/Wildfire	18.0	96.3	91	997	16.97	61.69	0.31	0.39	3.04	0.16
8	CCC/Pintail	13.8	92.0	88	1258	12.31	57.71	0.31	0.33	2.42	0.15
9	CCC/Prima	12.8	102.3	75	1182	14.22	59.83	0.39	0.30	2.60	0.19
10	CCC/Hazlet	15.8	68.0	89	1346	11.89	60.78	0.30	0.31	2.53	0.14
11	CCC/Metzger	3.8	75.0	85	1440	15.38	60.72	0.29	0.33	2.83	0.13
12	CCC/luoma	19.8	69.5	94	1285	12.66	59.37	0.27	0.34	2.66	0.13
13	CCC/CCC	18.5	80.5	89	1453	13.42	58.15	0.30	0.31	2.65	0.17
CV					23.42	29.4					
LSD					15.75	886					

Table 2 **BRRG Forage Seeded October 5, 2021**

		Plant count/m2		Avg	Dry	Nutritional Analysis					
		Fall	June	Ht	Matter						
Trt	Variety	m2	m2	cm	lb/A	CP	TDN	CA	P	K	MG
1	Wildfire	10.3	8.0	76e	2285cde	11.5	57.84	0.23	0.26	2.12	0.13
2	Pintail	9.8	4.0	77e	2072cde	10.5	57.47	0.21	0.26	1.96	0.13
2	Prima	21.3	2.5	123a	3126ab	10.7	60.66	0.28	0.24	1.81	0.10
4	Hazlet	14.8	2.8	107bc	3444ab	9.0	59.05	0.27	0.26	1.52	0.12
5	Metzger	15.3	2.0	102cd	2803bcd	9.3	55.68	0.19	0.24	1.57	0.09
6	Luoma	12.8	0.8	120ab	3989a	10.5	55.12	0.20	0.25	1.86	0.09
7	CCC/Wildfire	4.0	27.0	97cd	1997def	9.6	56.44	0.22	0.28	2.28	0.12
8	CCC/Pintail	4.8	18.0	99cd	1662ef	11.2	57.05	0.21	0.27	2.16	0.11
9	CCC/Prima	3.8	18.5	104cd	1219f	11.4	56.31	0.30	0.28	2.61	0.14
10	CCC/Hazlet	5.0	23.8	98cd	1765ef	11.2	58.99	0.29	0.29	2.31	0.14
11	CCC/Metzger	4.3	29.8	98cd	1426ef	12.8	59.87	0.32	0.33	2.61	0.14
12	CCC/luoma	2.8	25.3	92d	1412ef	12.2	59.48	0.21	0.24	1.89	0.12
13	CCC/CCC	1.3	58.3	96dc	1910def	12.8	60.85	0.46	0.30	2.84	0.17
Avg		8.5	17.0	99	2239	10.989	58.06	0.26	0.27	2.12	0.12
CV				10.02	28.56						
LSD				917	14.23						

Table 3 **BRRG Forage Seeded May 15, 2022**

		Plant Count/m2	Average	Dry	
		Fall	June	Height	Matter
Trt	**Plot**	**m2**	**cm**	(cm)	lb/A
1	Wildfire	61.5	44.7	45 ab	1887 ab
2	Pintail	66.5	47.0	47 ab	1861 ab
3	Prima	80.0	45.8	46 ab	2556 ab
4	Hazlet	95.8	45.9	46 ab	2436 a
5	Metzger	97.8	42.3	43 b	1716 b
6	Luoma	106.3	50.0	50 a	2270 ab
CV			8.34	19.91	
LSD			5.78	622	

BRRG Grain Seeded September 21, 2021 – no data due to poor germination

Table 4 **BRRG Grain Seeded October 5, 2021**

		Plant Count/m2		Avg Ht	Yield Data Yield
Trt	**Crop**	**Fall**	**June**	**(cm)**	**(Bu/A)**
1	Wildfire Winter Wheat	1	45.67	85	27.6
2	Pintail Winter Wheat	3.25	66.67	90	20.4
3	Prima Fall Rye	34.75	6.50	114	24.8
4	Hazlet Fall Rye	35.25	0.00	120	32.6
5	Louma Triticale	17.25	68.00	135	20.3
6	Metzger Winter Triticale	15.25	69.00	104	17.0
7	CCC/Spring Wheat	5	42.67	76	18.6
8	CCC/Spring Rye	9.25	107.00	74	37.1
9	CCC/Spring Triticale	11	69.50	106	16.0
		14.7	52.8	100.4	23.8

Table 5 **BRRG Grain Seeded May 15, 2022**

		Plant Count	Plant height	Yield
Trt	**Crop**	**m2**	**cm**	**bu/A**
1	Brandon Spring Wheat	125	82 b	40.0 b
2	Gazelle Spring Rye*	127	77 b	76.6 a
3	Taza Spring Triticale	122	131 a	24.0 b
Avg		124.6		
CV			3.35	25.38
LSD			5.58	12.36

Table 6 **CARA – Soil Moisture at Seeding**

	Sept 21	Oct 5
0-2"	5.30%	3.90%
2-4"	6.6	5.9
4-6"	6.5	5.5
6-8"	6.8	7.9
8-10"	5.1	7.8
10-12"	2.5	7.2

Table 7 **CARA Early Seeded Fall Plant Counts**

Crop	Tall Forage	Short Forage	Tall Grain	Short Grain
CCC Avg*	14.4	14.1	17.5	14.1
Fall Hazlet	21.5	14.0	25.5	12.5
Fall Luoma	31.75	20.0	35	18.5
Fall Metzger	26.75	18.25	21.75	20.5
Fall Pintail	30.25	16.25	23.75	18.5
Fall Prima	24.5	11.75	23	8.5
Fall Wildfire	26.75	8.25	17.75	16.25

*Average of all treatments which included fall seeded CCC

Table 8 **CARA Forage Seeded into Short Stubble September 20, 2021**

Trmt	Crop	Dry Matter (lb/A)	Avg Ht (Cm)	CP	ADF	NDF	TDN	Ca	P	K	Mg
1	CCC/Hazlet	1455	25	12.10	37.94	53.99	60.00	0.45	0.20	1.64	0.24
2	CCC/Prima	891	23	12.08	38.43	53.16	60.10	0.55	0.21	1.97	0.30
3	CCC/Metzger	802	21	10.25	41.97	56.68	59.23	0.45	0.19	1.65	0.28
4	CCC/Pintail	941	22	11.35	37.06	50.45	63.33	0.45	0.20	1.58	0.24
5	CCC/Wildfire	1060	21	12.57	37.28	52.38	62.96	0.43	0.20	1.97	0.23
6	CCC/Bobcat	795	24	12.67	35.72	52.77	62.57	0.45	0.20	1.92	0.25
7	CCC/CCC	2431	55	10.35	43.50	57.49	56.92	0.47	0.17	1.93	0.24
8	Spring Metzger	949	22	14.31	34.62	50.42	63.68	0.45	0.18	2.22	0.23
9	Spring Hazlet	665	25	8.05	40.29	58.20	61.96	0.15	0.16	1.14	0.11
10	Spring Prima	520	24	9.34	40.60	59.35	60.30	0.17	0.11	1.24	0.11
11	Spring Pintail	752	22	10.38	41.43	65.57	56.56	0.24	0.12	1.27	0.12
12	Spring Wildfire	841	23	9.91	42.90	64.01	56.63	0.24	0.10	1.35	0.14

13	Spring Bobcat	789	25	10.12	39.16	57.47	61.66	0.24	0.19	1.54	0.16
14	Fall Metzger	3685	90	12.08	40.15	54.56	59.23	0.52	0.19	2.21	0.26
15	Fall Wildfire	3140	59	9.42	41.72	60.87	57.99	0.21	0.15	1.32	0.11
16	Fall Bobcat	3913	97	11.97	40.29	55.19	59.80	0.52	0.19	1.99	0.23
17	Fall Hazlet	3155	81	10.07	41.14	56.99	60.09	0.39	0.18	1.75	0.21
18	Fall Pintail	2862	61	11.25	41.61	56.20	58.01	0.43	0.15	1.80	0.22
19	Fall Prima	2605	85	11.18	41.53	57.00	58.59	0.44	0.17	1.68	0.22

Table 9 **CARA Forage Seeded into Tall Stubble September 20, 2021**

	Crop	lb/A	Ht		ADF	NDF	TDN	Ca	P	K	Mg
1	CCC/Hazlet	1265	38		39.53	58.95	58.54	0.39	0.17	1.96	0.17
2	CCC/Prima	653	27		41.46	58.71	59.82	0.37	0.18	2.12	0.17
3	CCC/Metzger	592	25		39.84	62.21	58.72	0.38	0.13	1.71	0.16
4	CCC/Pintail	868	23		42.89	61.10	58.41	0.34	0.17	1.83	0.16
5	CCC/Wildfire	690	22		37.48	56.11	62.27	0.39	0.19	1.95	0.19
6	CCC/Bobcat	619	23		40.72	58.89	58.36	0.40	0.16	1.73	0.17
7	CCC/CCC	2648	69		39.04	56.65	60.82	0.38	0.18	1.94	0.16
8	Spring Metzger	623	25		43.43	60.77	57.14	0.37	0.16	1.84	0.16
9	Spring Hazlet	932	29		41.31	61.56	58.12	0.38	0.15	2.10	0.16
10	Spring Prima	703	28		39.05	58.67	61.32	0.32	0.18	2.18	0.18
11	Spring Pintail	1001	25		39.70	57.90	60.56	0.33	0.18	2.01	0.16
12	Spring Wildfire	1125	25		38.78	56.89	61.10	0.38	0.18	1.68	0.17
13	Spring Bobcat	637	26		38.08	58.54	60.55	0.32	0.16	1.79	0.15
14	Fall Metzger	2342	89		40.89	61.47	58.66	0.22	0.15	1.64	0.12
15	Fall Wildfire	2256	61		41.37	61.49	58.83	0.28	0.14	1.82	0.14
16	Fall Bobcat	2725	99		40.22	58.71	61.54	0.21	0.17	1.42	0.12
17	Fall Hazlet	2469	88		40.11	63.23	57.52	0.31	0.15	1.43	0.12
18	Fall Pintail	3125	66		41.27	62.35	57.98	0.28	0.14	1.47	0.13
19	Fall Prima	2536	92		42.82	65.42	55.99	0.26	0.13	1.39	0.11

Table 10 **CARA Grain Seeded into Short Stubble September 20, 2021**

Trmt	Crop	Spring Plant Count	Avg Ht	Protein (%)	Yield (bu/ac)	1000 KWT (g)	Bu Wt (lbs/bu)
1	CCC/Spring Rye		76	11	6	33	58
2	CCC/Spring Trit		76	11	12	31	56
3	CCC/Sprg Wheat		55	12	9	29	65
4	Spring Trit		73	11	11	30	55
5	Spring Wheat		50	13	9	28	64
6	Spring Rye		78	12	6	32	57
7	Fall Metzger	21	93	9	16	32	58
8	Fall Hazlet	21	78	7	30	31	60
9	Fall Wildfire	16	55	10	14	32	64
10	Fall Prima	28	90	8	20	27	59
11	Fall Bobcat	26	105	9	15	33	58
12	Fall Pintail	23	66	9	21	26	61
CV			8.7		33.04		
LSD			9.32		6.7		

Table 11 **CARA Grain Seeded into Short Stubble October 5**

Trmt	Crop	Spring Plant Count	Avg Ht	Protein (%)	Yield (bu/ac)	1000 KWT (g)	Bu Wt (lbs/bu)
1	Spring Wheat		53	13.0	11.4	28.7	64.8
2	Spring Rye		78	12.5	7.2	34.1	59.3
3	Spring Triticale		71	11.5	13.5	30.0	56.0
4	CCC/Spring Rye		81	11.7	7.9	33.8	58.6
5	CCC/Spring Trit		71	11.2	12.5	30.7	56.0
6	CCC/Spring Wheat		53	13.0	9.2	28.9	62.6
7	Fall Metzger	10	97	9.9	11.5	31.6	57.1
8	Fall Prima	19	93	7.8	23.0	27.3	58.8
9	Fall Bobcat	4	104	9.8	11.0	33.2	57.3
10	Fall Hazlet	4	92	8.4	16.5	32.0	59.9
11	Fall Wildfire	13	58	10.4	14.8	29.5	62.3
12	Fall Pintail	14	66	10.3	11.9	27.6	58.9
Avg			76.4	10.8	12.5	30.6	59.3
CV			7.07		32.09		
LSD			7.76		5.78		

Table 12 **CARA Grain Seeded into Tall Stubble September 20, 2021**

Trmt	Crop	Spring Plant Count	Avg Ht (cm)	Protein (%)	Yield (bu/A)	1000 KWT (g)	Bushel Weight (lbs/bu)
1	CCC/Spring Rye		83 bc	11.5 bc	7.0 fg	31.5 ab	57.5
2	CCC/Spring Trit	31	75 cd	11.1 cd	11.4 de	30.5 bcd	56.5
3	CCC/Spring Wheat		53 e	12.2 a	8.2 def	28.2 e	64.8
4	Spring Triticale		73 cd	10.8 c	10.2 def	29.7 d	55.9
5	Spring wheat		54 e	12.2 a	8.1 efg	27.6 ef	65.0
6	Spring Rye		78 bcd	11.6 b	6.1 g	31.1 abcd	n/a
7	Fall Metzger	35	95 ab	8.8 f	11.8 d	31.2 abc	58.2
8	Fall Hazlet	27	84 abc	7.4 g	24.8 a	29.8 cd	60.6
9	Fall Wildfire	27	61 de	10.0 e	15.8 c	30.4 bcd	64.8
10	Fall Prima	29	94 ab	7.6 g	18.3 bc	26.3 fg	59.5
11	Fall Luoma	30	106 a	8.8 f	11.2 de	32.2 a	57.8
12	Fall Pintail	43	82 bc	9.3 f	19.9 b	26.0 g	62.1
CV			15.92	3.78	20.1	3.3	
LSD			17.89	0.55	3.68	1.4	

Table 13 **CARA Grain Seeded into Tall Stubble October 5, 2021**

Trmt	Crop	Spring Plant Count	Avg Ht (cm)	Protein (%)	Yield (bu/A)	1000 KWT (g)	Bushel Weight (lbs/bu)
1	Spring Wheat		49	12.8	8.8	27.0	65.6
2	Spring Rye		74	12.6	6.2	32.4	58.3
3	Spring Trit		70	11.7	10.2	28.5	55.7
4	CCC/Spring Rye		82	11.5	7.0	32.5	57.5
5	CCC/Spring Triticale		68	10.9	10.8	29.7	56.2
6	CCC/Spring Wheat		48	12.2	8.1	28.6	64.3
7	Fall Metzger	12	95	9.6	9.4	30.1	57.2
8	Fall Prima	9	94	8.5	18.3	25.9	58.9
9	Fall Luoma	4	100	9.7	7.8	30.9	57.5
10	Fall Hazlet	15	85	8.1	13.7	29.5	60.1
11	Fall Wildfire	15	60	10.2	15.4	28.2	63.2
12	Fall Pintail	12	60	10.4	10.1	23.5	60.1
CV			51.9	6.21	24.8	3.44	
LSD			5.51	.95	224	1.43	

Table 14 **GRO Forage on Short Pea Stubble Seeded September 21, 2021**

Trt	Crop	Plants m2	Height (cm)	Dry Matter (T/A)	ADF	TDN	CP	Ca	P	K	Mg
1	CCC + Hazlet	0	67 f	6073 fg	31. 0	63.0	15.0	0.47	0.31	2.57	0.17
2	CCC + Prima	0	58 gh	6291 efg	28.3	65.2	15.0	0.50	0.28	2.53	0.19
3	CCC + Metzger	0	44 lm	4285 i	28.2	64.3	12.0	0.52	0.35	2.41	0.13
4	CCC + Pintail	0	46 lm	6793 d	31.1	57.4	8.6	0.30	0.21	1.32	0.11
5	CCC + Wildfire	0	53 hij	6694 efg	26.3	61.4	9.8	0.32	0.26	1.74	0.13
6	CCC + Louma	0	51 ijk	7812 d	28.4	56.2	8.7	0.27	0.19	1.17	0.09
7	CCC + CCC	0	40,65,125	14379 a	31.2	55.2	7.9	0.35	0.18	1.07	0.12
8	Spring Metzger	87	130 bc	14284 a	25.2	44.0	6.9	0.28	0.19	1.35	0.10
9	Spring Wildfire	62	86 e	11028 c	22.8	49.4	7.1	0.20	0.20	1.03	0.10
10	Spring Louma	89	154 a	14401 a	25.5	51.6	7.1	0.19	0.14	1.16	0.07
11	Spring Hazlet	81	111 d	14720 a	25.4	47.6	5.6	0.29	0.17	0.93	0.10
12	Spring Pintail	67	85 e	12304 b	27.0	42.0	6.5	0.24	0.20	1.47	0.14
13	Spring Prima	68	132 b	12440 b	25.7	52.6	6.2	0.27	0.20	1.06	0.12
14	Fall Metzger	60	42 m	4716 hi	27.9	62.9	10.8	0.44	0.26	1.83	0.13
15	Fall Hazlet	55	67 f	7228 de	29.6	67.4	12.8	0.39	0.26	2.16	0.14
16	Fall Prima	61	62 fg	6209 efg	31.1	67.9	13.8	0.55	0.38	3.11	0.15
17	Fall Pintail	59	47 klm	5700 gh	31.4	65.9	12.9	0.47	0.36	2.69	0.16
18	Fall Wildfire	60	50 jkl	5851 fg	31.9	66.0	10.1	0.62	0.29	2.87	0.20
19	Fall Louma	58	57ghi	6094 fg	32.5	65.9	12.3	0.54	0.27	2.41	0.20
				8835	28.3	58.2	9.95	0.38	0.25	1.84	0.15
CV			5.9	8.35							
LSD			6.4	1047							

Table 15 **GRO Grain on Tall Canola Stubble**

		Spring 2022		
Trmt	Crop	Plant Count (1 m)	Plant Count (plants/ m2)	Yield (bu/A)
1	CCC + Spring Barley	0	0	77 e
2	CCC + Spring Triticale	0	0	36 g
3	CCC + Spring Wheat	0	0	35 g
4	Metzger	20.5	90	53 f
5	Prima	19	83	68 de
6	Louma	17.3	75	61 e
7	Hazlet	21.5	94	69 de
8	Wildfire	21	92	69 c
9	Pintail	20.5	90	66 cd
10	Spring Wheat	38.8	170	77 b
11	Spring Barley	45.8	200	125 a
12	Spring Triticale	40.3	176	61 e
Avg		20	89	66
CV				4.67
LSD				4.2

Table 16 **GRO Grain on Pea Stubble**

		Spring 2022		Cereal	
Trmt	Crop	Plant Count 1m stick	Plant Count plants/ m2	Plant Height (cm)	Yield (bu/A)
1	CCC + Spring Barley	0	0	94 de	96 c
2	CCC + Spring Triticale	0	0	116 c	47 g
3	CCC + Spring Wheat	0	0	85 85	34 h
4	Fall Metzger	23	102	118 c	90 b
5	Fall Prima	21	91	119 c	96 b
6	Fall Louma	22	95	140 a	88 b
7	Fall Hazlet	22	97	114 c	109 a
8	Fall Wildfire	21	93	88 ef	82 f
9	Fall Pintail	19	81	85 f	55 f
10	Spring Wheat	24	105	91 def	77 d
11	Spring Barley	32	140	95 d	128 a
12	Spring Triticale	24	105	126 b	70 e
		17	76	106	81

Table 17 **LARA Forage Plant Counts and Height**

		12-May-23	12-May-23	22-Jun-23	22-Jun-23
Trmts	Treatment	Winter Cereal Avg Count	CCC Avg Count	Winter Cereal Avg Count	CCC Avg Ht
1	Fall Luoma	27.1		25.8	
2	Fall Prima	0.0		34.6	
3	CCC/Pintail	5.2	3.2	31.3	95.5
4	CCC/Prima	7.0	5.7	33.4	101.6
5	CCC/Hazlet	6.1	4.5	36.8	96.8
6	Spring Metzger	29.9		21.2	
7	Fall Pintail	0.0		32.3	
8	Spring Wildfire	20.3		24.1	
9	CCC/Luoma	4.3	3.9	35.4	107.3
10	Spring Pintail	19.0		15.1	
11	Fall Metzger	0.0		33.4	
12	Fall Hazlet	0.0		34.9	
13	Fall Wildfire	0.0		33.8	
14	CCC/CCC	4.5	4.9	13.6	123.2
15	Spring Prima	26.8		17.3	
16	CCC/Metzger	11.4	6.8	35.5	102.2
17	CCC/Wildfire	10.4	4.3	32.7	94.1
18	Fall Luoma	0.0		42.3	
19	Spring Hazlet	34.3		20.5	
Avg		10.9	4.8	29.2	103.0

Table 18 **LARA Forage Yield and Nutritional Analysis**

Trmts	Treatment	Yield	CP (%)	ADF (%)	NDF (%)	TDN (%)	Ca (%)	P (%)	K (%)	Mg (%)
1	Luoma	12167a	6.01	38.67	63.43	58.78	0.16	0.12	1.24	0.12
2	Prima 2022	4456de	11.5	26.54	49.6	68.23	0.37	0.21	2.93	0.3
3	CCC/Pintail	6281cd	12.51	29.17	49.79	66.18	0.42	0.23	2.25	0.38
4	CCC/Prima	7348c	9.65	32.06	54.14	63.93	0.29	0.2	1.7	0.23
5	CCC/Hazlet	6811c	10.9	28.24	51.6	66.9	0.24	0.25	2.04	0.22
6	Metzger	12545a	5.2	38.86	65.19	57.85	0.15	0.14	1.23	0.12
7	Pintail 2022	3226ef	13.19	28.22	48.97	66.62	0.37	0.28	3.04	0.32
8	Wildfire	11043ab	7.1	32.73	55.28	63.4	0.13	0.16	0.97	0.14
9	CCC/Luoma	6069cd	9.81	32.77	54.36	63.37	0.32	0.2	2.23	0.25
10	Pintail	10916ab	8.92	33.32	56.68	62.94	0.18	0.21	1.39	0.21
11	Metzger 2022	2078f	12.4	22.99	46.49	65.54	0.48	0.26	2.93	0.33
12	Hazlet 2022	3416ef	10.11	29.36	52.58	66.03	0.39	0.28	3.41	0.31
13	Wildfire 2022	3254ef	18.87	27.18	46.63	67.73	0.36	0.26	2.7	0.3
14	CCC/CCC	9944b	7.86	32.46	58.49	63.47	0.26	0.2	1.26	0.24
15	Prima	9784b	4.8	42.66	69.31	55.67	0.18	0.13	0.97	0.13
16	CCC/Metzger	7144c	11.77	29.28	51.44	66.09	0.32	0.23	2.02	0.26
17	CCC/Wildfire	6515c	9.27	31.31	54.59	37.71	0.25	0.24	1.77	0.24
18	Luoma 2022	3692ef	14.9	26.89	48.29	67.95	0.37	0.27	3.4	0.28
19	Hazlet	12480a	6.23	33.83	56.32	62.55	0.17	0.16	1.04	0.14
		7325	10.05	31.4	54.38	62.68	0.28	0.21	2.03	0.24
CV		19.37								
LSD		2012								

Table 19 **LARA Grain Trial**

	Treatment	Fall Cereal Avg Counts	Spring CCC Avg Counts	Spring Cereals Avg Counts	Fall Average Height (cm)	Spring Average Height (cm)	Yield (bu/A)	Yield (lbs/bu)	1000 KW (g)
1	CCC/Spring Rye	2.8	3.3	41.6	91	116	90 ab	61	39.54
2	CCC/Spring Triticale	4.4	3.2	28.8	123	93	86 cd	54	48.21
3	CCC/Spring Wheat	3.0	2.8	33.9	89	99	76 d	60	38.95
4	Spring Triticale	0.0		33.3	130		84 cd	55	51.73
5	Spring Wheat	0.0		39.6	89		89 ab	62	41.32
6	Spring Rye	0.0		34.1	88		92 a	63	39.5
7	Metzger W Trit	26.9		18.5	105		99 a	52	32.84
8	Hazlet F Rye	32.4		23.3	107		101 a	56	39.55
9	Wildfire W Wht	17.8		19.0	87		90abc	60	41.58
10	Prima F Rye	28.1		22.3	112		84 cd	55	32.4
11	Luoma W Trit	27.3		21.6	118		102bc	51	36.51
12	Pintail W Wht	27.8		21.0	88		85 e	56	31.98
	Average	18.9	3.1	28.1	102	103	90	57.1	39.5

Table 20 **CARA Short Forage 1 Soil Parameters Fall 2022**

		Compaction						
		200 psi	**300 psi**	**WInf**	**SMResp**	**ActC**	**BD**	**WAgg**
1	CCC/Hazlet	5.609	6.773 b	4.815 cd	0.3469	201	0.910 b	43.18 ab
2	CCC/Prima	7.726	9.737 a	4.815 abcd	0.4231	165	1.138 ab	34.19 ab
3	CCC/Metzger	6.773	8.361 ab	11.295 a	0.4216	175	1.078 ab	39.64 ab
4	CCC/Pintail	5.609	6.562 b	3.350 d	0.377	221	1.077 ab	39.55 ab
5	CCC/Wildfire	5.821	7.620 ab	3.860 d	0.3274	158	1.067 ab	20.84 b
6	CCC/Luoma	6.773	7.938 ab	6.815 abcd	0.3717	184	1.143 ab	25.45 ab
7	CCC/CCC	6.456	7.197 ab	5.465 cd	0.4036	238	1.084 ab	45.58 ab
8	Spring Metzger	6.35	7.091 ab	7.695 abcd	0.3912	178	1.054 ab	35.41 ab
9	Spring Hazlet	6.985	8.996 ab	6.355 abcd	0.3362	211	1.054 ab	42.36 ab
10	Spring Prima	7.091	8.149 ab	6.780 abcd	0.4854	250	1.190 ab	56.02 a
11	Spring Pintail	7.303	8.361 ab	5.285 cd	0.487	201	1.054 ab	28.49 ab
12	Spring Wildfire	6.033	7.620 ab	4.330 d	0.5011	153	1.143 ab	36.38 ab
13	Spring Luoma	7.408	8.784 ab	6.460 bcd	0.3078	183	1.02 ab	36.93 ab
14	Fall Metzger	6.562	8.149 ab	4.470 d	0.3008	181	.949 ab	40.03 ab
15	Fall Wildfire	7.197	8.255 ab	9.465 abc	0.3025	194	1.177 a	36.59 ab
16	Fall Luoma	6.456	7.726 ab	9.465 abc	0.4408	249	1.072 ab	39.29 ab
17	Fall Hazlet	6.773	7.938 ab	5.165 cd	0.3081	191	1.000 ab	29.17 ab
18	Fall Pintail	6.773	8.255 ab	10.905 ab	0.4125	195	1.083 ab	26.88 ab
19	Fall Prima	6.879	7.938 ab	7.475 abcd	0.4267	206	1.099 ab	38.05 ab
	Average	6.662	7.971	6.540	.3880	197	1.073	36.53

Table 21 **CARA Tall Grain 1 Soil Parameters Fall 2022**

		Compaction						
		200 psi	**300 psi**	**Winf**	**SMResp**	**ActC**	**BD**	**Wagg**
1	CCC/Spring Rye	8.467 d	9.313 c	5.308 bc	0.2417	163 b	1.121 ab	50.10 ab
2	CCC/ Spring Triticale	9.578 abcd	10.530 abc	5.153 bc	0.2851	226 a	1.084 ab	54.36 a
3	CCC/Spring Wheat	8.837 abcd	9.641bc	3.905 c	0.2445	131 b	1.139 ab	40.26 abcdef
4	Spring Triticale	9.895 ab	10.636 ab	4.968 bc	0.2429	131 b	1.141 ab	46.10 abc
5	Spring wheat	9.948 a	11.007 a	3.908 c	0.2556	149 b	1.101 ab	43.51 abcde
6	Spring Rye	9.790 abc	10.954 a	5.100 bc	0.2695	194 ab	1.064 b	44.583 abcd
7	Fall Metzger	8.784 abc	9.790 abc	4.785 c	0.2373	161 b	1.116 ab	37.02 bcdef
8	Fall Hazlet	8.673 cd	9.419 bc	4.318 c	0.2403	188 ab	1.124 ab	30.93 ef
9	Fall Wildfire	9.313 abcd	9.419 bc	5.725 abc	0.2633	176 ab	1.167 ab	36.64 cdef
10	Fall Prima	9.419 abcd	10.224 abc	6.115 abc	0.2687	164 b	1.215 ab	44.135 abcde
11	Fall Luoma	8.890 cd	9.843 abc	7.203 ab	0.2516	181 ab	1.236 a	28.20 f
12	Fall Pintail	9.525 abcd	10.689 ab	7.890 a	0.2369	179 ab	1.176 ab	31.87 def
	Average	9.26	10.179	5.365	0.2531	1.14	1.14	40.97

Table 22 **LARA Soil Parameter Measurements on Forage**

		Compaction					
		200 psi	**300 psi**	**Winf**	**SMResp**	**ActC**	**Wagg**
1	Fall Luoma	6.826	9.366	1.48	.2355	327	52.54
2	Spring Prima	5.239	7.779	3.00	.3030	347	54.41
3	CCC/Pintail	6.826	8.969	1.38	.2675	372	52.81
4	CCC/Prima	7.541	9.287	1.35	.2405	367	48.47
5	CCC/Hazlet	6.588	10.398	3.00	.3115	355	56.64
6	Fall Metzger	8.334	10.716	2.05	.3080	365	63.84
7	Spring Pintail	5.159	7.699	2.12	.3100	318	51.4
8	Fall Wildfire	6.985	10.160	1.19	.2850	307	57.24
9	CCC/Luoma	7.382	10.398	n/a	.3350	376	53.38
10	Fall Pintail	5.556	7.938	1.16	.1930	325	69.09
11	Spring Metzger	6.906	9.684	3.00	.3200	395	66.71
12	Spring Hazlet	5.271	9.366	2.48	.2015	301	74.64
13	Spring Wildfire	6.588	9.525	3.00	.2705	286	58.65
14	CCC/CCC	9.604	6.668	2.20	.2900	321	57.81
15	Fall Prima	6.668	9.684	2.16	.2245	314	65.95
16	CCC/Metzger	7.461	10.239	3.00	.3060	313	57.11
17	CCC/Wildfire	7.858	12.224	3.00	.2905	317	63.54
18	Spring Luoma	6.985	11.113	2.20	.3080	286	51.86
19	Fall Hazlet	9.763	15.716	1.05	.2475	292	50.53
Average		7.03	8.838	2.16	.2762	337	58.24

Table 23 **LARA Soil Parameter Measurements on Crop**

		Compaction					
		200 psi	**300 psi**	**Winf**	**SMResp**	**ActC**	**WAgg**
1	CCC/Spring Rye	6.350	10.795	.36	n/a	307	48.34
2	CCC/Spring Triticale	14.605	14.605	1.25	.298	331	99.88
3	CCC/Spring Wheat	6.033	6.350	2.53	.314	295	74.25
4	Spring Triticale	5.080	5.080	1.30	.3215	343	74.49
5	Spring Wheat	5.668	6.985	1.08	.282	287	77.26
6	Spring Rye	8.255	8.890	2.39	.429	315	83.46
7	Fall Metzger	11.430	13.018	1.32	.353	309	80.30
8	Fall Hazlet	10.160	17.145	1.56	.4685	319	83.35
9	Fall Wildfire	7.620	9.525	1.34	.383	295	91.93
10	Fall Prima	7.620	9.525	3.00	.419	304	84.91
11	Spring Luoma	15.875	23.495	3.00	.327	267	84.26
12	Fall Pintail	6.985	12.700	.58	.431	285	81.99
Average		8.807	11.509	1.64	.366	304.75	80.37