FINAL REPORT

ADOPT 20200535

DEMONSTRATION OF INTERCROPPING PERENNIAL RYEGRASS WITH OAT

USING DIFFERENT SEED PLACEMENTS AND SEEDING RATES

REDVERS, SK 2021 & 2022

Contents

Project Identification

1. Project Title

Demonstration of intercropping perennial ryegrass *Lolium perenne* L. with oat using different oat placements and seeding rates.

2. Project Number

ADOPT # 20200535 MIDAS# 000529

3. Producer Group Sponsoring the Project

Saskatchewan Forage Seed Development Commission (SFSDC)

4. Project Location(s)

GPS coordinates: 49.544257 N -101.660655 W
South East Research Farm (SERF)
Box 129,
Redvers, SK S0C 2H0
RM #61 Antler, SK

5. Project start and end dates (month & year)

Fieldwork contract executed between producer group and contractor (CLC) on May 05, 2021. Fieldwork began May 20, 2021. Project end date January 30, 2023 (seed samples quality analysis completed and trial data and reporting submitted).

6. Project contact person & contact details

Saskatchewan Forage Seed Development Commission
J. Relf-Eckstein, Executive Director
#5 Eagle Ridge Road, Eagle Ridge, SK S7K 2L6
office@saskforageseed.com
306-341-1347

South East Research Farm (SERF)
Lana Shaw, Research Manager
Box 129, Redvers, SK S0C 2H0
lshaw.serf@gmail.com
306-452-7253

Objectives and Rationale

7. Project objectives

The project will demonstrate the application of practical a ndscientific knowledge of intercropping to the practical use of intercropping an annual crop (oat) with a forage seed crop (perennial ryegrass).

This two-year project aims to assess plant establishment, agronomic performance seed yield and quality of oat, winter survival of the perennial ryegrass, and seed yield of perennial ryegrass by comparing two methods of seed placement of oat in relation to perennial ryegrass while assessing the effect of four oat seeding rates.

8. Project rationale

Saskatchewan producers have increased interest in intercropping. In response, intercropping projects at the AgriArm research farm locations in Saskatchewan collect performance data for growers. Field trials demonstrate planting two annual crops, such as chickpeas and flax, condiment mustard and peas, or pea-oat intercrop (Shaw, 2020). Shaw's research trials generate knowledge about the value proposition of intercropping, including income from two cash crops in one growing season, increased productivity relative to a monocrop, pest reduction, nutrient efficiency, and other potential benefits, including ecosystem services.

There is an opportunity to broaden intercropping to include the production of a seed crop where the revenue from two cash crops is derived over two growing seasons, but both crops are planted at once. Mixed intercropping is "the practice of growing two or more crop species together at the same time in a field without using any particular spatial configuration" (Bybee-Finley & Ryan, 2018, p. 2). Our trial demonstrates the potential of mixed intercropping and growing a grain crop as a companion crop with a short-lived perennial forage seed crop without using any particular spatial configuration.

We explicitly target demonstrations in areas potentially well suited to growing two or more species simultaneously. Innovative forage seed growers are doing mixed intercropping in northeast Saskatchewan, Manitoba, and the Peace Region of Alberta-British Colombia. These growers do not typically use the term - it is simply a management practice that has proven profitable and effective in establishing forage seed crops. The regions where mixed intercropping works tend to be the grey-wooded and black soil zones with sufficient rainfall and soil moisture reserves that support the simultaneous growth of two crops (Jefferson *et al.*, 2005).

For forage seed growers, mixed intercropping typically involves using a companion crop such as an annual cereal, pulse, or oilseed crop planted in the year of establishing a short-lived perennial forage seed crop. Pre-seed (pre-emergent) herbicides are often used for weed control. Both crops are planted at the same time. Fertilizer placement, products and rates are determined based on the yield expectations of the companion crop. The companion (annual) crop is harvested in the fall of year one, providing grain yield income from the field, while the forage seed crop is in its first-year vegetative growth stage. Fertilizing to compensate for the nutrient uptake by the annual crop may be done in the fall after the harvest of the companion crop, in spring, or as a split application (fall and spring). The stubble of the annual crop serves to minimize the risk of forage seed crop loss due to winterkill by trapping snow, conserving moisture, and protecting the forage plants from wind desiccation and severely cold temperatures. The forage seed crop is harvested in the late summer of the following year, although, in some situations, the forage seed crop may be left for seed production for an additional one to four years.

Annual crops commonly intercropped with short-lived perennials in the forage seed-producing regions of the prairies include canola (e.g., Liberty® and Clearfield® systems). Cereal crops, such as barley, wheat and oat, are particularly well suited to similar regions recommended for forage seed production regions (Jefferson *et al.*, 2005). This crop rotation strategy creates the opportunity to save input costs and time by planting two crops at once, reducing fuel costs and emissions while improving soil health by keeping roots in the soil for an extended period and offering grain yield income in two years. Demonstrating management options, such as seed placement and seeding rates, will provide knowledge to seed growers interested in diversifying their rotations.

The RM of Antler (#61) is in south-east Saskatchewan, the Black Soil Zone, Crop District #1. Historically, drought is a definite hazard and high winds are common. However, in recent years, Redvers has received rainfall more than adequate for crop production. Based on the Saskatchewan Varieties of Grain Crops 2022 data, the oat variety used in our demonstration, had similar yield to crop district 4 in northeast Saskatchewan; CDC Arborg yielded 105% of CS Camden in Area 1 and 106% Camden in Area 4.[1] A mixed intercrop system with oat has excellent potential for success in the Redvers area, given the shift in precipitation. Oat growers in the area wanting to diversify rotations may be interested in intercropping oat with a forage seed crop.

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[1] Sask Seed Guide. Varieties of Grain Crops 2023. Saskatchewan Agriculture. CDC Arborg has high test weight (250 g/0.5L), 20.1% hull, 85% plump kernels, medium maturity (less than 98 days maturity), 108 cm height, very good resistance to lodging, and has improved disease resistance over CS Camden with R (resistant) ratings for smut disease, and I (intermediate resistance) to crown rust; both varieties are susceptible to stem rust. Accessed online Varieties of Grain Crops 2023 Saskatchewan

Meanwhile, turf-type perennial ryegrass seed is in demand, and Saskatchewan production is trending upward. Compared to the past 17 years of production data, in 2021-2022, perennial ryegrass deliveries exceeded red clover, the traditional top-ranked forage seed crop produced based on deliveries documented by the Saskatchewan Forage Seed Development Commission (SFSDC).[2] Forage seed buyers are reporting increased more acres of perennial ryegrass are needed.

When perennial ryegrass is planted with a companion crop, the forage crop plants are generally slower to establish compared to a monocrop scenario. A good snowpack is also required, the stubble acting as a snow trap. As a Forage Seed Specialist in Manitoba reported, perennial ryegrass plants overwinter best as relatively small plants because the crowns are located just at, or below, the soil surface (Cattani, 2007).

Planting a companion crop with perennial ryegrass while reducing vegetative matter should also help reduce disease and insect pressure (Alberta Agriculture, 2004). On the contrary, there is also the risk that the oat crop could out-compete the perennial ryegrass. Seeding rates may be an influential factor. Fairey and Lefkovitch (2001) planted an annual cereal crop (barley) with perennial ryegrass and found a significant seeding rate x cultivar interaction for fertile tiller density and specific seed weight. There needs to be more information available on different seeding rates and seed placement for the oat-perennial ryegrass mixed intercropping combination. Furthermore, even in Minnesota, recognized for forage seed production, Koeritz *et al.* (2015) assert that the impact on perennial ryegrass plant growth and seed yield based on seeding rates and row-spacing width factors needs to be better characterized.

Given the different configurations of the seeding equipment available to growers, we demonstrate mixed intercropping of oat with perennial ryegrass and compare two placements - side-band and same-row planting of the oat crop in relation to the perennial ryegrass. Based on grower interest in selecting an optimum seeding rate for intercropping, we also assess the effect of four different oat seeding rates. The standard (1X) seeding rate and depths are determined based on the recommendation by the commercial seed suppliers.

Methodology and Results

9. Methodology

The crop varieties used in the demonstration were selected due to their market acceptance and a good fit for the production region. Subsequent to a conversation with a Ministry specialist and concerns about oat crown rust, we changed the oat variety proposed in the application to a variety with multiple sources of rust resistance. The ADOPT specialist assigned to this project approved the milling oat variety CDC Arborg. In addition to disease resistance, CDC Arborg, a milling oat, has strong stems, and the stubble is likely to remain upright (p. comm, Dr. Beattie, oat breeder), thus trapping snow and protecting the turfgrass type perennial ryegrass variety CE1. FP Genetics and Brett Young provided in-kind support by donation of seed supplies of oat and perennial ryegrass, respectively. Each company provided seed lot data, including source, germination, seed weight, and target plant stand. The targeted plant density for 1.0X oat rate was 350 plants/m^2, the equivalent of 136 lbs/ac given a germination of 98% and thousand kernel weight of 38.46 grams. The site was located where seedbed moisture was optimum, seed depth targeted at 2-3 cm (0.75 to 1.2 inches). For the turf type perennial ryegrass variety, CE1, the recommended seeding rate for the area is 8 lbs/ac. Seed should be planted at a (shallow) seeding depth of no deeper than 1.3 cm to 2.5 cm (0.5 to 1 inch).

The trial was designed as four replicates of ten treatments (see Appendix Table A.1.a), demonstrating placement of oat as either (a) side-band and seeded deeper than the perennial ryegrass, or (b) the oat was planted same-row as the perennial ryegrass. For each of the two placement positions, four oat seeding rates were used: ¼ seeding rate oat (0.25X); half rate (0.5X); ¾ rate (0.75X); and full-rate (1.0X). Individual plots were 27 m^2. Trial management was done by the personnel of the personnel of the SERF research farm, led by Lana Shaw, a research agronomist with expertise in intercropping in the Redvers area.

Soil fertility was assessed twice in 2021, before planting and after the harvest of the companion crop. In spring, a composite soil sample from the trial area was collected and analyzed by Agvise Laboratories, North Dakota (data not provided). The test was used to fertilize the ADOPT demonstration trial site and adjacent trials. Phosphorous as MAP was applied at 29 lbs/ac, 68 lbs/ac N was available in the soil, ESN was applied top-dress at 63 lbs – applied fertilizer was broadcast June 18. Soil nutrient availability for the perennial

[2] See audited financial statements Annual Reports, Information also presented at Annual General Meetings. SFSDC Governance Annual Reports and Audited Financial Statements

ryegrass was determined post-harvest of the oat crop. On October 04, after harvesting the oat, a composite soil sample was made for each of the ten treatments. Results are reported in Table A.2.a. The samples were analyzed using Plant Root Simulator (PRS®) probes at the Western Ag Innovations Inc.

The trial was seeded into wheat stubble on June 01 2021. Planting was delayed due to very dry conditions. Seeding was done using a commercial (SeedMaster) drill with a side band-configuration. The main seed row was planted at ¾-inch and the second row placed about ¾ inch to the side and planted ¾-inch deeper than the seed row (see Figure 1)

In spring 2022 treatment #10 plots were seeded with oat. Also in May, fertilizer was applied to each treatment (broad cast by handheld spreader). Treatment-based fertilizer recommendations were developed using PRS Cropcaster® software and reported in Table A.2.b.

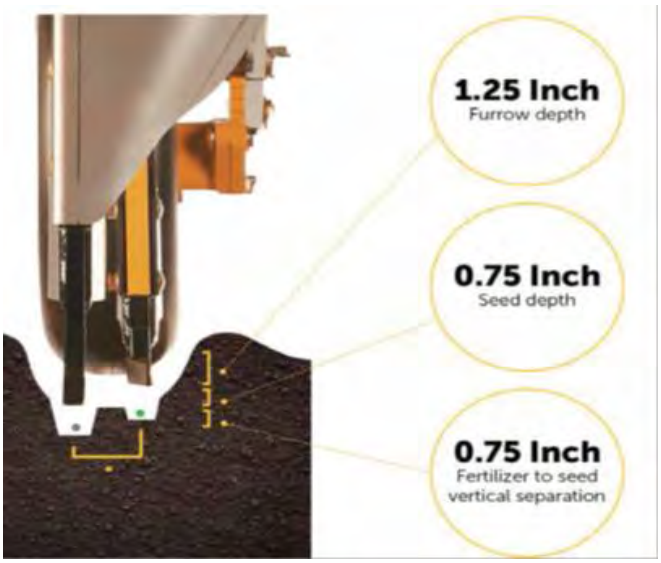

Figure 1: Schematic of SeedMaster opener used on commercial seed drills, same as the seed drill used to plant the ADOPT trial. (Source: SeedMaster product catalogue on-line and in print form).

Spring 2021 trial preparation and maintenance included pre-emergent control of weeds using an application of glyphosate on May 31 at a rate of 0.7L/ac (540 g ae/ac). In-crop weed control was done by hand rogueing. In 2022, a group 6 and 27 herbicide, Infinity (Bayer Crop Science Canada) was applied. The product and use pattern to control broadleaf weedy species is registered for one use in perennial ryegrass per season.

Agronomic performance was first evaluated by collecting emergence data. *Emergence* was rated in each plot after seeding in 2021, oat plants were counted June 18 and perennial ryegrass plants counted June 24. The total number of plants in each of four rows within each plot was determined. *Above-ground biomass* samples of oat, perennial ryegrass and weeds were collected on August 11, 2021 at the oat swathing stage using a 0.5-m quadrant. Biomass samples were air-dried and weighed. Information on the plant stand of the perennial ryegrass prior to freeze up. Results were summarized in the Interim Report, December 2022.

Biomass of the perennial ryegrass was observed post-harvest of the oat crop using drone imagery. A qualified drone pilot captured the images on November 4 using a DJI Phantom 4 Pro, SN 0AX3G96002W212, C-1935143258. The mapping mission included use of RGB aerial imagery at ~0.9-cm ground sample distance and the data was provided as unprocessed JPEG images, for processing by a second industry UAV services provider (as an in-kind contribution to the project). The purpose of the flight was to collect nadir mapping images to create an orthomosaic of the area. The drone captured oblique imagery of the area from multiple angles, creating a visualization of the different treatments and the trial site before the perennial ryegrass going into winter. (Winterkill may reduce the yield potential of the perennial ryegrass in year two). If additional funding can be sourced, in the future, the data collected in the files could be used to identify plant stand (biomass) on a plot basis and cross-tabulate the imagery data with seed yield.

In 2022, collecting data on the amount of *spring regrowth* of the perennial ryegrass was challenging. Differentiating the individual perennial ryegrass plants from each other required separating the plants to count and this may have affected subsequent growth. Consequently, in early June 2022, a non-destructive approach was chosen. Digital image capture using Canopeo, an app, was used to estimate canopy development; a method used by Patrignani and Ochsneand (2015). The mobile phone app was also used to in

New Zealand to estimate biomass yield in winter forage crops. Jáuregui *et al.* (2019) concluded the green canopy cover (% GCC) data captured by the camera was a "fast and reliable method to estimate biomass accumulation and light interception of forage crop" and had high R^2 (correlation) values with crop biomass measurements, light interception and NDVI measurements, however, the % CGC does not differentiate the type of canopy, for example weedy species from crop.

Oat and perennial grass plant height was measured in each plot by taking three measurements and calculating the average. General observations were made on standability (lodging). The 2021 results were summarized in the Interim Report, December 2022. Days to maturity on the perennial ryegrass treatment was not completed due to the within-plot variability.

Oat yield data were collected from all plots using a plot combine, nine oat treatments in 2021 and nine perennial ryegrass treatments plus one oat treatment (monocrop planted in 2022) in 2022. Plot samples were dried and cleaned to assess seed yield. The plan was to prepare a composite seed sample from the four replicates of each treatment and have it analyzed to determine thousand kernel weight, seed dockage, and germination after harvest of each crop. Unfortunately, in 2021 the harvest bulks were discarded before the sub-samples were drawn. In 2022, individual samples from all plots were collected; a bulk composite was created by drawing equal volume from replicates 1, 2 and 3, for each treatment. Replicate 4 was excluded due to poor establishment. The composite bulk representing each treatment was send for *seed quality analysis*, Discovery Seed Labs, Saskatoon. Germination tests were done according to Methods and Procedures of Testing, C.F.I.A. Thousand kernel weight and dockage were not determined due to budget limitations for this project.

Analysis of agronomic performance data was done by SERF personnel using Statistix™ v10 software, testing for differences between means with Analysis of Variance (ANOVA). For weed biomas, mean comparisons were determined, Tukey's 1 Degree of Freedom Test for Non-Additivity was included in the analysis and all pairwise comparisons were tested, and Least Significant Differences (LSD) reported. Significance was determined at $p<0.05$. The other 2021 data is reported as plot average of 4 plots per treatment with plot data used to create average values for the two main factors (seed placement and rate). In 2022, statistics were run as a factorial analysis to better understand the factor effect (i.e., oat seed placement and oat seeding rate) on the forage seed crop. The monocrop oat and perennial ryegrass data points were not included in the factorial analysis. Yield data analysis excluded the 4th rep due to winterkill in some areas of the outmost (exposed) replicate.

Fertilizer was applied in the perennial ryegrass plots as (hand) broadcast on 3rd May 2022. Fertilizer application rates for perennial ryegrass seed yields recommended by Western Ag used canary seed as a proxy because datasets (calibration curves) for perennial ryegrass fertilizer-yield goal recommendations are not available.

10. Results

In comparison to other regions of the province, for the 2021 season, the Redvers location was a fortuitous choice for demonstrating mixed intercropping. The management choice to delay seeding was likely very effective in uniform early emergence. The rainfall came in mid to late spring and the experienced contractor had delayed seeding until the seedbed conditions were conducive for good establishment.

Pre-emergent herbicide was applied for weed control and the demonstration was planted into wheat stubble on June 01. Pre-planting information, including the treatment list and plot plan, is summarized in Appendix A.1. In 2022, weed control was done using Infinity herbicide registered for use on perennial ryegrass. Fertilizer was applied in a timely manner at rates recommended for oat and perennial ryegrass seed yield (canary seed yield targets used as proxy for perennial ryegrass). Soil test results are summarized in Appendix A.2. Oat plots were harvested with a small plot combine at maturity and the perennial ryegrass plots were harvested in order of maturity. There may have been a delay in harvest due to variability within the plots. This delay may have resulted in an underestimation of seed yield.

10.1 Environmental conditions for mixed intercropping

During the year of establishment, Redvers received approximately 155 mm rainfall. Detailed information on temperature and precipitation relevant to the mixed intercrop rotation spring 2021 to fall 2022 are reported in Appendix A.3. The conditions created the opportunity for good forage seed crop establishment and economically viable seed yield from the milling oat.

While total rainfall in 2021 was far-from the long-term average of 530 mm, the timing of the rainfalls, as well as the moderate temperature conditions, created the environmental conditions for a harvest yield of 66 bu/ac oat from the monocrop oat treatment. This was not typical for 2021 harvest in many parts of the province. The estimated average 2021 oat yield for Saskatchewan released by the provincial government was 49 bu/ac with a 10-year average of 83 bu/ac (Government of Saskatchewan, 2021). Oat yield in the intercrop perennial ryegrass trial were all above the provincial average as reported in the interim report with further commentary in section 10.3.

From the time the oat crop was maturing until freeze up (August to end of October) approximately 68 mm rainfall had accumulated. The perennial ryegrass plants should not have been stressed for moisture before going into dormancy. There was limited precipitation from November to March (total of 27.8 mm). November temperatures were seasonal with a monthly average -2.9 C with minimum of -13.2 C and maximum of +5.3. However, the remainder of winter of 2021-2022 had cold temperatures. Starting in December, and through to the end of February, monthly average temperatures were approximately -15 C or lower with minimums of -30 C and maximum average daily high of 1.3 C in December, -3 in January and two days of 0 C in February. March remained cool with a maximum of 1.4 C and minimum temperature of -22 C. Temperature conditions were not favourable for the perennial ryegrass plants to begin growth. With arrival of spring, and through to early July, temperatures were moderate and total rainfall of 661 mm April to October, was well above long-term average of 530 mm. With sufficient fertilizer and moisture reserves, the perennial ryegrass plants had the opportunity at the trial site to set up good seed yield.

10.2 Agronomic performance of intercropped oat and perennial ryegrass

Early emergence data for oat plant counts in 2021 averaged 118 plants across all treatments, ranging between 50 to 224 plants, 75 oat plants was the target density for the area counted. There were noteworthy and not unexpected trends as seeding rate increased.

The relationship of increased oat plant density with increased seeding rate was linear for oat same-row placement as show in Table 1, but not for side-band. The intercropping of oat with perennial ryegrass did not reduce the early emergence of oat as evidenced by the value of 152 plants for monocrop oat, compared with oat planted same-row at the 1.0X rate, although, there was a slight reduction in oat density when planted 1.0X and placed side-band. The differences between all treatments were not statistically significant. Intercropping oat with perennial ryegrass, however, did have a negative, but not statistically different, effect on perennial ryegrass plant density in spring 2021. In 2022, the average perennial ryegrass plant density based on images captured and estimated by the Canopeo app resulted in a 3-replicate average for perennial ryegrass planted as monocrop of 80%. Thus, intercropping of oat with perennial ryegrass as a strategy to establish perennial ryegrass reduced plant density in both years. Using percent green canopy cover (% GCC) as a proxy, the data indicates that the highest % GCC was at the lowest oat seeding rate placed side-band, which was higher than Same-row placement at the same (0.25X) rate. Side-band placement of oat and 0.5X rate was the third highest % GCC. Further increases in seeding rate resulted in nearly a 25% to 50% reduction in PGR canopy cover compared to monocrop perennial ryegrass. Tables 2 and 3 summarize the differences in each of the two factors.

The 0.25X and 0.5X seeding rates, when analysed over both placement positions, as shown in Table 2, resulted in the highest proportion of green canopy cover, approximately 70% for the 0.25X and 0.5 X rates with less canopy with increased oat seeding rate (approximately 55% less canopy relative to monocrop perennial ryegrass). Side-band placement of oat resulted in the most canopy coverage when analysed over all seeding rates, however, the differences were not statistically significant. Table 3 analysis of seed placement similarly shows no difference in seed placement when analyzed over all seeding rates, both placements were 52 and 48%, side-band and same-row, respectively. Figures 3 and 4 illustrate the differences of intercrop treatments.

Table 1: Analysis of seed placement and rate factors on plant densities when oat and turf type perennial ryegrass (PRG) are planted as mixed intercrop, Redvers, SK, spring, 2021 and 2022*

Oat Placement, Rate	Oat Seeding Rate	Plant Density Oat June 18	Plant Density PRG June 24	Plant Density early June
		(# plants per plot, 2021)		(% green canopy cover 2022)
Side-band and deeper than PRG	0.25 X	69.5	104.1	62.0 a
	0.5X	97.0	170.7	60.8 a
	0.75 X	96.5	131.7	44.3 b
	1.0X	144.4	133.9	40.1 b
Same-row as PRG	0.25 X	79.6	102.7	54.9 ab
	0.5X	117.2	133.6	45.8 ab
	0.75 X	160.6	99.5	40.8 b
	1.0X	185.9	135.3	49.2 ab
Mono-crop PRG	0X	-	149.6	80.1
Mono-crop Oat	1.0X	152.3		96.8
Standard error for comparing differences of two means		12.4	28.7	16.3

*2022 data is a Least Significant Difference All-Pairwise Test for the two factors, seed placement and rate. There are 2 groups (a.b) in which the means are not significantly different from one another at p-value of 0.05.

Table 2: Analysis of seeding rate factor on plant densities when oat and turf type perennial ryegrass (PRG) are planted as mixed intercrop, Redvers, SK, spring, 2021 and 2022*

Oat Seeding Rate	N	Plant Density Oat June 18	Plant Density PRG June 24	Plant Density early June
		(# plants per plot, 2021)		(% green canopy cover, 2022)
0.25 X	8	75	103	58.4 a
0.5 X	8	107	152	53.3 ab
0.75 X	8	129	116	44.7 b
1.0 X	8	165	135	42.6 b
1.0 X (monocrop PRG)	4	152		80.0
1.0 X (monocrop oat)	4		150	96.8
Standard error for comparing differences of two means				11.5

*2022 data is a Least Significant Difference All-Pairwise Test for the two factors, seed placement and rate. There are 2 groups (a.b) in which the means are not significantly different from one another at p-value of 0.05.

Table 3: Analysis of oat seed placement factor on plant densities when oat and turf type perennial ryegrass (PRG)re planted as mixed intercrop, Redvers, SK, spring, 2021 and 2022*

Oat placement	N	Plant Density Oat June 18	Plant Density PRG June 24	Plant Density PRG early June
		(# plants per plot, 2021)		(% green canopy cover, 2022)
Side-band	16	102	135	51.8 a
Same-row	16	136	118	47.7 a
Mono-crop PRG	4	-	150	80.0
Mono-crop Oat	4	152	-	96.8
Standard error for comparing differences of two means				8.1

*2022 data is a Least Significant Difference All-Pairwise Test for the two factors, seed placement and rate. There are 2 groups (a.b) in which the means are not significantly different from one another at p-value of 0.05.

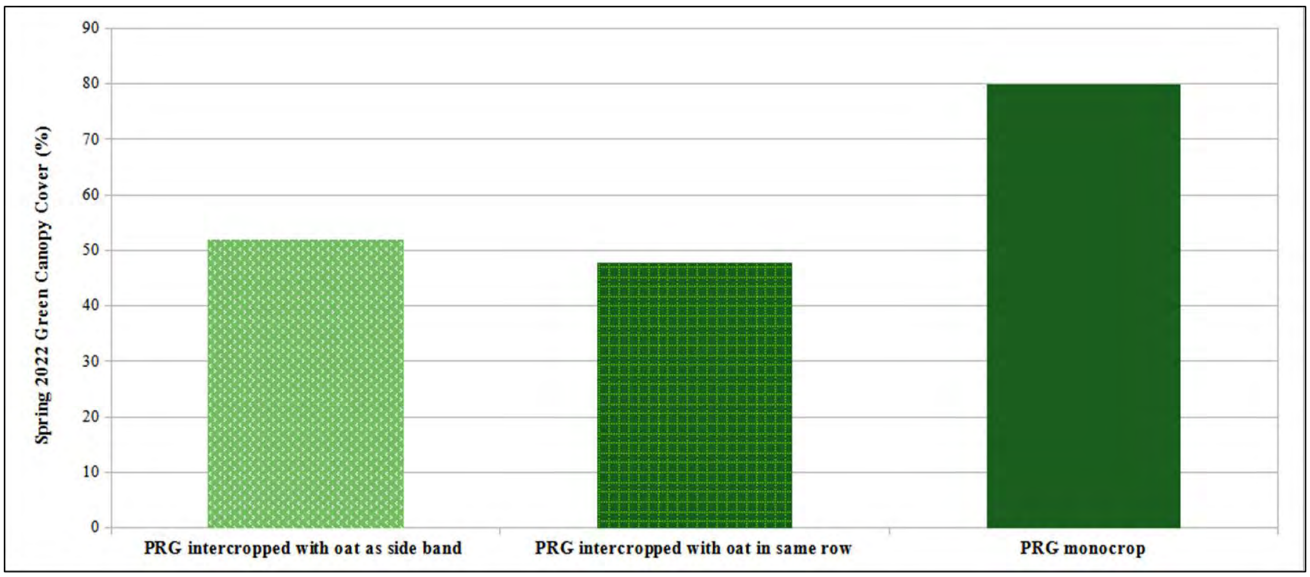

Figure 3: Green canopy cover of perennial ryegrass as influenced by oat seed placement when planted as an intercropping or as a monocrop, Redvers, SK, 2022.

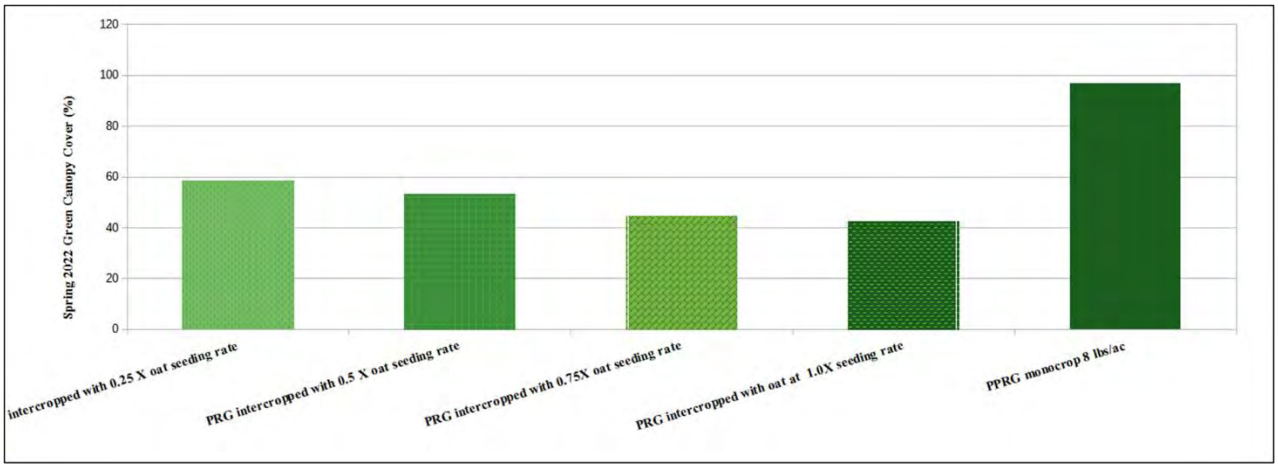

Figure 4: Green canopy cover of perennial ryegrass as influenced by oat seeding rate when planted as an intercropping or as a monocrop, Redvers, SK, 2022.

Plant height of oat in 2021 was highest at the lowest (0.25X) oat seeding rates, 87 cm and 86 cm, side-band and same-row, respectively, both treatments resulting in taller plants than when oat was planted as a monocrop (Table 6). In comparison to expected performance, in 2021, oat height in the trial was considerably shorter than the typical height of 108 cm for CDC Arborg. The highest seeding rate (1.0X) resulted in the shortest oat plants, 79 cm for both placements, and nearly equal to monocrop oat height of 80 cm. At both placement positions, oat plant height at the 0.5X rate was similar and 3 cm taller than monocrop oat. In 2022, there were no major differences in height of perennial ryegrass for all intercrop combinations which ranged from 52 cm to 57 cm, compared to monocrop perennial ryegrass (57 cm). Tables 7 and 8 summarize the substantive intercropping effect on perennial ryegrass plant height in comparison to the monocrop. When comparing oat seeding rates, over both placement positions, there was no difference between the 0.25X and 0.5X rate, 55 cm plant height at 0.25X and 56 cm at 0.5X. Similarly, the 0.75X and 1.0 X rates were not different, 53 cm, and 54 cm, respectively. Table 8 analysis of seed placement similarly shows no difference in plant height when analyzed over all seeding rates, both placements resulted in 55 cm tall perennial ryegrass plants.

Table 6: Analysis of seed placement and rate factors on plant height when oat and turf type perennial ryegrass (PRG) are planted as mixed intercrop, Redvers, SK, spring, 2021 and 2022*

Oat Placement, Rate	Oat Seeding Rate	Plant Height Oat	Plant Height PRG
		(cm, 2021)	(cm, 2022)
Side-band and deeper than PRG	0.25 X	87.2 a	56.1 a
	0.5X	83.0 abc	56.7 a
	0.75 X	85.2 ab	53.5 ab
	1.0X	79.5 c	52.2 b
Same-row as PRG	0.25 X	86.4 a	54.6 ab
	0.5X	82.9 abc	55.7 a
	0.75 X	81.1 bc	52.1 b
	1.0X	78.6 c	55.7 a
Mono-crop PRG	0X		56.7
Mono-crop Oat	1.0X	80.0 c	99.5
Standard error for comparing differences of two means		4.6	3.5

*2022 data is a Least Significant Difference All-Pairwise Test for the two factors, seed placement and rate. There are 2 groups (a.b) in which the means are not significantly different from one another at p-value of 0.05.

Table7: Analysis of seeding rate factor on plant height when oat and turf type perennial ryegrass (PRG) are planted as mixed intercrop, Redvers, SK, spring, 2021 and 2022*

Oat Seeding Rate	Plant Height Oat**	Plant Height Oat , PRG
	(cm, 2021)	(cm, 2022)
0.25 X	-	55.4 a
0.5 X	-	56.2 a
0.75 X	-	52.8 b
1.0 X	-	54.0 ab
1.0 X (monocrop PRG)		56.7
1.0 X (monocrop oat)		99.5
Standard error for comparing differences of two means		2.4

Table 8: Analysis of oat seed placement factor on plant height when oat and turf type perennial ryegrass (PRG)re planted as mixed intercrop, Redvers, SK, spring, 2021 and 2022*

Oat Placement	Plant Height Oat**	Plant Height PRG
	(cm, 2021)	(cm, 2022)
Side-band	-	54.7 a
Same-row	-	54.6 a
Mono-crop PRG	-	56.7
Mono-crop Oat	-	99.5
Standard error for comparing differences of two means	-	1.7

*2022 data is a Least Significant Difference All-Pairwise Test for the two factors, seed placement and rate. There are 2 groups (a.b) in which the means are not significantly different from one another at p-value of 0.05.

Oat seed yields in 2021 were all above the provincial average with few differences in yield across all treatments, except oat when seeded the same row as perennial ryegrass at the highest seeding rate reduced yield, but not statistically significant. Yields in Table 9 are reported as adjusted yield, correcting for moisture content (range 10.4-13.1%) and plot size. The estimated average 2021 oat yield for Saskatchewan released by the provincial government is 49 bu/ac and the 10-year average was 83 bu/ac (Government of Saskatchewan, 2021). The average oat yield when intercropped was 2385 kg/ha (66 bu/ac) compared to monocrop oat 2367 (66 bu/ac).

Table 9: Analysis of seed placement and rate factors on seed yield when oat and turf type perennial ryegrass (PRG) are planted as mixed intercrop, Redvers, SK, spring, 2021 and 2022*

Oat Placement, Rate	Oat Seeding Rate	Seed Yield Oat	Seed Yield Oat, PRG	Seed Yield PRG	Seed Quality Oat, PRG
		(kg/ha, 2021)	(kg/ha, 2022)	(lbs/ac, 2022)**	(% germination, 2022)
Side-band and deeper than PRG	0.25 X	2303	595 ab	531	92
	0.5X	2541	633 a	565	88
	0.75 X	2352	546 ab	487	90
	1.0X	2516	358 b	319	92
Same-row as PRG	0.25 X	2515	561 ab	500	91
	0.5X	2404	439 ab	392	88
	0.75 X	2325	534 ab	476	88
	1.0X	2126	499 ab	445	92
Mono-crop PRG	0X		786	701	91
Mono-crop Oat	1.0X	2367	4720		97
Standard error for comparing differences of two means		218	240		-

*2022 data is a Least Significant Difference All-Pairwise Test for the two factors, seed placement and rate. There are 2 groups (a.b) in which the means are not significantly different from one another at p-value of 0.05.
** conversion factor perennial ryegrass kg/ha x 0.892 is the equivalent of lbs/ac.

Perennial ryegrass seed yields were reduced relative to monocrop planting, the average yield of intercrop treatments was approximately 520 kg/ha; whereas the monocrop perennial ryegrass yield was 786 kg/ha (Table 9). Yield reductions were lowest at the lowest (0.25X) oat seeding rate with a 24% reduction in perennial ryegrass seed yield when intercropped with oat that was placed side-band, and a 28% yield reduction when oat was placed in the same-row as perennial ryegrass. The highest yield reduction (approximately 54%) was recorded when oat was placed side-band and at 1.0X rate. Provincial average perennial ryegrass seed yield data is not typically reported as crops are grown under contract production. Lower yields in any given year tend to be compensated by increased price per pound depending on demand (use in turf grass mixtures such as soccer fields or in commercial and residential lawn mixtures) and production in other major perennial ryegrass seed production regions such as Oregon and in western Canada, Manitoba and the Peace Region. There were no differences among the perennial ryegrass seed samples analyzed for seed quality. The variability in the results shown in Table 9 reflects typical variability observed by the certified seed analysts (p. comm).

Increased oat seeding rate of 0.75X and 1.0X resulted in lower oat yields, 2338 kg/ha (65 bu/ac) and 2321 kg/ha (65 bu/ac), respectively, when compared to the 0.25X rate (2410 kg/ha, 67 bu/ac) and 0.5X rate (2472 kg/ha (69 bu/ac) (Table 10 and Figure 5).

The placement of oat in relation to the perennial ryegrass did not have a major impact on oat yield (Table 11 and Figure 6) with the higher yield for the side banded compared to same-row placement when averaged over all seeding rates. On average, the side-band placement, over all rates yielded 2428 kg/ha or approximately 68 bu/ac whereas the seed-placed perennial ryegrass -oat combination had an average yield of 2205 kg/ha or 65 bu/ac.

Table 10: Analysis of seeding rate factor on seed yield when oat and turf type perennial ryegrass (PRG) are planted as mixed intercrop, Redvers, SK, spring, 2021 and 2022*

Oat Seeding Rate	Seed Yield Oat	Seed Yield PRG
	(kg/ha 2021)	(kg/ha, 2022)
0.25 X	2410	578 a
0.5 X	2472	545 a
0.75 X	2338	536 a
1.0 X	2321	428 a
Standard error for comparing differences of two means	-	169

*2022 data is a Least Significant Difference All-Pairwise Test for the two factors, seed placement and rate. There are 2 groups (a.b) in which the means are not significantly different from one another at p-value of 0.05.

Table 11: Analysis of oat seed placement factor on seed yield when oat and turf type perennial ryegrass (PRG) are planted as mixed intercrop, Redvers, SK, spring, 2021 and 2022*

Oat Placement	Seed Yield Oat	Seed Yield PRG
	(kg/ha 2021)	(kg/ha, 2022)
Side-band	2425	533 a
Same-row	2204	511 a
Standard error for comparing differences of two means	-	120

*2022 data is a Least Significant Difference All-Pairwise Test for the two factors, seed placement and rate. There are 2 groups (a.b) in which the means are not significantly different from one another at p-value of 0.05.

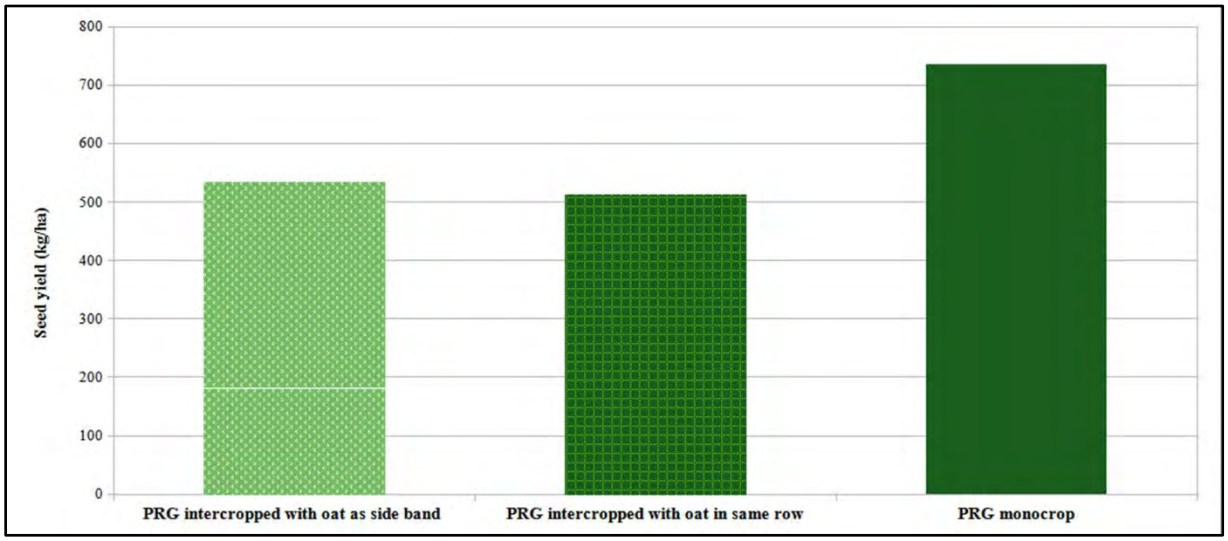

Figure 5: Seed yield of perennial ryegrass as influenced by oat seed placement when planted as an intercropping or as a monocrop, Redvers, SK, 2022.

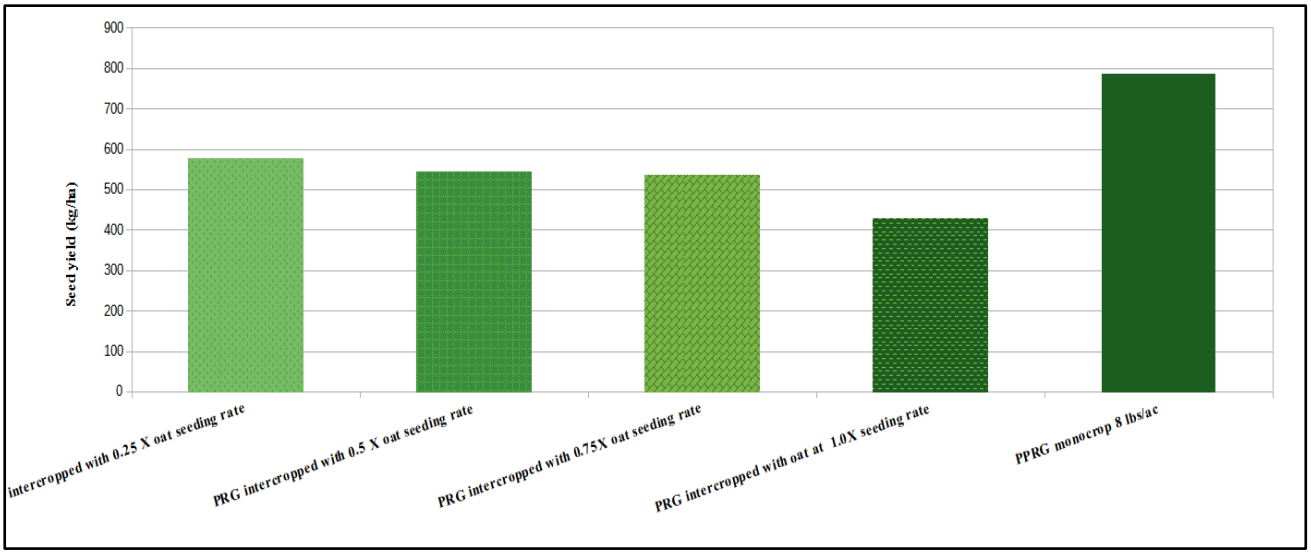

Figure 6: Seed yield of perennial ryegrass as influenced by oat seeding rate when planted as an intercropping or as a monocrop, Redvers, SK, 2022.

An approximate economic analysis based on farm gate prices in 2021 (oat) and 2022 (perennial ryegrass) are estimated and presented in the Appendix A.5. Input from an economist is needed before any conclusions on this analysis may be drawn, especially with the record high oat prices in 2021 which have the potential to put upward bias on the 2-year gross income estimates.

10.3 Nutrient Availability and Overwintering Assessment

Fall soil test results are presented A.2. Industry sources report that soil test calibration curves are not available in western Canada to accurately recommend fertilizer application rates, especially fertilizer recommendations after harvest of the companion crop. (The main source of fertilizer recommendations for perennial ryegrass seed crops are from Oregon, Hart *et al.*, 2007; Young *et al.*, 1997; Young *et al.*, 1996, where the crop is grown under irrigation and the region and N fertilizer recommendations are much higher than when grown under dryland production in Saskatchewan with a shorter growing season). Therefore, this demonstration used Plant Root Simulator (PRS®) probes to measure actual plant nutrient availability (supplies) under actual field conditions. This method provides a close simulation of the plant systems, bio-mimicking nutrient absorption by plant roots, and the nutrients available for the perennial ryegrass to overwinter and continue growth in the spring. Using these results, individual treatments were fertilized based on PRS Cropcaster® service, recommendations, and the use of canary seed as a proxy for perennial ryegrass. Among the intercropped treatments, were no noteworthy trends in the amount of fertilizer recommended. The variation is likely due in part to variability within the plots and replicate effects.

Images of the approximately one-acre trial site after harvest of the oat plots were collected using multispectral aerial survey mapping with a ground sampling distance of 3.76cm/pixel. Two flights were needed due to technical difficulties and high winds. Data was captured on October 22 and 28, 2021. Processing (stitching) of the images was done at the end of November. The orthomosaic map, as shown below in Figure 1, provides a visualization of the plant stand of the perennial ryegrass before freeze-up. As the files contain rich information about the plant biomass, the drone flight data will be used for further analysis of plant stand, provided additional funds are secured, and the perennial ryegrass plots survive the winter of 2021-22. An image of the plot plan (Figure 7) is included below as a reference for the orthomosaic map, the orange arrow pointing to plot 101. Figure 8 illustrates the late fall growth stage of the perennial ryegrass.

Figure 7: NDVI Image of trial site, November 3, 2021. (orange arrow indicates plot 101, Rep 1. See Appendix A.1 for plot plan)

Figure 8: September 30, perennial ryegrass growth in the same row as a nurse crop.

10.4 Extension Activities

An in-person tour was held at the Redvers research farm on July 14, 2021; 23 guests were in attendance and the tour group stopping at the trial site. In 2022, the field tour was held on July 28th. A reporter was among the crowd and an article was published in the Western Producer, Sask. research farm tackles intercropping, by Melissa Bezan, August 5, 2021. https://www.producer.com/crops/sask-research-farm-tackles-intercropping/

Throughout the 2021 growing season, the SERF Research Manager used social media to share information about the demonstration. Using Twitter, Lana at SE Research @SE_ResearchFarm, posted photos of the trial and responded to questions about the project. (See Appendix A.5 for information-tweets). A presentation, Perennial Ryegrass Establishment with a Nurse Crop, was given by Lana Shaw during Crop

Production Week, 12:20 PM, January 13, 2022, as part of the annual AgriARM Research Update. The 2022 update was a free-of-charge virtual event.

In the fall 2021 issue of the industry magazine, Forage Seed News, a short description of the project was prepared, and ADOPT funding was acknowledged as per the contractual agreement with SFSDC and GOS. The magazine is published and mailed free of charge to each forage seed producer in Saskatchewan who contributes a levy to the SFSDC. The Fall issue was mailed to 252 Saskatchewan forage seed growers.

A feature 2-page article was published in the winter 2022 issue of Forage Seed News and mailed out in February 2022. The colour print magazine has a circulation of approximately 1800 growers, forage seed industry firms operating in western Canada, researchers and government extension specialists; 297 copies were mailed to forage seed growers in Saskatchewan. The article was based on the interim report's year-one data on weed biomass and seed yield, with October 2021 oat farm gate prices reported along with color photographs illustrating the seed placement as the SeedMaster drill is commonly used in the Redvers region. Due to copyright restrictions with the Forage Seed News publication, a duplicate copy of the article will not be posted on the SFSDC website, however, a summary (blog) was written for the Home page of the SFSDC website.

The Saskatchewan Forage Seed Development Commission created a new website in 2021, saskforageseed.com. The section, Latest News highlighted Forage Seed Research Trials 2021. From Jan 1–Dec 31, 2022, Google Analytics reports 79 views for the article posted on https://www.saskforageseed.com/research-projects/demonstration-of-intercropping-perennial-ryegrass-prg-with-oat

The information posted on the website is provided in the text box below.

List of field trials 2021:

https://www.saskforageseed.com/news-articles/forage-seed-research-trials-2021

Demonstration of intercropping perennial ryegrass (PRG) with oat using different seed placements (side-band and deeper than PRG, same row as PRG, mono-crop PRG, mono-crop oat) and seeding rates (0.25 X, 0.5X, 0.75, 1X). Three locations were planted in 2021 (Redvers SE Research Farm, Prince Albert Conservation Learning Center); the Melfort NE Agriculture Research Foundation site was discontinued and will be re-seeded in 2022. The CDC Arborg oat crop is harvested at two locations and' so far-so good' for CE-1 PRG. Following a field tour at the Redvers field site, an article was published as a farm news media release, August 5, 2021. Click to read the Sask. research farm tackles intercropping article. This is an ADOPT 2020 project funded by Saskatchewan Agriculture with industry contribution of seed from FP Genetics and Brett Young.

Upon approval of the interim report by the Ministry, the report was posted under the Research section. https://www.saskforageseed.com/research-projects/demonstration-of-intercropping-perennial-ryegrass-prg-with-oat

Based on Google Analytics, from January 01, 2022, to December 31, 2022, Browse Research Projects received 557 views. Acknowledgement of funding was indicated as follows: The project is funded by Saskatchewan Agriculture under the Government of Saskatchewan's Ag Demonstration of Practices and Technologies (ADOPT) program. The ADOPT project activities are a collaborative venture with partial funding contributed by the Government of Saskatchewan and the Government of Canada under the Canadian Agricultural Partnership. The project was further supported by SFSDC check-off funds and industry contributions of seed and technical support from FP Genetics and Brett Young.

Recently, the Country Guide magazine published an article, '***One plus one equals****... Intercrop trials continue at Saskatchewan's South East Research Farm, and crop insurance is considering coverage'* by Julienne Isaacs. March 28, 2023. In the article, Lana Shaw explains the potential of intercropping oat with perennial ryegrass based on the demonstration plots. She is quoted in the Country Guide magazine as follows:

"We're trying to see how much the oat co-crop hurt the perennial ryegrass establishment," says Shaw. "We're getting two harvests of seeds with only planting one. If we can do that with these oats, that could be attractive economically, but the risk is that you're relying on the establishment of the perennial ryegrass seed crop and you don't want to compromise that, but it might reduce the yield of the seed or leave more room for weeds."

The idea, says Shaw, is that economically, there's a year with something to harvest during establishment of the perennial grass, and there's improved soil protection, weed competition and stubble to catch snow.

Julienne Isaacs, Country Guide/Vol. 142 Issue No. 6/March 28, 2023. Used with permission from editor. Tom Button.

11. Conclusions and Recommendations

In the Redvers area, perennial ryegrass can be successfully established when grown as an intercrop with oats. This allows producers to harvest a crop in the year of perennial ryegrass establishment, which is not possible when perennial ryegrass is grown on its own. This intercropped combination does not appear to affect oat yields when compared to oats grown as a mono-crop.

Surprisingly, there was no significant difference in oat yield considering the large range in densities. The low-density oats tillered a lot and took advantage of some late-arriving moisture. One hypothesis is that given the unusual conditions, it may be that oat has a tremendous ability to compensate for low density, given enough time. Oat biomass was also similar between treatments but weed biomass was much higher in the perennial ryegrass monoculture than in the oat intercrops or oat monocrop. Even though the monoculture perennial ryegrass was mowed to reduce weed seed production, there will still be a substantial addition to the weed seed bank in those plots from wild millet and other weeds. The side-banded oat appeared to accommodate more growth of the perennial ryegrass for Treatments 1, 2, and 3.

Based on the observations in 2021, at this location, we offer a hypothesis that treatments 2 and 3 will be the best ones for the balance between perennial ryegrass establishment and oat agronomy. The lowest seeding rates of oats had too much tillering and delay in maturity (data not shown). Delayed maturity increases the risk of shattering losses and quality problems. the most sensible intercrop option is likely intercropping oat with perennial ryegrass using a 0.5 or 0.75 rate and placing oat as side-banded. Lower oat seeding rates ended up with too much variability in maturity of the oats the first year and high weed pressure.

As a final lesson, the study has identified merit in intercropping oats with perennial ryegrass. However, it would be beneficial to repeat the trial to understand better the optimal method (i.e., seeding rate and placement) for establishing the forage seed crop while deriving grain yield income in year one. Trials in small-plot research settings concurrent with evaluations in nearby commercial fields would also be advantageous. The dual stream assessment could better account for the weed competition in the presence or absence of hand rogueing. The use of promising commercial pesticides - for example, recent minor use registration of products such as Stellar XL - appropriate for application on the companion crop and the forage grass seed crop could be done parallel to small plot hand rogueing of the forage seed crop.

12. Supporting Information

12.1 Acknowledgements

The Ministry's support for the project was acknowledged in the Forage Seed News magazine, and industry magazine mailed to forage seed growers in the prairie region and industry. The colour print magazine has a circulation of approximately 1800 for the Spring/Summer 2021 issue and Winter 2022 issues.

Acknowledgment of the ADOPT funding was provided when the first-year results at Prince Albert and Redvers were reported by Lana Shaw at virtual presentation of the Agri-Arm Research Update coinciding with Crop Production Week, January 2022.

The 2020-2021 Annual Report for the Saskatchewan Forage Seed Development Commission, page 15, acknowledges the Ministry's funding as follows: "Government of Saskatchewan's Ag Demonstration of Practices and Technologies (ADOPT) program. The ADOPT project activities are a collaborative venture with partial funding contributed by the Government of Saskatchewan and the Government of Canada under the Canadian Agricultural Partnership. The publication is available for download at: SFSDC Governance: Annual Reports and Audited Financial Statements

FP Genetics (Simranjit Singh) and Brett Young (Doug Senko) kindly provided in-kind contribution for the project through donation of seed supplies of oat and perennial ryegrass, respectively. The agronomists further supported the project by providing recommendations for planting, weed control and harvest. Western Ag, Ken Greer and Eric Brenner, provided technical support, analysed the soil samples using Plant Root Simulator® (PRS) technology, advised on fertilizer recommendations for perennial ryegrass and provided comments on the results.

Lana Shaw and the staff at SERF conducted all activities relating to fieldwork and statistical analysis.

The drone flights were conducted by a certified drone pilot, Dave Wilson (Regina, SK). The mapping mission was done at no greater than 100 feet at a set speed of 12 mph. The scope of the flight operation fitting within the budget and the data transfer was coordinated by Matthew D.G. Johnson, Volatus Unmanned Services, Winnipeg, MB. Mr. Johnson is a recognized trainer and educator in UAV technology and Volatus Project Manager, based in Winnipeg, MB (closest center with accessible and available drone experts).

Compilation of the drone image files into an orthomosaic was done free of charge by Warren Genik, Chief Technology Officer, Green Aero Tech. Mr. Genik had provided input on the methodology for the grant application but was not available to conduct the drone flight in Redvers https://www.greenaerotech.com/

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12 Appendices

A.1 Pre-planting information

Table A.1 Treatment list and seeding rate to demonstrate different management practices for a 2-year rotation intercropping oat with perennial ryegrass, Redvers, SK, 2021.

Treatment	Main crop	Placement of companion crop (oat) in relation to perennial ryegrass	Seeding rate of companion crop (oat)
1	Perennial ryegrass	Side-band and deeper than perennial ryegrass	0.25 X (34 lbs/ac)
2	Perennial ryegrass	Side-band and deeper than perennial ryegrass	0.5X (68 lbs/ac)
3	Perennial ryegrass	Side-band and deeper than perennial ryegrass	0.75 X (102 lbs/ac)
4	Perennial ryegrass	Side-band and deeper than perennial ryegrass	1.0X (132 lbs/ac)
5	Perennial ryegrass	Same-row as perennial ryegrass	0.25 X (34 lbs/ac)
6	Perennial ryegrass	Same-row as perennial ryegrass	0.5X (68 lbs/ac)
7	Perennial ryegrass	Same-row as perennial ryegrass	0.75 X (102 lbs/ac)
8	Perennial ryegrass	Same-row as perennial ryegrass	1.0X (132 lbs/ac)
9	Perennial ryegrass	Mono-crop perennial ryegrass	1.0X (8 lbs/ac)
10	Oat	Mono-crop oat	1.0X (132 lbs/ac)

Target population 350 plants per square meter, 98% germination, thousand kernel weight 38.46 grams.

Plot plan, Redvers, SK 2021

Guard		Guard		Guard		Guard	
101	3	201	9	301	5	401	3
102	5	202	4	302	7	402	6
103	7	203	5	303	1	403	8
104	10	204	3	304	9	404	4
105	9	205	8	305	3	405	1
106	8	206	6	306	10	406	5
107	6	207	1	307	8	407	2
108	2	208	7	308	2	408	9
109	4	209	2	309	6	409	7
110	1	210	10	310	4	410	10
Guard		Guard		Guard		Guard	

A.2 Soil fertility data

Table A.2.a: Post-harvest soil fertility based on plant root simulator (PRS) probe method analysis of available nutrients determined from a composite of soil samples collected from each treatment, Redvers, SK, fall 2021.

Soil Parameter	Available nutrient supply	The optimal level for maximum yield (canary seed 30.8 bu/ac proxy)
Total N*	6.1	70.8
P2O5	1.2	20.9
K2O	13.2	49.3
S	4.8	8.0
Ca	344.3	5.5
Mg	76.8	7.7
Cu	0.04	0.05
Zn	0.07	0.15
Mn	0.38	0.18
Fe	0.32	0.15
B	0.04	0.02
Soil pH	7.44	
Electrical conductivity (EC)	0.16	

Sandy soil (40%) *Total of NO3--N and NH4+-N.

Table A.2.b: Treatment-based fertilizer recommendations from on a composite soil sample collected from four replicates of each treatment, Redvers, SK, fall 2021.

Treatment	Management factors (Placement oat relative to forage seed and seeding rate oat)	pH	EC	Fertilizer recommendations (lbs/ac)[1]. N	P_2O_5	K_2O	S
1	Side-band oat 0.25X rate	8.0	0.8	49	20	32	0
2	Side-band oat 0.5X rate	8.0	0.2	46	11	26	0
3	Side-band oat 0.75X rate	8.4	0.2	37	12	25	0
4	Side-band oat 1.0X rate	8.8	0.2	42	15	21	0
5	Same-row oat-& PRG 0.25X rate	8.4	0.2	41	17	27	0
6	Same-row oat-& PRG 0.5X rate	8.3	0.3	49	17	35	0
7	Same-row oat-& PRG 0.75X rate	8.1	0.2	37	15	29	0
8	Same-row oat-& PRG 1.0 X rate	8.4	0.2	45	11	25	0
9	Mono-crop PRG 1.0 X rate (8 lbs/ac)	8.3	0.1	39	12	23	0
10	Mono-crop Oat 1.0Xrate (122 lbs/ac)	7.4	0.1	50	14	20	0
Average				44	14	26	0
Maximum				50	20	35	0

All treatments available water to a depth of 9.8-inches.

1.Yield expectations of 26.8 bu/ac to maximum 30.8 bu/ac based on canary seed proxy and cost of fertilizers as follows: N $0.55/lb, P $0.40/lb, K $01.45/lb. Analysis by Western Ag Professional Agronomy, Saskatoon, https://www.agvise.com/.Further information about the PRS Cropcaster® service, powered by PRS® Probe technology is available at https://www.westernag.ca/professionalagronomy/PRSCropcaster

A.3 Climate data

Table A.3a: Average monthly and range in air temperature (C°) and average monthly and total precipitation (mm), April to October, at South East Research Farm, Redvers, SK, 2021, 2022.[1]

	April	May	June	July	August	September	October
2021 monthly average	3.1	9.6	18.7	20.8	17.5	14.3	9.6
Minimum air temperature	-6.1	0.5	10.2	12.7	10.3	5.4	1.5
Maximum air temperature	11.6	17.4	25.8	28.5	24.6	23.8	19.0
2022	-1.3	10.2	16.3	19.2	18.9	13.5	5.1
Minimum air temperature	-8.8	2.2	11.8	15.4	13.8	7.1	-0.5
Maximum air temperature	5.6	16.9	25.1	25.4	22.2	22.3	11.8

	April	May	June	July	August	September	October
2021 monthly average	0.18	1.3	3.2	1.2	2.3	0.2	1.6
Total rainfall (mm)	5.32	41.4	95.2	38.3	72.3	9.2	29.5
2022 monthly average	0.7	4.5	3.1	9.8	2.4	0.5	0.6
Total rainfall (mm)	21.6	135.6	92.4	303.3	73.1	15.5	20.1

1.Data collected from the SERF weather station data.

The long -term average annual rainfall at the SERF is approximately 530-mm. Total rainfall April to October, was 297 mm in 2021, 662 mm in 2022.

Table A.3.b: Average monthly air temperature and precipitation for November 2021 to March 2022, at South East Research Farm, Redvers, SK, 2021, 2022.[1]

	November	December	January	February	March
2021 -2022 monthly average	-2.9	-14.8	-16.0	-17.3	-6.4
Minimum air temperature	-13.2	-32.6	-32	-29.3	-22.2
Maximum air temperature	5.3	1.3	-3	0	1.4
	November	December	January	February	March
Total rainfall (mm)	13.0	3.8	5.1	4.1	1.8

1.Data collected from the SERF weather station data.
Total rainfall November 2021 to end of March 2022 was 26.9 mm.

A.4 List of tweets from Lana Shaw

- May 21, and 24 -news of rain;
- May 31 “Got no seeding done but we prepped a perennial ryegrass trial with oats as a 'nurse crop'. The intent is for PRG seed production yield varying oat placement and rate”
- June 01 “Perennial ryegrass and oat trial got seeded.”
- June 02 “Who has intercrops in the ground this year? We are doing chickpea-flax, pea-canola, pea-oat, perennial ryegrass-oat, sunflower-winter peas, sunflower-vetch, sunflower-lentil, and camelina-lentil”
- June 11 – more rain news, “We got 44 mm from last night's storm.”
- July 18 – more rain news.
- June 25 – more rain news and “The crops are looking good, if shorter than usual”
- July 25 regarding the field tour “We had a small crowd but lots of good questions.”
- August 5 retweet the WP article, Sask. research farm tackles intercropping.
- August 5 – responses to questions. “I expect we'll find that a moderate rate of oats sideband is the best treatment with oats in it. Whether that ends up beating the PRG monocrop will depend on winter survival.” “This is a replicated trial and we will combine oats soon. Next summer we will harvest and determine the yield of perennial ryegrass seed. We also assess establishment and survival of the perennial ryegrass into the second year.”
- August 5 acknowledging sponsors not mentioned in WP article, “Project funded by Sask Forage Seed Development Commission and ADOPT (SK-Ag)”
- August 11 “Today we did biomass sampling on a perennial ryegrass trial. We took biomass of oats and weeds to check how much oats and weeds were there for different treatments. The trial will continue to next year to see how PRG stand survives winter.”
- September 27 plot photos posted, “52 lb/ac oats side-banded vs seed-placed oat with perennial ryegrass. PRG is for seed production in 2022. Idea is to get some value and weed control from the establishment year of PRG. Also snow trapping for winter survival.” … “Color adjusted to see the perennial ryegrass better: L. Side-banded oat nurse crop R. Seed-placed oat nurse crop 52 lb/ac oats, 29 lb/ac PRG”
- September 27 response to producer question, “How did you determine your prg seeding rate? We’ve grown it for a few years in southern Manitoba and always seeded 8-10 lb in spring with a nurse crop. 29 seems quite high” – Lana Shaw response, “Correction - that was the MAP rate. PRG was 8 lb/ac.”
- September 27 “The side-banding with a medium rate of oats seems like a good practice at this point. How they survive the winter and produce seed yield is still an open question. The adequate establishment is for sure a requirement though. This is straight PRG with lots of wild millet.”
- September 30 “I got as much or more oat yield off my perennial ryegrass plots as the mono oat plots. The 26 lb/ac low-density oats even worked. It all ran between 65 and 70 bu/ac. (Maturity was delayed with low density”
- September 30 “Some plots have nicely established Perennial Ryegrass, which will be measured for grass seed production next year. We are also soil sampling using @Western_Ag method to determine fertilizer requirements for PRG”.
- October 1, the response from a producer to Lana’s posts, “We’ve never done yield strips but never felt PRG reduced our yields. It’s such a small plant during the main growth stages of the nurse crop it doesn’t really compete.”

A.5 Economics of mixed intercropping

Two grouping of the following assumptions were used in the calculation in Table A.6.a

Group A: Source: Government of Saskatchewan Crop Planning Guide 2022

1. 2022 Oats Economics Black Soil Zone
2. Seeding: A seed rate of 135 lb./ac. is used in all soil zones.
3. Fertilization: Fertility costs are based on nutrient removal rates given the targeted crop yield. These are: 90 lb./ac. N and 37 lb./ac. P_2O_5 for the black soil zone.
4. Insect control: Cutworms, aphids, thrips, mites, grasshoppers, armyworm, slugs and wireworms might require control. Seed treatments are available for wireworm control.
5. Disease control: Leaf diseases may result in yield losses in oat crops. Fungicide application can be used to protect leaf tissue from disease infection. This estimation includes the cost of a single fungicide application in the black soil zone. Fungicide application should be based on disease pressure in the field.
6. Weed control: Because oats are very competitive, growers can often reduce the number of herbicide applications from those listed. Some buyers of milling oats do not allow the use of pre-harvest glyphosate in their contracts. Herbicide costs are based on the following herbicide timings. Please refer to general assumptions for details.
7. Variable Expenses per acre include treatments/inoculants $1.04/ac); fertilizer N $119.84/ac, P $31.55/ac, S $0; plant protection herbicides $24.78+ insecticides $21.89+ fungicides $19.35, machine operating cost fuel $19.14, repair $11.29; custom work/labour $21.05; crop insurance premium $8.11, hail insurance premium $12.25, utilities and mis $6.93. [crop planning guide seed costs of $50.35 removed from calculation]
8. Other expenses per acre ($116.87) includes building repair $0.95; property tax $8.42; business overhead $3.74; machinery depreciation $46.67; building depreciation $2.00; machinery investment $17.92; building investment $0.66; land investment $36.72.

Group B: Source: Industry sourced information for forage seed growers in the NE-SK area

1. Seed costs for oat based on farm gate price 2021 same for 2022; oat $0.50/lb and perennial ryegrass $2.50/lb/ Total seed cost based on oat seeding rate factors and 8 lbs/ac perennial ryegrass.
2. Farm gate value of seed harvested based on price paid to forage seed growers who practice mixed intercropping in the NE-SK area, 2021 and 2022. Price offered for perennial ryegrass in 2022-2023 averaged an initial price of approximately $1.00/lb. CS Camden milling oat $4.80/

Table A.6. Economics of mixed intercropping oat with perennial ryegrass as influenced by seeding rate and placement of oat and two price scenarios., Redvers, SK 2021, 2022.

Variable[1]	Side-band oat relative to perennial ryegrass				Seed-row oat and perennial ryegrass				Perennial ryegrass	Oat
	0.25X	0.5X	0.75X	1.0X	0.25X	0.5X	0.75X	1.0X		
2021 Oat Yield (bu/ac)	64	71	65	70	70	67	65	59		66
Oat Price ($/bu)	$18.00	$18.00	$18.00	$18.00	$18.00	$18.00	$18.00	$18.00		$18.00
2021 Gross Rev($/ac)	$1,152	$1,278	$1,170	$1,260	$1,260	$1,206	$1,170	$1,062		$1188
2022 PRG Yield (lbs/ac)	531	565	487	319	500	392	476	445	701	
2022 PRG Price ($/lb)	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	$1.00	
2022 Gross Rev ($/ac)	$531	$565	$487	$319	$500	$392	$476	$445	$701	
2021 + 2022 Gross Revenue ($/ac)	$1683	$1843	$1657	$1579	$1761	$1598	$1655	$1507	$1889	
Average Gross Revenue 2-year mixed intercropping	$841	$921	$829	$790	$880	$799	$827	$753	$944	

1. Farmgate value based on average fall 2022 delivery price for milling oat, $4.80/bu CS Camden milling oat, initial price $1.00/lb perennial ryegrass

13 Abstract

The oat was an effective partner with the perennial ryegrass in this demonstration in Redvers in 2021 and 2022. There was a numerical but not statistically significant suppressive effect of oat intercrop on the perennial ryegrass yield. Based on limited results, it seems a reduced rate of oats and side-banding (T3) was a good balance of oat yield and perennial ryegrass yield. Being able to establish an perennial ryegrass crop with no signficant loss in oat yield should be very attractive to growers. This is also an environmental benefit in improving soil protection relative to either oat or perennial ryegrass alone.

In 2021, environmental conditions were such that oat, planted as a monocrop in the replicated trial yielded 66 bu/ac, or as a mixed intercrop. For an oat seed grower, there was no yield penalty for planting the perennial ryegrass with the oat. Neither oat placement as side-band nor same-row had a negative impact on oat yield, 68 bu/ac sideband over all rates and 65 bu/ac, respectively (data reported Interim Report, December 2022). Similarly, there was no significant difference in seeding rate on oat yield, 0.25X rate, over both seed placement positions was 67 bu/ac, 0.5X 69 bu/ac, 0.75X 65 bu/ac and 1.0X 65 bu/ac. A possible explanation for the data as recorded was that the ability of the oat crop, given the environmental conditions at Redvers in 2021, was able to tiller when seeded at the lower rates and the growing season was of sufficient duration for plants to mature despite seeding on June 01.

In 2022, the trial site did have plants which winter-killed (the outer replicate #4). There was minimal amounts of precipitation from November to March, however, it is likely the sustained cold temperatures in combination may have signalled the perennial ryegrass plants to slowly come out of dormancy as temperatures began to increase in May. With fertilization specific to the trial area, when the perennial ryegrass plants started active growth, they would have had sufficient nutrients available for setting up good seed yield and the above average rainfall would have further supported growth.

With advances in weed control, and continued pursuit of knowledge to fine-tune seed placement and rates for annual grain crops seeded with a turf type forage seed grass, our demonstration is a starting point for planning additional and grower relevant intercropping demonstrations.

14 Finances

Grant funds were received and deposited into a research grant account for ease of administering grant-based resources from SFSDC to the collaborator, the SERF. In addition to the contract with GOS and SFSDC (see proposed and approved budget below), a contract was executed between SFSDC and SERF.