Annual Forage Intercrop to Build Soil Health

2022 D25

Project Lead:	**Manitoba Beef & Forage Initiatives**
MBFI Location(s):	Brookdale Farm
Start Date:	2022 Status: In Progress

Background

Soil health is important for the ongoing function of agricultural systems. It is the ability of a soil to sustain a living community of plants and soil organisms[1]. Managing soil health includes five principles: keep soil covered, reduce mechanical disturbance, keep living roots, increase plant diversity, and incorporate livestock grazing. Intercrops, also known as polycrops or polycultures, are diverse annual forage crops seeded for cattle forage to fulfill several of these principles.

Producers seed intercrops or cover crops to keep living plants longer in annual fields. Annual forages have a key role in providing nutritious winter feed through greenfeed or silage[2]. An intercrop is a mix of different plant species seeded together. By seeding an annual crop with species that will regrow following harvest, producers maintain a living root while also adding grazing days. Fall grazing of annual forages diversifies grazing plans, adds flexibility, and allows for perennial pastures to rest.

Producers are seeding intercrops to benefit soil health, including increasing soil organic matter, improving water infiltration, and benefiting the soil microbial community[3]. A diverse mixture of plants is used to mimic the function of a grassland ecosystem as different plants fill different niches in the system[4]. In some studies, soil organic carbon was higher in certain landscape positions and soil depths under intercrop management compared to monoculture[5]. In pea-cereal intercrops the peas were found to transfer nitrogen to the cereal crop, which may reduce need for adding fertilizer[6]. Soil microbial communities do not always see changes under an intercrop treatment, but this may be due to the short-term nature of many studies[7].

Intercrops have been shown to increase crude protein and some micronutrients in the forage as compared to a monoculture[3]. A study in Saskatchewan and Manitoba found higher micronutrients as

well as higher Total Kjeldahl Nitrogen in the polycrop treatments[7]. The same study found lower NDF in the intercrop, which will increase an animal's voluntary intake compared to the monoculture. Forage yields may be affected by the intercrop species selected as nutrient interactions between the planted species affects yield[4,6,7].

In a multi-year demonstration at Manitoba Beef & Forage Initiatives (MBFI), planning for regrowth by inter-seeding companion crops with the target cereal is proposed to improve soil health measures in addition to providing valuable livestock forage.

Objectives

Compare two annual cropping treatments grown for greenfeed and their yearly and cumulative effects.

1. Determine differences in annual crop forage yield, including impact on desirable species and weed pressure. Forage yield at harvest and regrowth after harvest is considered.
2. Determine differences in forage quality.
3. Determine differences in soil fertility.
4. Determine differences in soil health indicators.
5. Examine the costs of implementing each treatment.

Project Design and Methods

Site Background

Manitoba Beef & Forage Initiatives' (MBFI) Brookdale Farm is located on Newdale clay loam soil[8]. A 20-acre annual field was chosen for this project. This field hosted a corn grazing demonstration for four growing seasons from 2018-2021. The combination of four years of corn growth and cattle grazing made this site an interesting choice for examining effects of annual forages on soil health.

Site Design

Two treatments are explored in this project:

1. Monocrop annual cereal crop
2. Intercrop annual crop

The field chosen for this project is highly variable and oddly shaped. Therefore, each treatment is replicated seven times to capture the variability of the field (Figure 1). Treatments were paired and assigned a random plot.

Eighty feet from the fence was allocated to the headlands and planted to the monocrop cereal. Each plot was 80 feet wide but of varying length due to the odd shape of the field. Plots 7 & 8 have a large slough in the middle.

Crop species were selected for the intercrop to fill different functional groups, including annual cereal, legume, brassica, and herb (high-energy forage). A variety of root structures and above ground structures were chosen for the mix.

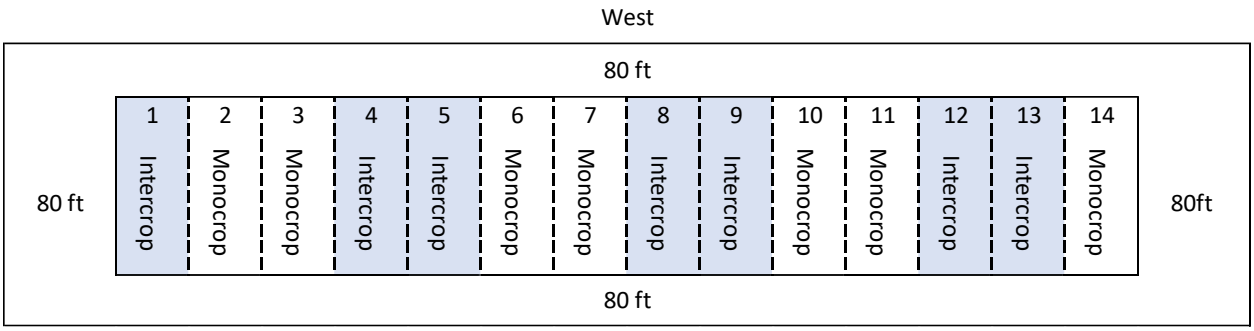

Figure 1. Plot map for monocrop and intercrop treatments.

Seeding & Field Management

Field preparation, spraying, and seeding were delayed due to the cold, wet weather in May 2022. Soil in the field was too wet for heavy equipment. By June 2022 tractors could enter the field but were unable to pass through several low areas, which impacted the area seeded in the plots.

Weed control was performed June 8 2022 by spraying glyphosate at 384 g/ac.

Minimal tillage was desired but practical decisions were made to deal with the wet conditions. On June 10 2022 the field was disced, which chopped the corn stalk residue. The field was harrowed twice on June 20 2022 to dry out the topsoil and improve conditions for the tractor and seeder.

Seed and fertilizer were placed simultaneously using a John Deere 752 zero-till drill. Headlands were sown June 20 2022. Monocrop barley plots were sown June 23 at 105.5 lb/ac. Intercrop plots were sown June 24 at 89.5 lb/ac (Table 1). Fertilizer was applied in both plots at 27.6 lb/ac nitrogen and 13.8 lb/ac phosphorus.

Table 1. Seeding rates.

	Seeding Rate (lb/ac)	
Crop	**Monocrop**	**Intercrop**
AB Advantage Barley	105.5	34.8
4010 Forage Pea		10.9
Snowbird Fababean		32.6
Jeanne Italian Ryegrass		5.1
Red Prosso Millet		2.6
Berseem Clover		0.9
Chicory		0.9
Plantain		0.9
Phacelia		0.4
Brassica		0.4

Areas that were too wet to seed in June had high weed pressure. These areas were mowed August 8 2022 to prevent these weeds seeding out.

Greenfeed was cut August 25, raked August 29, and baled September 1 2022. The entire field was harvested as one, so forage yield and quality were taken directly prior to cutting.

The high weed pressure and large unseeded areas led to a management decision to terminate the remaining crop. The entire field was sprayed September 3 2022 with a mix of 2-ethylexyl ester at 199 g/ac, bromoxynil at 106 g/ac, and glyphosate at 378 g/ac. On September 8 2022 the field was cultivated and harrowed twice. Fall rye was seeded September 9 2022 at 146 lb/ac to aid in weed control.

Sampling and assessment methods

After the field was seeded, three locations per plot were chosen for sampling. These locations are marked with GPS coordinates and used for all soil and forage sampling. The same locations will be used in all years of this project.

Due to the wet field conditions, baseline soil fertility samples were not taken until July 11 and 12 2022. Fall soil fertility samples were taken October 26 2022. All soil fertility samples were taken at the 0-6" and 6-24" depths. Two soil cores were taken at each sampling location and all six cores from each plot were composited into one sample for topsoil and subsoil. Samples were sent to Agvise Laboratories for analysis and completed at certified lab standards.

Forage samples were taken on August 22 2022, three days prior to harvest, using a quarter meter square frame. To gain a greater understanding of weed pressure, these samples were separated into seeded crop and weeds. Samples were dried and dry weights were used to calculate yield of the seeded crop, the weeds, and the overall biomass.

Both seeded crop and weed samples from all three locations were composited and sent to Central Testing Laboratory for forage quality analysis.

Further soil sampling did not occur in 2022 due to poor field conditions.

As the field was terminated and reseeded in September to control the high weed pressure, no forage yield or quality sampling occurred on regrowth from any of the plots.

Weather summary

The winter of 2021-2022 had frequent snowfall. April and May 2022 were wet and cold. This impacted the ability to prep the field for seeding.

Table 2. 2022 Weather information for the MBFI Brookdale Farm

Month	Precipitation (mm)	Average Temperature (°C)
January	11.3	-18.1
February	12.9	-19.4
March	5.0	-7.6
April	38.7	-1.6
May	172.2	9.7
June	136.6	15.9
July	68.1	19.0
August	40.7	18.4
September	41.4	13.0
October	30.0	5.1
November	6.4	-6.1
December	15.3	-15.9

Cost of Practice

To determine cost of practice, all input costs are calculated on a per-acre basis. Actual costs are used for seed, fertilizer, and herbicide. The Manitoba Agriculture 2022/2023 Cost of Production Farm Machinery publication is used as a reference for equipment and labour rates[9].

Establishment cost is compared to yield as well as pounds of crude protein and pounds of total digestible nutrients, as all three components affect the cost of feeding to cattle.

No grazing occurred in 2022, so no cost-benefit analysis of grazing the regrowth occurred.

Results

In the first year of the trial, the monocrop barley treatment yielded 650lb/ac less than the intercrop treatment (Figure 2). Weed pressure was similar in both treatments, around 10% or less of the total yield.

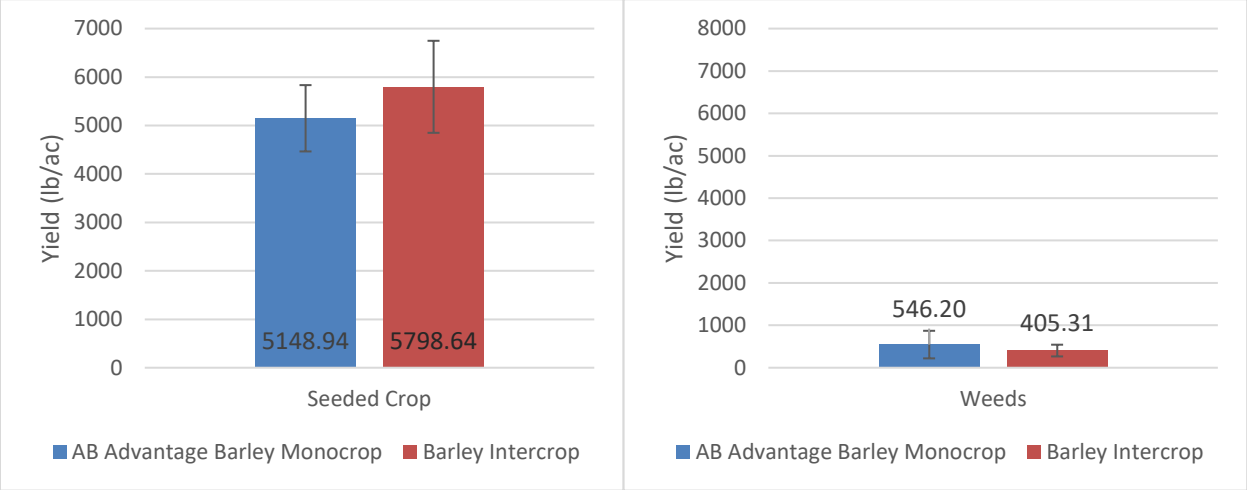

Figure 2. Seeded crop and weed yield for the barley monocrop and intercrop in 2022.

No regrowth sampling occurred due to the termination of the field for weed control.

Forage Quality

Forage quality was slightly higher in the intercrop treatment than in the monocrop treatment (Figure 3). The addition of legumes increased the crude protein in the forage by around 3%. Acid detergent fibre (ADF) is higher in the intercrop, indicating higher levels of cellulose and lignin and lower digestibility. Neutral detergent fibre (NDF) is lower in the intercrop forage, suggesting that an animal's voluntary intake of the intercrop will be higher.

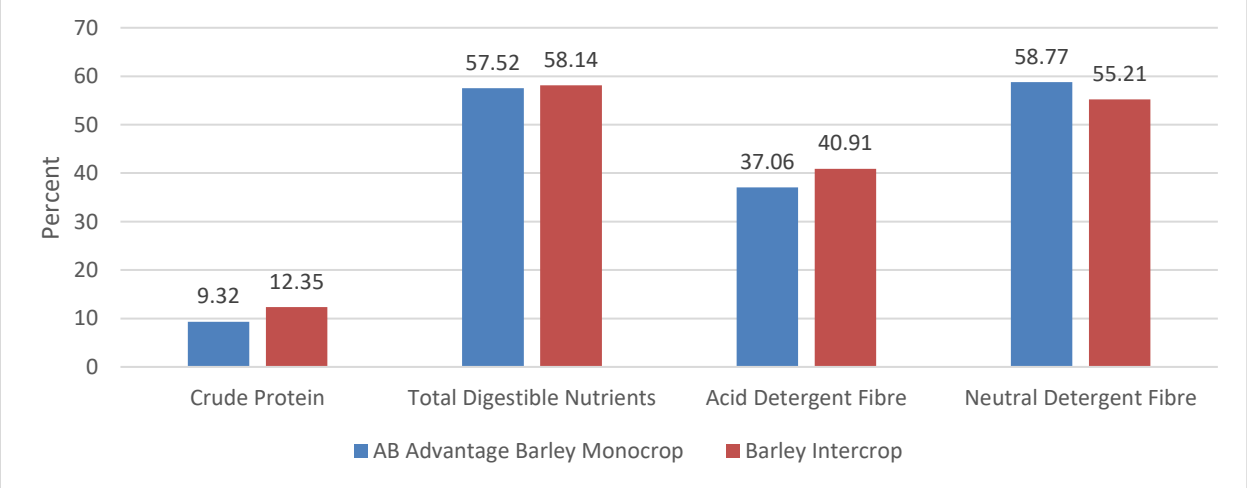

Figure 3. Forage macronutrients for the barley monocrop and intercrop treatments in 2022.

Micronutrients are higher in the intercrop forage than in the monocrop forage (Figure 4). The exception is phosphorus, which is similar between treatments.

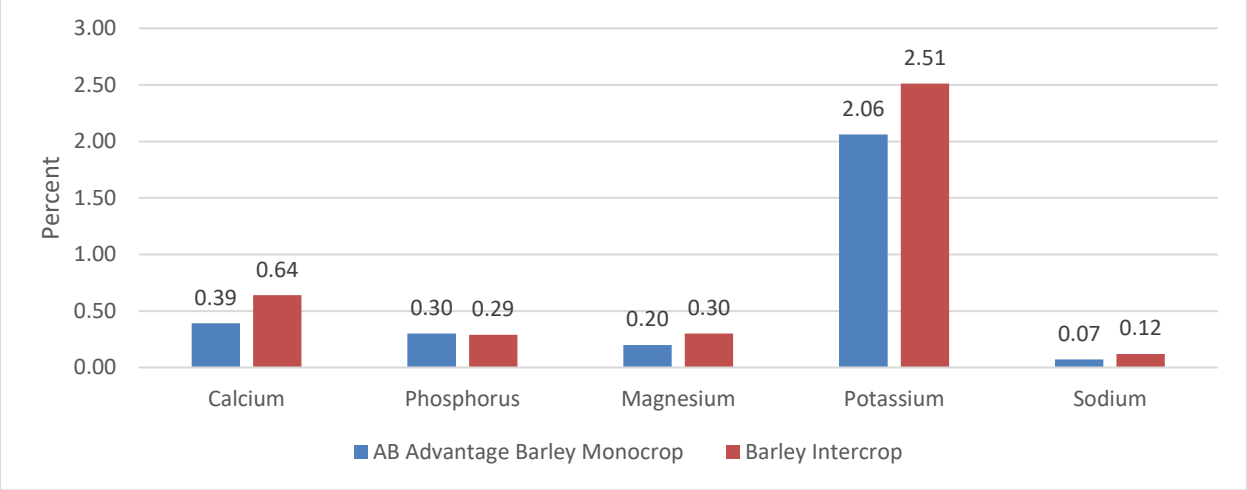

Figure 4. Forage micronutrients in the barley monocrop and intercrop treatments in 2022.

Soil Fertility

Baseline soil sampling was completed after the field was fertilized. Therefore, some soil fertility numbers may be elevated in the baseline sampling period.

There was very little difference in soil organic matter between treatments either at the first sampling or at the fall sampling after one crop (Table 3). Nitrate was slightly higher in the intercrop plots in both sampling periods. Phosphorus is at similar levels between treatments in both sampling periods. Calcium, magnesium, and potassium are at similar levels between treatments in both sampling periods. The monocrop and intercrop treatments did not have different effects on these soil minerals after one year. Annual crop treatment has not affected the levels of sodium, soluble salts, or pH.

Soil sulfur is higher in the subsoil than the topsoil (Table 3). There are only small differences between treatments and sampling period in the topsoil. In the subsoil, the baseline samples show similar sulfur levels. In the fall sampling period, the intercrop treatment shows about 50 lb/ac increase in sulfur in the subsoil compared to the monoculture treatment. It is unlikely this change can be attributed solely to crop treatment.

Zinc is similar between treatments in both sampling periods (Table 3). The intercrop is showing slightly higher levels of zinc at both sampling times and therefore any differences in the fall cannot be attributed to the annual crop treatment.

After one growing season, it does not appear that the intercrop is using more soil nutrients than the monocrop, despite some differences in forage quality (Figures 2 & 3). Cumulative effects of the monocrop and intercrop treatments will be explored in 2023 and 2024.

Table 3. Soil sampling results for baseline sampling and after one growing season.

	Baseline (July 2022)		October 2022	
	Monocrop	**Intercrop**	**Monocrop**	**Intercrop**
pH	7.8	7.8	7.8	7.8
Soil Organic Matter (%)	5.7	5.9	5.5	5.7
Nitrate (lb/ac)				
Topsoil 0-6”	15.0	17.9	9.4	10.1
Subsoil 6-24”	42.9	45.0	5.6	6.9
Phosphorus (ppm)	17.7	16.6	10.0	10.7
Potassium (ppm)	341	307	261	243
Calcium (ppm)	5343	5546	4717	4896
Magnesium (ppm)	746	790	684	720
Sulfur (lb/ac)				
Topsoil 0-6”	22.9	43.1	36.6	57.1
Subsoil 6-24”	111.4	114.0	148.3	198.9
Zinc (ppm)	0.95	1.05	0.79	0.83
Sodium (ppm)	22.4	22.6	23.9	23.1
Soluble Salts (mmho/cm)				
Topsoil 0-6”	0.41	0.45	0.47	0.43
Subsoil 6-24”	0.58	0.68	0.58	0.63
Cation Exchange Capacity (meq)	33.9	35.2	30.1	31.2

Soil Health

No soil health data was collected in 2022. Further sampling will occur in 2023 and 2024.

Cost of Practice

Table 3. 2022 input costs for barley monocrop and intercrop.

	Cost ($/ac)	
	Monocrop	**Intercrop**
Seeding costs		
Seed cost	$31.87	$72.74
Equipment & labour	$22.01	$22.01
Herbicide costs		
Herbicide cost	$13.24	$13.24
Equipment & labour	$6.16	$6.16
Fertilizer costs		
Fertilizer cost	$34.70	$34.70
Equipment & labour	-	-
Field prep costs		
Cultivation	$9.78	$9.78
Discing	$14.20	$14.20
Harrowing	$9.72	$9.72
Total Cost	**$141.67**	**$182.54**

Cost of seeding, herbicide application, fertilizer application, and field preparation are the same between treatments. In 2022, herbicide and fertilizer were applied at the same rates on both treatments, so herbicide and fertilizer cost are the same for both treatments. Fertilizer and seed were applied at the same time, so no equipment & labour costs were included for fertilizer application. Seed prices between treatments are different as the intercrop has ten species sown at different rates compared to the one crop in the monocrop treatment (Table 1). Field preparation costs are included in this analysis as they were required due to the wet field conditions. In a year and site where no field preparation was required, these costs would be $0/acre.

As the entire field was treated the same in 2022, only seed costs are different between treatments (Table 3). Seed cost for the monocrop barley treatment was $31.87/acre and seed cost for the intercrop treatment was $72.74/acre, or a difference of $40.87/acre.

Table 4. Cost comparison of 2022 barley monocrop and intercrop to yield and key nutrients.

			Cost per pound of:		
Treatment	**Cost ($/ac)**	**Yield (lb/ac)**	**Dry Matter Yield**	**Crude Protein**	**Total Digestible Nutrients**
Monocrop	$141.67	5149	$0.028	$0.295	$0.048
Intercrop	$182.54	5799	$0.032	$0.255	$0.054

Seeding costs are compared to yield to determine the relative cost of the practice (Table 4). Intercrop greenfeed was $41 more per acre to seed, but resulted in a higher forage yield. The resulting cost per pound of dry matter was $0.004 more for the intercrop. Costs per pound of crude protein and per pound of total digestible nutrients are presented to compare output as key forage quality metrics. With 3% higher crude protein and 0.6% higher TDN, resulting cost per pound was $0.04 less and $0.01 more respectively for the intercrop greenfeed.

Project Findings

The intercrop treatment showed higher yield and crude protein. Calcium, magnesium, and potassium were also higher in the intercrop forage. There are some differences in soil nutrients after one growing season. It does not appear that the intercrop is removing more soil nutrients than the monocrop. Combining the higher seeding costs for the intercrop with its higher yield, there is little difference in the cost-to-yield comparison.

Future years of this study will explore differences when using a different annual cereal and study cumulative effects of the intercrop treatment compared to the monocrop treatment. In 2022, field limitations, including weed pressure and wet soil, impacted potential activities. In future years, more soil health metrics and regrowth of the intercrop and monocrop will be studied.

Acknowledgements

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Thank you to SeCan and DLF Pickseed for providing the seed in-kind for this trial and to Ron Kristjansson for reviewing the report.

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Figures

Table 4. Forage yield and quality of the barley monocrop and intercrop in 2022.

	Monocrop		Intercrop	
	Mean	**Standard Deviation**	**Mean**	**Standard Deviation**
Yield (lb/ac)				
Total	5695	934	6204	968
Seeded Crop	5149	684	5799	950
Weeds	546	325	405	139
Crude Protein (%)	9.32	0.62	12.35	1.27
Calcium (%)	0.39	0.05	0.64	0.11
Phosphorus (%)	0.30	0.03	0.29	0.02
Magnesium (%)	0.20	0.03	0.30	0.06
Potassium (%)	2.06	0.17	2.51	0.20
Sodium (%)	0.07	0.04	0.12	0.07
Acid Detergent Fibre (%)	37.06	4.46	40.91	7.35
Neutral Detergent Fibre (%)	58.77	2.31	55.21	3.01
Non-Fibre Carbohydrates (%)	21.11	2.18	21.63	2.74
Total Digestible Nutrients (%)	57.52	2.55	58.14	2.81
Metabolizable Energy (Mcal/kg)	2.10	0.09	2.13	0.10
Net Energy for Lactation (Mcal/kg)	1.29	0.06	1.35	0.15
Digestible Energy (Mcal/kg)	2.54	0.11	2.56	0.13
Net Energy for Maintenance (Mcal/kg)	1.25	0.09	1.27	0.09
Net Energy for Gain (Mcal/kg)	0.68	0.08	0.70	0.09
Relative Feed Value	94	6	101	8

Table 5. Baseline soil sampling results in July 2022.

	Monocrop		Intercrop	
	Mean	**St Dev**	**Mean**	**St Dev**
pH	7.81	0.07	7.77	0.18
Soil Organic Matter (%)	5.67	0.52	5.86	0.63
Nitrate (lb/ac)				
Topsoil 0-6”	15.00	5.72	17.86	6.72
Subsoil 6-24”	42.86	10.06	45.00	18.17
Phosphorus (ppm)	17.71	4.54	16.57	4.89
Potassium (ppm)	341.14	82.93	306.86	57.08
Calcium (ppm)	5342.71	645.78	5545.86	618.08
Magnesium (ppm)	746.43	110.14	789.71	15.88
Sulfur (lb/ac)				
Topsoil 0-6”	22.86	14.37	43.14	40.99
Subsoil 6-24”	111.43	115.40	114.00	114.84
Zinc (ppm)	0.95	0.20	1.05	0.57
Sodium (ppm)	22.43	4.65	22.57	6.75
Soluble Salts (mmho/cm)				
Topsoil 0-6”	0.41	0.03	0.45	0.11
Subsoil 6-24”	0.58	0.27	0.68	0.55
Cation Exchange Capacity (meq)	33.91	2.38	35.20	2.70

Table 6. Soil sampling results after one growing season, October 2022.

	Monocrop		Intercrop	
	Mean	**St Dev**	**Mean**	**St Dev**
pH	7.87	0.11	7.81	0.15
Soil Organic Matter (%)	5.49	0.83	5.74	0.76
Nitrate (lb/ac)				
Topsoil 0-6”	9.43	2.76	10.14	2.41
Subsoil 6-24”	5.57	3.21	6.86	3.76
Phosphorus (ppm)	10.00	2.45	10.71	4.35
Potassium (ppm)	261.43	77.82	243.00	51.67
Calcium (ppm)	4716.86	622.99	4896.29	583.28
Magnesium (ppm)	683.86	151.85	719.71	140.16
Sulfur (lb/ac)				
Topsoil 0-6”	36.57	37.23	57.14	47.79
Subsoil 6-24”	148.29	102.34	198.86	141.33
Zinc (ppm)	0.79	0.23	0.83	0.36
Sodium (ppm)	23.86	11.92	23.13	7.45
Soluble Salts (mmho/cm)				
Topsoil 0-6”	0.47	0.33	0.43	0.12
Subsoil 6-24”	0.58	0.51	0.63	0.38
Cation Exchange Capacity (meq)	30.06	2.54	31.20	2.57

Figure 5. Seedlings emerging July 5, 2022.

Figure 6. Interccrop prior to harvest. August 2022.

Figure 7. Regrowth one week after harvest. Left: monocrop, Right: intercrop