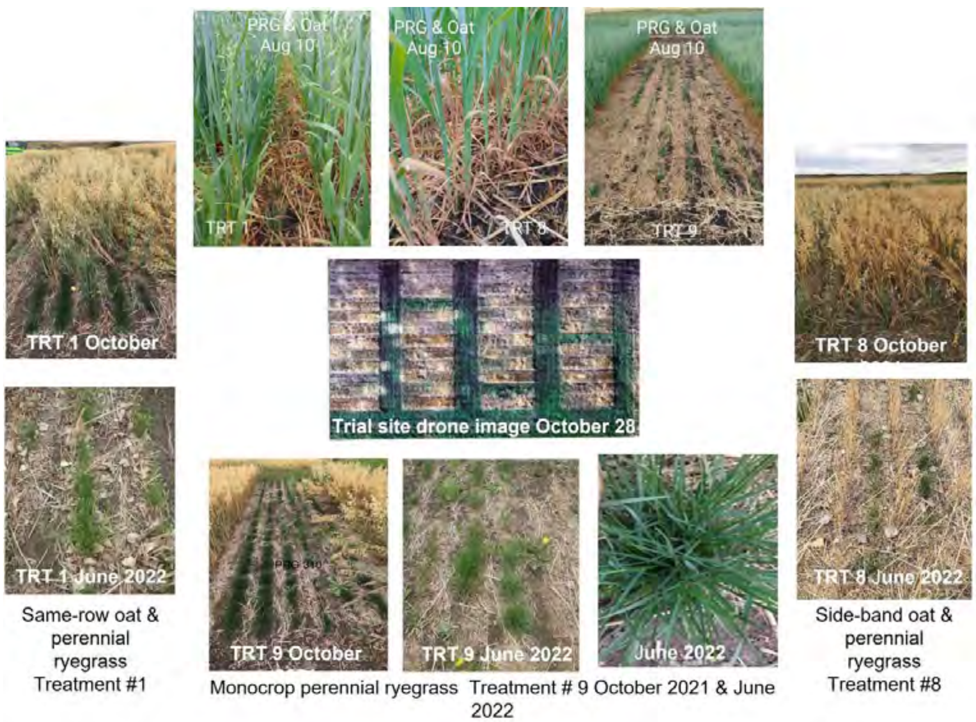
FINAL REPORT

ADOPT 20200536

DEMONSTRATION OF INTERCROPPING PERENNIAL RYEGRASS WITH OAT USING DIFFERENT SEED PLACEMENTS AND SEEDING RATES



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 # 20200536 MIDAS# 000529

3. **Producer Group Sponsoring the Project**

Saskatchewan Forage Seed Development Commission (SFSDC)

4. **Project Location(s)**

Project location is described as follows: GPS Coordinates: N53˚01.386' W105˚46.565', N53˚01.364' W105˚46.561' and N53˚01.364' W105˚46.561', N53˚01.362' W105˚46.539'.
SW-20-46-26-W2, RM 461
Conservation Learning Centre (CLC)
AgriARM site
Box 1903 Station Main
Prince Albert, SK, S6V 6J9

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

Fieldwork contract executed between producer group and contractor (CLC) on May 03, 2021. Fieldwork began May 20, 2021. Trial was worked under on agreement by both parties, June 30, 2022.

6. **Project contact person & contact details**

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Objectives and Rationale

7. **Project objectives**

The project will demonstrate the application of scientific knowledge of intercropping to the practical use of planting a companion 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

Social media (farm Twitter) signals that growers have increased interest in intercropping. Intercropping projects at the AgriArm research farm locations in Saskatchewan are collecting performance data for growers based on the trials demonstrating the planting of 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, such as increased productivity relative to a monocrop, pest reduction, nutrient efficiency, and other potential benefits, including ecosystem services. Mixed intercropping is defined as "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). The mixed grain intercropping research at the AgriArm sites aligns with this definition and provides income from two cash crops in one growing season.

There is an opportunity to broaden the interpretation of mixed intercropping to include the production of a seed crop where the income from two cash crops is derived over two growing seasons. 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. This management strategy, best suited to ecozones with sufficient rainfall and soil moisture reserves that will support the simultaneous growth of two crops, such as the moister parts of the grey-wooded and black soil zones (Jefferson et al., 2005), is increasingly being used by forage seed growers in Saskatchewan, Manitoba, and the Peace Region of Alberta-British Colombia. In these regions, mixed intercropping 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.

Various legume and grass species of forage seed crops are grown under the mixed intercropping system. The forage seed grass and legume crops are typically treated as a biennial on the prairies. However, with good stand establishment, sufficient moisture reserves, reasonable weed control and a 4R fertility management approach, seed crop production of forage grasses or legumes may be extended for another two to five years. Typical annual crops used as companion crops for 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.

In the northcentral Saskatchewan region, the Prince Albert area is known for its high yield potential in cereal crops. Oat grain yields are typically the highest in the province, and an oat mixed intercrop has excellent potential for success. Oat growers wanting to diversify rotations may want to try intercropping oat with a forage seed crop.

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). 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 compare two placements - sideband 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. The varieties we selected based on performance potential and seed quality observed in the Prince Albert area. [1]

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 has strong stems, and the stubble is likely to remain upright (p. comm, Dr. Beattie, oat breeder), thus trapping snowfall 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 information determined seeding rates (see Appendix A.1, Table A.1a). The targeted plant density for 1.0X oat rate was 350 plants/m2 and a plot area of 13.7-m2. The 1.0X rate for CDC Arborg was the equivalent of 122 lbs/ac given a germination of 98% and thousand kernel weight of 38.46 grams, 0.75X rate was planted based on approximately 92 lbs/ac, 0.5X 61 lbs/ac and 0.25X 31 lb/ac.

The trial was designed as four replicates of ten treatments (see Appendix Table A.1.b), 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). Trial management was done by the personnel of the CLC research farm, led by Brooke Howat (spring to end September 2021) and Robin Lokken (October 2021-December 2022).

Soil nutrient levels were determined prior to planting. CLC staff collected a composite soil sample from the trial area and sent it for nutrient analysis by Agvise Laboratories, North Dakota. (Appendix Table A.1.c).

The trial was seeded on 20th May into corn stubble using a Fabro plot seeder with double disc openers and 10-inch row spacing. Plots were 1.75-meter (m) wide and 7.5-m long. Due to issues with setting the depth on the plot drill it was determined that the perennial ryegrass had been seeded too deep, even though estimated depth was less than 2 inches with oat seeded at 2-2.5 inches. Consequently, the emergence was extremely poor. After consultation with Brett Young, the trial was re-seeded at a new location. Modifications were made to the Fabro drill which provided planting depths of 0.5 inches for perennial ryegrass (notch 1, 2

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[1] 2023 Sask Seed Guide. Varieties of Grain Crops 2023. Saskatchewan Agriculture. In Zone 3 and 4 (RM 461 in Zone 4), over 7 years of evaluation, the seed yield of CDC Arborg is 106% of check variety CS Camden. 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]

large and 1 small spacer used) and side-banded oat planted at 1.5-2 inches (notch 1 medium and large spacers).

The second seeding was completed on 17th June, planting into oat stubble. Soil temperature at the time was 14.5°C at a 2-inch depth. The perennial ryegrass was seeded shallow (½ inch depth), and the oat was seeded deeper at 1½ to 2 inches. Weeds were controlled pre-emergent with an application of glyphosate on 18th June at a rate of 0.94 L/ac (510 g ae/ac) and water rate of 67 L/ac, the temperature at the time of application was 16℃, with a north wind at 15 km/hr. In-crop weed control was done by hand rogueing.

Agronomic performance indicators were recorded by CLC personnel. Establishment of both crops was rated on 28th June and plant growth was monitored throughout the season (spring plant density, oat-specific data collection of lodging, biomass, height). The early growth stage (spring) plant density of oat was determined three weeks after seeding by counting individual plants in two 1-m sections of the row located at the front and back of each plot. Plant densities were not determined for perennial ryegrass in the intercropped plots since the 'bunchgrass nature' of perennial ryegrass makes data collection on individual plants difficult. Crop staging was documented on 26th July and 10th August. Lodging of oat was rated using the Belgian Lodging Scale (area (1-10) x intensity (1-5) x 0.2). Data on the biomass of each oat plot was collected on 15th September using a 0.5-m2 quadrant and reported as wet weight. Data on plant height was collected from each oat plot by taking three measurements and calculating the average of the heights. Oat grain yield was determined by combine-harvesting all six rows of each plot with a Wintersteiger Quantum plot combine on 12th October. Plot yields were adjusted to 12.5% moisture content. The oat moisture content at the time of harvest ranged from 13-18.5%. Seed weight, measured as thousand kernel weight (TKW), was determined for each treatment from a composite sample of all replicates.

Analysis of agronomic performance data was done by CLC personnel using Statistix™ v10 software, testing for differences between means with Analysis of Variance (ANOVA), Mean comparisons were determined by Least Significant Differences (LSD), significance was determined at $p<0.05$. Plots impacted by the shelterbelt location were removed from the data set before statistical analysis. This improved variability in the data, but, unfortunately, resulted in unequal sample sizes, including treatment #1 only having two replicates. Therefore, statistical analysis was completed on each factor individually.

Soil nutrient availability for the perennial ryegrass was determined post-harvest of the oat crop (fall 2021). CLC personnel prepared a 4-replicate composite soil sample by collecting 0-6-inch and 6 to12-inch samples from each plot of the ten treatments. Samples were submitted to Western Ag in Saskatoon and processed using PRS probe ® analysis and PRS Cropcaster® service. 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 the 4-replicate average value of plant nutrient availability. Canary seed fertilizer recommendations as used a proxy for perennial ryegrass. The samples were analyzed for nitrogen (N) supply rate (combined NO3- and NH4+ supply rates), P, K, and S.

Biomass of the perennial ryegrass was recorded post-harvest of the oat crop using drone imagery. A qualified drone pilot captured the images on 28th October, at the georeferenced location of 53°01'22.0"N 105°46'31.2" W). A DJI Matrice 200V2 was used as the drone platform, with a MicaSense RedEdge-MX multispectral sensor to record the images. The sensor recorded at five different light bands, which were green light (475 nm, 32nm bandwidth), blue light (560 nm, 27nm bandwidth), red light (668 nm, 14nm bandwidth), red-edge light (717 nm, 12nm bandwidth), and near-infrared light (842 nm, 57nm bandwidth). The flights were done at a 14-m altitude with a front and side overlap of 85% and a flight speed of 0.7m/s, resulting in a ground sampling distance of 3.76 cm/pixel. The flights were mapped using the Pix4D Capture App. Pictures were calibrated and stitched in Pix4D Mapper to form ortho mosaics for the five light bands. The ortho mosaic provided a visualization of the different treatments and the trial site before the perennial ryegrass went into winter.

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. Nitrain was applied at a rate of 90 lb N/ac, monoammonium phosphate (MAP) at 35 lb P_2O_5/ac, potash at 25 lb of K_2O/ac and ammonium sulfate (AMS) at 10 lb S/ac.

Spring 2022 trial maintenance included seeding wheat in the borders and in the 2021 monocrop oat treatment plots, rototilling pathways, and regular staging and scouting.

Agronomic performance of the perennial ryegrass seed crop was assessed in spring, 2022. The new spring growth from the established crown roots was rated on 13th June 2022 using percent coverage as the bunch nature of the grass made individual plant counts difficult. Percent coverage was assessed in two 1-m rows per plot and reported on a scale of 0-100%. Weed competition was observed as weedy species present in the trials. Percent coverage weedy species was rated in the front and back of each plot on a scale of 0-100% to determine any differences in weed competition between treatments. Data from the two rows of treatment plots nearest to the shelterbelt was omitted as the crop in these plots displayed stunting due to shelterbelt effects in 2021. Performance data was analyzed using Statistix 10 software, ANOVA was used for parametric data and Kruskal-Wallis test for non-parametric data.

10. Results

10.1 Field trial site

The first trial location was discontinued due to poor emergence. The second site, planted on 17th June, was located adjacent to a shelterbelt. This likely influenced the agronomic performance of the treatments, especially when combined with the hot and dry environmental conditions in year one (2021). While the trial was set 15-m away from a shelterbelt, the first three plots closest to the shelterbelt were relatively shorter and sparser than the rest of the plots. Typically, there are no shelterbelt effects when trials are set at least 15-m away, but in this instance, as a result of hot and dry conditions, the CLC research manager observed that there was a shelterbelt effect and it impacted height, biomass, and yield. For example, on 26th July, the oat treatments were generally at plant growth stages 43-45, whereas plants located close to the shelterbelt were stunted and staging was delayed (stage 37-39). On the same date, the perennial ryegrass plants in the overall trial had four tillers. In addition, there was excessive lodging in a single plot due to deer. By 10th August, oat had reached stage 59 with the perennial ryegrass plants remaining vegetative, tillering, and showing no elongation.

Results of analysis of observations in 2021 on early growth stage were presented in the interim report, December 2021 and repeated in our final report as Appendix 3.

The vegetative growth of perennial ryegrass on 28th October 2021 is illustrated using drone images and presented in Figures 1 and 2. The drone images of the trial taken, 16 days after oat harvest, do not show any specific trends related to treatment effect. (the plot plan in Appendix A directly relates to the drone image (i.e., plot 101, appears in the drone image bottom left, moving left to right along Replicate #1 to plot 109. The CLC trial manager noted that the strip of green at the left edge of both images shows the border and pathways seeded around the trial and between reps. The drone images, however, illustrate that not much perennial ryegrass was imaged in the plots after the oat was harvested. This may be due to straw cover after oat harvest.

Figures 3 and 4 illustrate plot and plant views of early spring growth of perennial ryegrass as it comes out of winter dormancy. Photos were taken on 26th April 2022. The images clearly show extensive straw coverage and the challenge of straw management in small plot replicated research trials. In a commercial field, the oat straw and chaff would likely be more finely chopped or dropped and picked up with a baler.

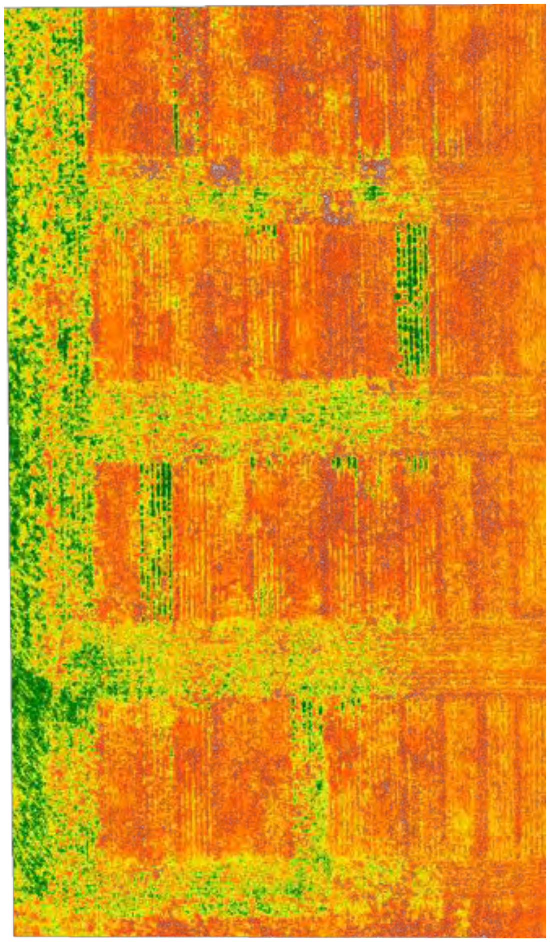

Figure 1: NDVI Image of trial site, October 28, 2021. (green on left and between replicates indicates perennial ryegrass borders).

Figure 2: RGB Image of trial site, October 28, 2021. (green on left and between replicates indicates perennial ryegrass borders)

Figure 3: Photo of trial site April 26, 2022

Figure 4: Photo of perennial ryegrass plants beginning spring growth, April 26, 2022.

10.2 Environmental Conditions during the first year of establishment

The 2021 growing season at Prince Albert, SK, Conservation Learning Centre (CLC) was hot and dry compared to the long-term averages. The CLC has been exceptionally dry over the past few years, and soil moisture reserves were depleted. The situation became even more severe for plant growth when precipitation remained low throughout the 2021 growing season. While timely rains in June helped with earlier seeded crops, we re-seeded the demonstration trial after June rains. Unfortunately, the meagre precipitation in July resulted in slow emergence and delayed growth in the trial. Total precipitation in June and July 2021 was 94-mm compared to 2012-2020 data of 164-mm. Rainfall in August was 14-mm above the long-term average, favouring late-season growth, too late to contribute to oat yield. Furthermore, the temperatures in 2021 for June and July were higher than the longer-term data (see Appendix 2 Environmental data from Saskatchewan Research Council/SRC, Table A.2.a).[2]

In the winter of 2021/2022, the first major snowfall of 15-cm occurred on 11th November. Snow cover remained at 15-cm or more until 23rd April. During that day, the air temperature reached 12.2°C and by 24th April, only 1-cm snow cover remained, with no snowfall reported for the remainder of the spring. Throughout November through to mid-April, a snowpack of at least 30-cm remained, peaking at 72-cm on 7th March 2022. The Mean Temperature for April (0.4 °C) was below the long-term average of 1.5°C. After 23rd April, maximum temperatures were above approximately 10°C except for two days (25th 4°C and 26th 7°C). No snow cover remained by 25th of April, and only 0.9-mm precipitation was recorded in the weighing gauge for the remainder of April (Table A.2.b). Despite having excellent snow cover, moisture conditions in spring 2022 were still very dry, a carryover from the previous (dry) growing season Total precipitation in May 2022 at the CLC was 17.9-mm, much lower than the long-term average for the region of 38.3-mm (Table A.2.c). Moreover, the cumulative average for 2022 was 68.1-mm at the end of May compared to the 2012-2021 long term cumulative average of 99.7-mm. After the 14th of April, the maximum daily temperatures did not fall below 0°C (see Appendix Figure A.2.a, and May Figure A.2.b) The perennial ryegrass plants would begin rapid growth with no snow cover remaining.

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[2] Sask Research Council weather station environmental data from the Prince Albert location, Conservation Learning Centre. Data available for download at: SRC weather-summaries

10.3 Agronomic performance of intercropped oat and perennial ryegrass

The CLC Research Manager rated the growth of the perennial ryegrass seed crop and the weedy species on 13th June. Images of the plots around that time are presented in Figures 6 and 7. Ratings were based on percentage cover of the plot (combined data summary in Appendix table A.4.d). Data from the two rows of treatment plots nearest to the shelterbelt was omitted as the crop in these plots displayed stunting due to shelterbelt effects observed in 2021. The wetter conditions in June (29.5 mm rainfall on June 10, 13, and 14) resulted in additional perennial ryegrass plants initiating spring growth. However, in general, many plots had very patchy new growth.

Ground coverage values for the perennial ryegrass plots averaged 32% across all treatments, ranging between 14% to 48%. The monocrop perennial ryegrass coverage averaged 29%. There were no significant differences between the treatments based on the Analysis of Variance test for parametric data and the Kruskal-Wallis test for non-parametric data (Table 1). Due to wetter conditions in June, some late regrowth of the perennial ryegrass was observed, though all plots remained very patchy.

Figure 5a: Plot photo, plot 401 replicate 4, treatment 8, adjacent to shelterbelt not shown), June 9, 2022

Figure 5b: Plot photo, replicate 4, oat straw and chaff and aspen shelterbelt leaf cover, June 9, 2022.

Figure 6a: perennial ryegrass monocrop, CLC June 9, 2022.

Figure 6b: oat sideband, June 9. 2022.

Figure 6c: oat same row. June 9, 2022.


Figure 6d: Seed head forming June 9, 2022


Figure 7: A full plot view, replicate 1. CLC trial site, Prince Albert SK. June 9, 2022.

Table 1: Perennial ryegrass early spring plant growth as percent ground cover when oat is used as a companion crop for the establishment of perennial ryegrass, Prince Albert, SK, spring, 2022.[1]

Oat Placement	Oat Seeding Rate	N	Perennial ryegrass coverage (%)
Side-band and deeper than perennial ryegrass	0.25 X	2	43
	0.5X	3	26
	0.75 X	4	31
	1.0X	3	27
Same row as perennial ryegrass	0.25 X	4	29
	0.5X	3	14
	0.75 X	3	39
	1.0X	3	48
Monocrop perennial ryegrass	0X	4	29
Monocrop oat	1.0X	3	-
P- value			0.5872

1.Multiple comparisons were completed using the Least Significant Difference method, Statistix™ v10. ANOVA

Ground coverage of the weedy species was rated on 13th June. Weedy species present included shepherd's purse, cinquefoil, narrow-leaved hawksbeard, stinkweed, sow thistle, dandelion, lamb's quarter, black medick, flixweed, goat's beard, American dragonhead, pygmy flower, Canada thistle, wood whitlow grass, volunteer canola, and cleavers. The average ground coverage value was 21%, ranging from 8% in the same-row placement and 1.0X seeding rate, to 33% in the side-band placement and 0.5X seeding rate.

Weedy species in the monocrop perennial ryegrass treatment covered 65% of plot area, compared to 5% in monocrop oat with the lowest weed populations. Using the data set with 8 plots removed due to observed shelterbelt effects in 2021 and using non-parametric Kruskal-Wallis test with Dunn's pairwise comparison, we end up with unequal sample sizes and differences between treatments were highly significant ($p<0.0027$). Although, the intercropped treatments did not differ significantly in weed coverage from the monocrop oat control. Figure 8 box plot illustrates the analysis and variability based on the complete data set (N=40 plots).[3] Only the monocrop oat control and the perennial ryegrass monocrop control were statistically different from one another. While there are no obvious clear trends, the boxplot does illustrate that percent weed ground cover in oat is low, likely due to the aggressive nature and height of the oat crop and that the percent weed ground cover in monocrop turf type perennial ryegrass likely due to its tightly clumped nature. The addition of oat in any of the intercropped plots can be seen to reduce percent weed ground cover to varying degrees.

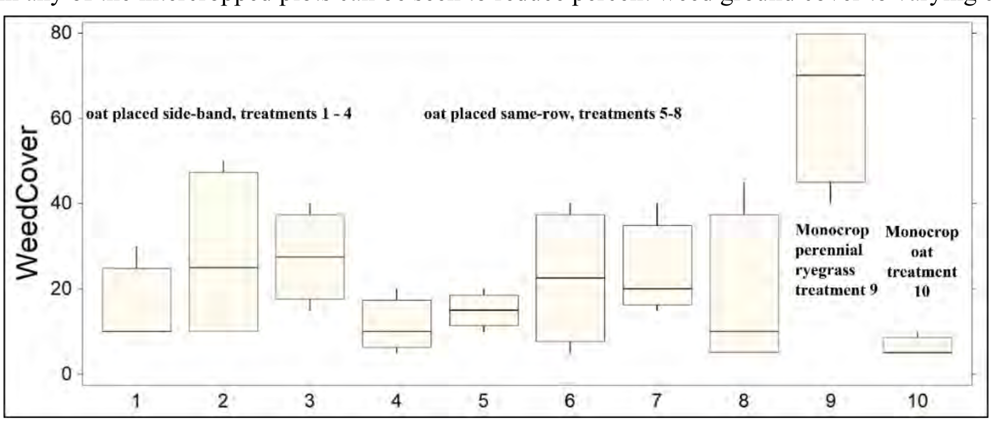

Figure 8: Box plot graph of weedy species plant growth as percent ground cover when oat is used as a companion crop for the establishment of perennial ryegrass, N=40. Prince Albert, SK, June 13, 2022

33 The range of scores from lower to upper quartile is referred to as the inter-quartile range. The middle 50% of scores fall within the inter-quartile range. Seventy-five percent of the scores fall below the upper quartile.

Agronomic performance of milling oat:

The agronomic performance data of the oat and perennial ryegrass plots in the year of establishment (2021) is described in the Interim Report (December 2021). Results are summarized below with the tables presented in Appendix A.4. Of note are the following results.

The hot and dry conditions throughout the growing season affected standability (lodging), plant height and oat grain yield (Table A.4.a). Across all treatments, essentially no *lodging* was recorded for oat. There were no observable trends in oat *plant height* between all treatments. In this trial, the monocrop oat plant height of 81-cm was considerably shorter than the typical height of 108-cm expected for CDC Arborg. The estimated average 2021 oat yield for Saskatchewan was low (49 bu/ac) compared to the 10-year average of 83 bu/ac (Government of Saskatchewan, 2021). Similarly, *oat yields* in the demonstration were lower than the provincial average, with yields of 34.0 bu/ac for monocrop oat. Grain yield across the mixed intercrop treatments was variable, ranging from 13.2 bu/ac to 40.0 bu/ac. *Thousand kernel weight* was in the range expected for oat, 30-40-g. Monocrop oat seed weight was 38 g/1000 seeds; the treatments ranged from 36-g/1000s (side-band, 0.75X) to 45-g/1000s (same-row, 0.5X).

When oat is planted in the same row as the perennial ryegrass, although there was essentially no lodging, there were consistent, and a statistically significant difference was revealed (Table A.4.b). Biomass differences were observed, however, the difference from 15,777 kg/ha for side-band placement to 20,050 kg/ha same-row placement, was not statistically significant when analyzed for Least Significant Differences (LSD). The placement of oat relative to perennial ryegrass did not significantly influence yield., side-band and same-row grain yield were approximately 27 bu/ac.

Reductions in seeding rate had no significant difference on lodging, oat plant height or oat biomass of the mixed intercrop treatments (Table A.4.c). Grain yield was impacted by reduction in seeding rate from 1.0X when analyzed across both placement positions. Reduction in yield was not a linear trend. The highest yield (35.8 bu/ac) resulted from the 1.0X rate, with a highly significant (p=0.0001) difference based on the LSD method. The 0.75X and 0.5X rates were not significantly different from each other, 25.8 bu/ac and 26.7 bu/ac, respectively. The 0.25X seeding rate was (highly) significantly lower than the other rates (18.8 bu/ac, p=0.0001). As reported above, monocrop oat yield was 34 bu/ac.

10.4 Nutrient availability considerations for perennial ryegrass when oat is used as a companion crop

Grain yield is the single largest driver of profitability for seed growers and fertilizing to meet target yield goals is a common practice, although there is a gap in knowledge for fertilizing to meet seed yield goals in a mixed intercropping system. In the 2007 report on perennial ryegrass seed production by Manitoba extension specialist Doug Cattani, reported that based on observations by soil science researchers such as John Head and others and forage seed industry agronomists, nitrogen fertility was often lacking in commercial fields in Manitoba. Symptoms of nitrogen deficiency are recognizable as a light green (lime green) colour of the early spring growth. Therefore, a spring application of 'an additional' 45 lbs/ac was recommended in Manitoba. In Minnesota, Koeritz et al. (2015) concluded that in commercial perennial ryegrass seed production fields, early season plant density is significantly improved with nitrogen management.

Building on these observations, soil testing for our demonstration was done prior to seeding and fertilizer applied to align with oat grain yield expectations of 145 bu/ac. The soil test results from AgVise indicated that nitrate-nitrogen levels were very low (<37 lbs/ac), whereas phosphorus, as measured by the Bray 1 phosphorus test appropriate for soils with pH<7.0, was high (16-20 ppm). Potassium levels were in the very high range (>160 ppm) whereas the sulfate-sulphur levels were low (26-59 lbs/ac). Soil organic matter was of a medium level at 3.8%, and with an Electrical Conductivity (EC) mm/cm below 4.0, the soil is considered a sandy soil texture (AgVise Interpreting a Soil Test Report), and non-saline. Physical soil nutrient levels, salt content, and pH at various depths are reported in Appendix A.1, Table A.1.c.

Fertilizer recommendations for the oat crop provided by AgVise, included the application of urea (46-0-0) and MAP (11-52-0) to provide 145 kg N/ha and 17 kg P_2O_5/ha. The application was done at seeding with the urea and MAP mid-row banded 2-2.5inches deep. With an average oat seed yield of 28 bu/ac, far short of the 145 bu/ac target yield. The drought conditions in 2021 affected crop growth, but the dry soil conditions reduced nutrient uptake and influenced nutrient cycle processes. According to soil scientist, Dr. Rigas Karamanos, lack of moisture may also result in reduced nitrogen movement in the soil, potentially stratifying nitrogen in the top six inches (Barker, 2022). Nitrogen is the most limiting nutrient for perennial ryegrass seed crops according to the Oregon State University Extension publication EM9051 (Hart et al. 2013)

Soil fertility recommendations for seed production of perennial ryegrass are not available for Saskatchewan soils, therefore, for this demonstration we used a method developed locally to measure plant available nutrients, the Plant Root Simulator® (PRS) technology.[4] Samples were collected from two depths, 0-6 inches and 6-12 inches, October 2021 (post-harvest oat plots). The results from fall 2021 are reported in Table A.5.a. Nutrient supply rate is expressed as lbs/ac actual nutrients available. The N supply rate is reported as combined NO_3- and NH_{4+} supply rates.

Statistical analysis was not done on the nutrient availability, therefore the data presented is an average of the nutrient availability over all the mixed intercrop treatments (not including the monocrop treatments). For the 0–6-inch sampling depth, a log scale is used to visualize the smaller values more easily on the chart (Figure 9). Tables 2 and 3 present the supply rates at the 6–12-inch depth.

N supply rate

When averaged over all four seeding rates and two seed placement positions, at the 0–6-inch depth, the *nitrogen (N) supply rate* averaged 16 lbs/ac N for the mixed intercrop combinations compared to the monocrop perennial ryegrass and oat, 60.2 lbs/ac and 14.6 lbs./ac, respectively. In comparison, lower amounts of N were available at the 6–12-inch depth. The N supply rate at the 6-12 inch depth for the mixed intercrop treatments averaged 14.4 lbs/ac, slightly less than at the 0-6 inch depth, and while the monocrop oat treatment had 16.4 lbs/ac N supply rate, the N supply rate of 47.1 lbs/ac for the perennial ryegrass roots at the 6-12 inch depth were much lower than the 0-6 inch depth (60.2 lbs/ac). Of all the treatments, including monocrop plots, the highest supply of N was recorded when oat was seeded at 0.75X rate and placed as side-band. Oat yield from this mixed intercrop treatment was 26.4 bu/ac (5.6 bu/ac lower than monocrop oat 32 bu/ac). The maximum N supply levels in this treatment occurred at both depths, 23.7 lbs/ac at the 0–6-inch depth and 20.4 lbs/ac at the 6–12-inch depth. The same N supply rates, 18.7 lbs/ac, were available at both depths when oat was seeded at 0.75X rate and seeded same-row as perennial ryegrass; oat yield was 21.3 bu/ac. There was no clear association for minimum N supply rate, 8.6 lbs/ac at the 0–6-inch depth 0.25X and side-band placement (oat yield 12.4 bu/ac, the lowest oat yield in the demonstration); and 8.2 lbs/ac available N with the 0.5X rate and same-row placement (oat yield 29.8 bu/ac).

Comparing the nutrient availability at the 0–6-inch depth as influenced by seed placement of oat over all seeding rates, when the companion crop oat is *placed sideband* and deeper than the forage seed crop perennial ryegrass, the average the N supply rate was 16.2 lbs/ac, ranging from 8.6 to 23.7 lbs/ac, 0.25X and 0.75X seeding rates, respectively. When oat is planted in the *same row* as perennial ryegrass, average N supply rate was 15.9 lbs/ac, ranging from 12.9 to 18.7 lbs/ac. There are no apparent trends for nutrient availability at the 0–6-inch depth where the majority of the perennial ryegrass roots would be situated.

K supply rate

Research done on the influence of N and K on cold tolerance suggests maximum cold hardiness of turf type perennial ryegrass occurs with low to moderate N and medium to high levels of K (Webster and Ebdon, 2005). In the Massachusetts, United States environment, optimum shoot growth in the spring occurred with moderate levels of applied N (49 to 147 kg/ha/yr) and medium-high to high levels of K (245 to 441 kg/ha/yr, corresponding to soil exchangeable K levels from 200 to 206 mg/kg. While these findings are not directly applicable to prairie soils, the nutrient availability of K in this demonstration is examined for relationship to N. Data from the Prince Albert site did not align with Webster and Edbon, although we used a different method for measuring soil nutrients.

Potassium (K) supply rate in the mixed intercrop treatments at the 0–6-inch depth averaged 30.2 lbs/ac across all treatments, level in monocrop oat were higher (41.6 lbs/ac) and monocrop perennial ryegrass was slightly lower (28.1 lb/ac). A similar trend is observed at the at the 6–12-inch depth. The average K supply rate in the mixed intercrop treatments was 18.8 lbs/ac, the monocrop oat treatment was higher (38.5 lbs/ac) and monocrop perennial ryegrass 22 lbs/ac. The maximum K supply rate occurred at both depths - similar to

[4] For more information on the PRS technology, refer to Western Ag PRS probes

the N supply rate - although the maximum levels occurred in a different treatment. With a 0.75X oat seeding rate and same-row placement, K supply at the 0–6-inch depth was 42 lbs/ac and 31.3 lbs/ac at the 6–12-inch depth. Oat yield in this treatment was 21.3 bu/ac. Dissimilar to N supply rate, there was a clear association for minimum K supply rate, the lowest rates in the same treatment and both depths, 16.4 lbs/ac at the 0–6-inch depth and 12.6 lbs/ac at the 6–12-inch depth when oat was seeded at 0.25X rate and same-row placement (oat yield 20.5 bu/ac).

Comparing the nutrient availability at the 0–6-inch depth as influenced by *seed placement of* oat over all seeding rates, the average K supply rate, when oat is placed sideband, was 26.2 lbs/ac, ranging from to 21.4 to 29.6 lbs/ac, 0.5X and 0.25X seeding rates, respectively When oat is planted in the same row as perennial ryegrass, average K supply rate was 34.1 lbs/ac, ranging from 16.4 to 42 lbs/ac, 0.25X and 0.75X rates, respectively.

S supply rate

Sulphur nutrient availability is important for perennial ryegrass seed production, reported to be one of the nutrients limiting seed yield, along with N, K and low soil pH (Hart et al 2013). At the 0–6-inch depth, the average S nutrient availability for the mixed intercrop treatments was 6.9 lbs/ac compared to a lower amount 8.4 lbs/ac available S in the monocrop oat after a seed yield of 32 bu/ac. The S availability of 10.9 lbs/ac in monocrop perennial ryegrass was higher than in both the intercrop treatments and oat monocrop. A similar trend is observed at the 6–12-inch depth with 7.2 lbs/ac, 8.8lbs/ac and 8 lbs/ac available S in the mixed intercrop treatments, oat, and perennial ryegrass monocrops, respectively.

Comparing the nutrient availability at the 0–6-inch depth as influenced by *seed placement* of oat *over all seeding rates*, the average S supply rate, when oat is placed sideband, was 7.0 lbs/ac, ranging from 4.4 to 9.7 lbs/ac, 1.0X and 0.75X rates, respectively. When oat is planted in the same row as perennial ryegrass, average S supply rate was 7.0 lbs/ac ranging from 6.5 to 7.4 lbs/ac, 1.0X and 0.25X rates, respectively.

P supply rate

The average *phosphorous (P) supply rate* for the mixed intercrop treatments was 6.5 lbs/ac at the 0–6-inch depth with monocrop oat at slightly higher at 6.7 lbs/ac and 6 lbs/ac monocrop perennial ryegrass. Supply rates for the mixed intercrop treatments were similar at the lower depth, 6.1 lbs/ac and monocrop oat 6.3 lbs/ac, whereas the P supply rate for monocrop oat, 4.5 lbs/ac, was noticeably less at the 6–12-inch depth. Interestingly, across all treatments, the maximum P supply rate occurred at both depths - similar to the K supply rate and in the same treatment. With a 0.75X oat seeding rate and same-row placement, P supply at the 0–6-inch depth was 25.4 lbs/ac and 25.7 lbs/ac at the 6–12-inch depth.

Comparing the nutrient availability at the 0–6-inch depth as influenced by *seed placement of oat over all seeding rates*, the average P supply rate, when oat is placed sideband, was 3.3 lbs/ac, range 2.6 to 5.1 lbs/ac, 0.25X and 0.75X rates, respectively. When oat is planted in the *same row* as perennial ryegrass, average P supply rate was 9.7 lbs/ac, range 4 to 25.4 lbs/ac (the high value observed at the 0.75X seeding rate was an outlier).

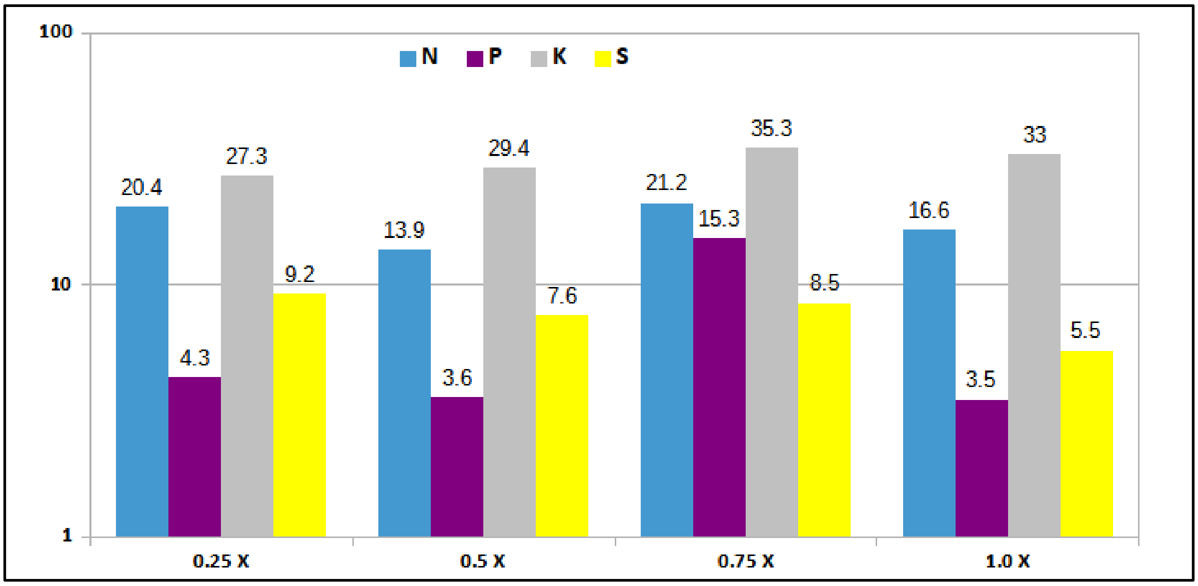

Figure 9: Seeding rate effect on plant nutrient availability in oat-perennial ryegrass intercrop,0 to 6-inch sampling depth, measured using Plant Root Simulator® (PRS) technology, Prince Albert, October 2021.

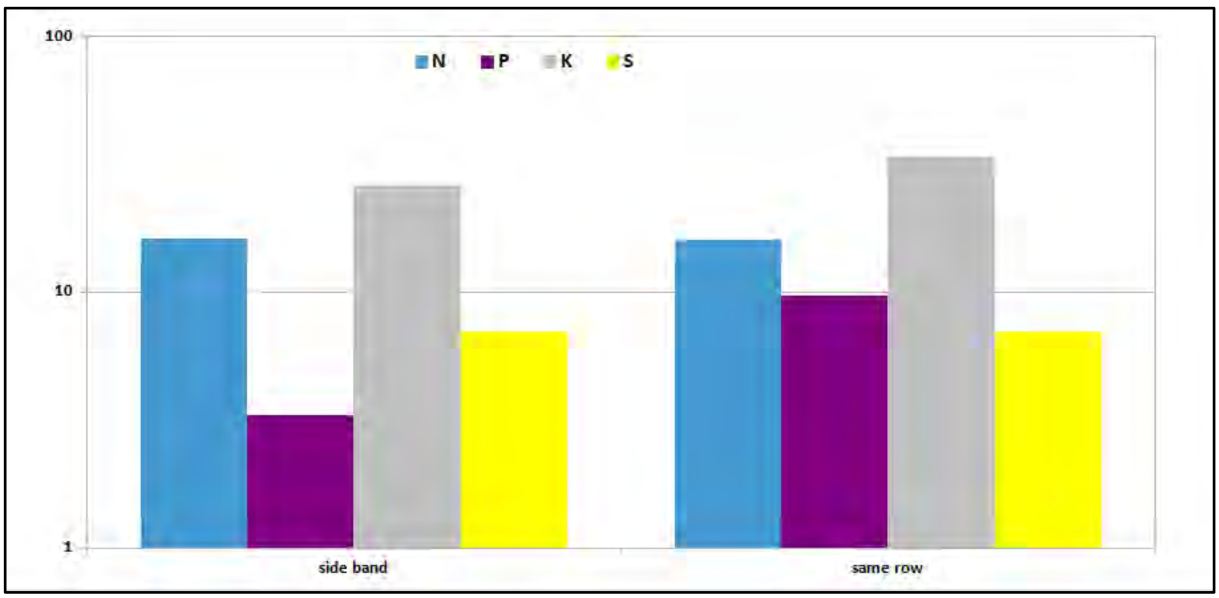

Figure 10: Oat seed placement effect on plant nutrient availability in oat-perennial ryegrass intercrop, 0 to 6-inch sampling depth, measured using Plant Root Simulator® (PRS) technology, Prince Albert, October 2021.

Nutrient availability at the 6–12-inch depth is summarized in Tables 2 and 3.

Table 2: Nutrient availability at 6 – 12-inch depth, as influenced by seed placement of oat when used for the establishment of perennial ryegrass, measured using Plant Root Simulator® (PRS) technology, Prince Albert, SK, October 2021.

Oat Placement	Nutrient	Average supply rate	Minimum supply rate (seeding rate)	Maximum supply rate (seeding rate)
		lbs/ac		
Side-band	N	14.9	10.5 (1.0X)	20.4 (0.75X)
Same-row	N	14.0	8.2 (0.5X)	18.7 (0.75X)
Side-band	P	3.1	2.3 (1.0X)	3.8 (0.75X)
Same-row	P	9.2	3.2 (0.5X)	2.7 (0.75X)
Side-band	K	16.2	15.4 (0.5X)	17.3 (0.25X)
Same-row	K	21.4	12.6 (0.25X)	31.3 (0.75X)
Side-band	S	7.1	4.9 (1.0X)	8.5 (0.75X)
Same-row	S	7.3	4.0 (0.5X)	9.3 (0.75X)

Table 3: Nutrient availability at 6 – 12-inch depth, as influenced by seeding rate of oat when used for the establishment of perennial ryegrass, measured using Plant Root Simulator® (PRS) technology, Prince Albert, SK, October 2021.

Oat seeding rate	Nutrient	Average	Side-band placement	Same-row placement
		lbs/ac		
0.25 X	N	12.1	11.4	12.8
0.5 X	N	12.7	17.2	8.2
0.75 X	N	19.6	20.4	187
1.0 X (122 lbs/ac)	N	13.4	10.5	16.2
0.25 X	P	3.3	3.2	3.3
0.5 X	P	3.1	2.9	3.2
0.75 X	P	14.8	3.8	25.7
1.0 X (122 lbs/ac)	P	3.5	2.3	4.6
0.25 X	K	15.0	17.3	12.6
0.5 X	K	15.8	15.4	16.1
0.75 X	K	23.6	15.8	31.3
1.0 X (122 lbs/ac)	K	21.0	16.2	25.7
0.25 X	S	7.4	6.7	8
0.5 X	S	6.2	8.4	4.0
0.75 X	S	8.9	8.5	9.3
1.0 X (122 lbs/ac)	S	6.4	4.9	7.8

10.5 Extension Activities

Due to COVID-19 group size and site access restrictions, the demonstration trial was not featured at the Conservation Learning Centre's Field Day in 2021. Plans were made to create a video in Year 2 of the trial to share on the CLC's social media and YouTube channel. However, the trial was terminated in July 2022

As a proxy for a producer field day, notice of the trial and report of the findings were done in multiple ways. First, an article was written and published in the Forage Seed News magazine, circulated to approximately 1800 growers, forage seed industry firms operating in western Canada, researchers and government extension specialists. Next, an article was written and posted as a blog on the Saskatchewan Forage Seed Commission website. 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

Lana Shaw, manager at the Southeast Research Farm of the AgriARM network of research farms, presented findings from the Prince Albert and Redvers sties at virtual presentation of the Agri-Arm Research Update coinciding with Crop Production Week, January 2022. The presentation was delivered remote and audience size was not reported, although, in general, the AgriARM Annual Research Presentations are a popular venue for producers. http://agriarm.ca/event/agriarm-research-update/

11 Conclusions and Recommendations

For oat seed producers, mixed intercropping of oat with turf-type perennial ryegrass did not have a statistically significant negative influence on the agronomic performance of oat, based on either seed placement as a side-band or when planted in the same row. Similarly, there was no significant oat yield impact based on three incremental reductions of seeding rates from 1.0X rate of 122 lbs/ac CDC Arborg to 0.75X, 0.5X and 0.25X rates. Compared to the monocrop oat, the best yields were achieved when the mixed intercrop oat was seeded as a side-band and at the 1.0X rate, yielding 6 bu/ac more than when grown as a monocrop. However, due to the extremely hot and dry spring growing conditions in 2021, oat did not perform as expected for the region. There was minimal weed pressure as the small plot trials were hand-weeded. Oat plants were stunted, low-yielding and had minimal lodging. When an estimate of the economics of mixed intercropping is calculated from the perspective of the oat seed producer, we estimate that the monocrop oat showed a negative return of -$175.33 per acre in 2021 (Appendix Table A.6).

We based our calculations on the oat crop economics for the Black Soil Zone as published in Saskatchewan provincial government Crop Planning Guide 2022. We included the Crop Planning Guide value for Variable Expenses ($352.46 per acre) minus the cost of oat seed and inoculant ($50.35+1.04/acre). Then we accounted for the farm gate price paid for mixed intercrop seed cost and the four different seeding rates ($35.50/acre 0.25X to $81.00/ac 1.0X). The adjusted Variable Expenses for mixed intercrop planting in 2021 ranged from $336.57/ac to $382.07/acre, oat monocrop $362.07, and perennial ryegrass monocrop $321.07/ac.

We added the Total Other Expenses value of $116.87 from the Guide, bringing the adjusted total expenses to $453.44/ac (0.25X) to $498.94/ac (1.0X seeding rate), oat monocrop $478.94, and perennial ryegrass monocrop $437.94/ac. We calculated the return per acre using the 2021 oat yield data from the demonstration trial. The farm gate oat prices included amounts offered to some forage seed growers in the northeast region in fall 2021 ($4.80/bu) and fall 2022 ($9.50/bu).

Using the farm gate price offered in fall 2021, the gross return for mixed intercropping ranged from $63.17/ac (0.25X rate, side-band) to $192.05/ac (1.0X, side-band) with monocrop oat gross return of $163.41/ac. (no seed yield data recorded for perennial ryegrass). The adjusted Net Return was the difference between adjusted Total Expenses.

All net returns were negative due to the 2021 low oat yield in either monocrop or mixed intercropping. The side-band oat planted at 1.0X rate had the least amount of negative return -$118.85/ac, followed by monocrop oat -$155.53/ac; seed row placed oat at 0.5X rate -$167.02/ac and seed row placed oat at 1.0X rate -$181.62/ac.

From the perspective of a forage seed producer, despite the reduced precipitation in 2021, there were established clumps of perennial ryegrass when the oat crop was ready to harvest. This being the case, and depending on potential contract price conditions, a forage seed grower may have decided to apply fertilizer, fall or split fall and spring applications.

According to perennial ryegrass production guidelines, the *nitrogen supply rate in* the fall is very important for harvesting high seed yields. The Oregon State University research program found that 60% of fall-supplied N was measured in the plant and the seed; 15% was in the soil and 5% in the roots. However, a fall N application is optional when the spring N rate is adequate, and this was likely the case for the Prince Albert site in 2021. With low yield and nutrient draw from the oat crop, there was likely sufficient N remaining in the soil for the perennial ryegrass plant. However, there were notable differences between the N supply rate measured by the Plant Root Simulator probes for the mixed intercrop treatments and the monocrop perennial ryegrass. Without oat as a companion crop, the N supply rate for perennial ryegrass at the 0-6-inch depth was 60.2 lbs/ac compared to the average of the eight mixed intercrop treatments of 16.0 lbs/ac. In comparison, oat monocrop had a lower supply of N (14.6 lbs/ac). At the 6-12-inch depth, the N supply rate for monocrop perennial ryegrass dropped to 47.4 lbs/ac, whereas the nutrient supply for monocrop oat increased from the upper level with 16.4 lbs/ac N supply rate.

Although not required in substantive amounts, *K supply* is essential for maximizing seed yield in perennial ryegrass (OREGON). It is a crucial water balance mechanism, drawing potassium from the roots to the leaves. Soil test analysis is typically done at 0-7-inch depth. According to state seed production recommendations in Oregon, soil K levels above 100 to 150 ppm should adequately supply first-year seed production. A direct correlation with the Oregon guidelines for K and PRS-based K supply rate is beyond this project's scope. It should be noted, however, that in spring 2021, soil K levels determined by AgVise based on sampling at 0-15 cm depth was 206 ppm, well beyond the 100-150 ppm threshold. Based on the fall 2021 available nutrient supply measured by the PRS probes, for all treatments, more K was available at the 0-6-inch depth compared to 6-12-inch. These results were not surprising considering K (as well as P) have limited mobility in the soil yet are highly mobile in the plant from roots to leaves, old (lower) leaves to new (upper) leaves. Analysis of Variance for statistical differences between treatments was not done due to limited sample size; however, there are indications that side-band K, at both depths, had less available K supply. A similar observation is made for *P nutrient supply*. This is unsurprising as P has limited soil mobility and greater P mobility within the plant. There are some indications that perennial ryegrass uptake of K was greater than in oat monocrop at the 0-6-inch and 6-12-inch depth.

Supply rates for S showed the least amount of variability across treatments, oat seed placement and seeding rates. There would need to be evidence for a grower to apply additional sulphur. While the Oregon State University recommendations acknowledge the importance of S in biomass increases in the spring, a gap is noted in the methodology for determining S deficiency. Therefore, they suggest growers consider using the N:S ratio when determining the rate of N. Timing of application may play a role as early spring application of N with S will help support the rapid spring growth of perennial ryegrass.

For all conclusions related to nutrient supply, it should be noted that from a technical aspect, the physical location of where the soil sample was drawn may influence the nutrient supply testing results. Western Ag advisors commented on the variation in the PRS data, potentially reflecting the impact of the shelterbelt and the drought in combination with the compositing of soil samples.

The (poor) survivability of the perennial ryegrass was likely due to the conditions of 2021, which were made worse from April to June 2022. Although snow cover came early, the dry spring in 2022 may have slowed the new spring growth of the perennial ryegrass as it quickly came out of dormancy after mid-April. Figures 3 and 4 of the trial site illustrate the (promising) new green growth on 26th April. Unfortunately, the sharp and sustained drop in temperature concurrent with the disappearance of snow cover likely caused severe damage to the crown root area of the perennial ryegrass plants. Spring rains arrived after 9th of June, and by the end of June, only a few perennial ryegrass plants had survived the extreme growing conditions. The genetics of the perennial ryegrass may also be a contributing factor. Many current cultivars originate from somewhere other than a placed-based (local) western Canadian prairie-wide breeding program. Moreover, most cultivars are bred for performance characteristics demanded by the turfgrass market rather than selection for seed production in Saskatchewan. Developing a few locally adapted cultivars would benefit monocrop and mixed intercropping seed producers in Saskatchewan and the prairie region.

Funding for this demonstration created the opportunity to gain new knowledge. Additional trials and purposive trial designs are recommended to confirm the influence of seed placement on K and P availability. Without the *a posteriori* knowledge gained from this demonstration and production under extreme drought conditions, there would be no good reason to make an inference such as 'side-band placement of oat with perennial ryegrass uses more K than same-row'. A similar hypothesis could be stated for P levels observed in this demonstration. In comparison, there is no such evidence - based on this demonstration - for an inference of either K or P nutrient availability as influenced by decreasing oat seeding rate. There is, however, evidence that oat as a companion crop may positively impact the reduction in the ground cover of weeds.

As a final recommendation, 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 and commercial fields would also be advantageous. The dual stream assessments could better account for the weed competition in the presence or absence of hand rouging and the use of commercial pesticides appropriate for use on the companion crop and perennial ryegrass, for example, using recent minor use registration of products such as Stellar XL.

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.

The research farm manager, Brooke Howat (spring to October 2021) and Robin Lokken (October 2021 to current), and the technical staff at the Conservation Learning Centre are thanked for their interest in mixed intercropping and patience in taking care of the trial site amidst challenges of COVID-19 staffing and access and environmental condition. In particular, the Managers are thanked for their care and attention to the project and effective communication skills. When signs of a problem were noted, both managers quickly investigated solutions, contacting Sask Forage Seed Commission and experienced industry agronomists. The drone flights were conducted by graduate student, David MacTaggart. Mr. MacTaggart is a certified drone pilot, and his thesis research involves the application of drone imagery for measuring plant performance of breeding nurseries of forage crops.

12.2 References

Alberta Agriculture. Perennial Ryegrass Seed Production Guide. 2004. Agdex 127/20-1. Available for download at: http://www.peaceforageseed.ca/research.html .

Barker, Bruce. "Fertilizing after a drought." Top Crop Manager. 18 April 2022. https://www.topcropmanager.com/fertilizing-after-a-drought/#:~:text=Schoenau%20says%20that%20under%20dry,moisture%20to%20dilute%20the%20salt.

Bezan, Melissa. "Sask. Research Farm Tackles Intercropping." The Western Producer, The Western Producer, 5 Aug. 2021, https://www.producer.com/crops/sask-research-farm-tackles-intercropping.

Bybee-Finley, K. A., & Ryan, M. R. (2018). Advancing intercropping research and practices in industrialized agricultural landscapes. Agriculture, 8(6), 80.

Cattani, Douglas. (2007). Perennial Ryegrass Seed Production. Available for download on Research Gate. Perennial_Ryegrass_Seed_Production

Fairey, N. A., & Lefkovitch, L. P. (2001). Effect of seeding rate on seed production of perennial ryegrass after establishment with a grain companion crop in the Peace River region of north-western Canada. Canadian Journal of Plant Science, 81(2), 265-271.

Hart, J. M., Anderson, N. P., Chastain, T. G., Flowers, M. D., Ocamb, C. M., Mellbye, M. E., & Young, W. C. (2013). Perennial ryegrass grown for seed (western Oregon) EM9086, November 2013.

Jefferson, P. G., Lyons, G., Pastl, R., & Zentner, R. P. (2005). Companion crop establishment of short-lived perennial forage crops in Saskatchewan. Canadian Journal of Plant Science, 85(1), 135-146.

Koeritz, E. J., Watkins, E., & Ehlke, N. J. (2015). Seeding rate, row spacing, and nitrogen rate effects on perennial ryegrass seed production. Crop Science, 55(5), 2319-2333.

Shaw, Lana. 2020. Mixed Grain Intercrops: The Value Proposition. Available for download at http://agriarm.ca/wp-content/uploads/2020/02/Mixed-grain-intercrops-The-value-proposition-Lana-Shaw.pdf

Webster, D. E., & Ebdon, J. S. (2005). Effects of nitrogen and potassium fertilization on perennial ryegrass cold tolerance during deacclimation in late winter and early spring. HortScience, 40(3), 842-849.

13 Appendices

A.1 Pre-planting information

Table A.1.a: Determination of seeding rates based on a plot size of 13.7 m^2

	Seeding Rate			Total needed
Treatment	Seeds/plot	lbs/ac	kg/ha	(g)
Oat 1.0X	4892.9	122.4	137.4	6774.4
Oat 0.75X	3669.6	91.8	103.0	5080.8
Oat 0.5X	2446.4	61.2	68.7	3387.2
Oat 0.25X	1223.2	30.6	34.3	1693.6

	(kg/ha)	(kg/m2)	kg/plot	Total needed (g)
Perennial ryegrass	8.97	0.0009	0.0123	491

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

Treatment	Main crop	Placement of companion crop (oat) in relation to PRG	Seeding rate of companion crop (oat)
1	Perennial ryegrass	Sideband and deeper than perennial ryegrass	0.25 X (31 lbs/ac)
2	Perennial ryegrass	Sideband and deeper than perennial ryegrass	0.5X (61 lbs/ac)
3	Perennial ryegrass	Sideband and deeper than perennial ryegrass	0.75 X (92 lbs/ac)
4	Perennial ryegrass	Sideband and deeper than perennial ryegrass	1.0X (122 lbs/ac)
5	Perennial ryegrass	Same row as perennial ryegrass	0.25 X (31 lbs/ac)
6	Perennial ryegrass	Same row as perennial ryegrass	0.5X (61 lbs/ac)
7	Perennial ryegrass	Same row as perennial ryegrass	0.75 X (92 lbs/ac)
8	Perennial ryegrass	Same row as perennial ryegrass	1.0X (122 lbs/ac)
9	Perennial ryegrass	Mono-crop perennial ryegrass	1.0X (8 lbs/ac)
10	Oat	Mono-crop oat	1.0X (122 lbs/ac)

Plot Plan

Plots should be 1.75 m x 9 m.

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

Legend:

Trt #	Seeded as Main Crop	Factor 1: Placement of Companion (oat) Crop	Factor 2: Oat seeding rate
1	PRG, cv. CE-1	Side band and deeper than PRG - fertilizer row	0.25 X
2	PRG, cv. CE-1	Side band and deeper than PRG - fertilizer row	0.5X
3	PRG, cv. CE-1	Side band and deeper than PRG - fertilizer row	0.75 X
4	PRG, cv. CE-1	Side band and deeper than PRG - fertilizer row	1.0X
5	PRG, cv. CE-1	Same row as PRG - seed row	0.25 X
6	PRG, cv. CE-1	Same row as PRG - seed row	0.5X
7	PRG, cv. CE-1	Same row as PRG - seed row	0.75 X
8	PRG, cv. CE-1	Same row as PRG - seed row	1.0X
9	PRG, cv. CE-1	Monocrop PRG - seed row	0X
10	Oat, cv. ORe3542M	Monocrop Oat - seed row	1.0X

Table A.1.c. Pre-seeding soil test data based on a composite soil sample collected from the trial area., spring 2021.

Soil Depth	Nutrient				Organic Matter	pH	Electrical Conductivity
(cm)	Nitrate-Nitrogen (lbs/ac)	Phosphorus (ppm)	Potassium (ppm)	S-Sulfate (lbs/ac)	(%)		salts (mmho/cm)
0-15	7	19	206	10	3.8	6.0	0.11
15-30	9			36		6.8	0.15

Analysis by AgVise Laboratories, Northwood, ND https://www.agvise.com/ .
Interpretation of soil test levels and methodology available for download following the Helpful Documents hyperlink, Interpreting Soil Tests.

To achieve a yield goal of 145 bu/ac oat, recommendation was application of N at 145 kg/h using 46-0-0, and P at 17 kg/ha using 11-52-0.

A.2 Climate data

Table A.2a: Average monthly air temperature and precipitation for May to October, plus long-term averages, at Conservation Learning Center, Prince Albert, SK, 2021.[1]

	April	May	June	July	August	September	October	Average
					--- Mean Temperature (°C) ---			
2021	4.1	10.1	18.3	20.3	17.0	13.5	4.9	n/a
2012-2020	-	11.4	15.9	18.5	17.1	11.4	2.9	n/a

	April	May	June	July	August	September	October	Cumulative Precipitation
					--- Precipitation (mm) ---			
2021	4.8	30.1	80.3	8.6	59.9	9.5	13.6	242.2
2012-2020	-	40.4	79.6	84.6	42.9	31.2	20.7	299.4

1.Data collected from the SRC Climate Reference Station Daily Data Report. Precipitation as recorded in Geonor Weighing Gauge.

Table A.2.b: Average monthly air temperature and precipitation for November 2021 to March 2022, plus long-term averages, at Conservation Learning Center, Prince Albert, SK.[1]

	November[2]	December[3]	January[4]	February[5]	March[6]	April[7]	Average
				--- Mean Temperature (°C) ---			
2021 -2022	-5.1	-18.6	-17.5	-18.7	-8.2	0.4	-
2012-2021	n/a	n/a	-14.6	-16.1	-7.1	1.5	-

	November	December	January	February	March	April	Cumulative Precipitation
				--- Precipitation (mm) ---			
2021-2022	27.2	28.8	19.1	9.0	15.2	6.9	106.2
2012-2021	n/a	n/a	17.9	9.8	14.1	19.6	n/a

1.Data collected from the SRC Climate Station. Precipitation from Weighing Gauge measurements.
2. Snow on ground at 09:00: First snow cover of 1-cm occurred on November 10th, followed 15-cm snow cover on November 11th, 17-cm November 16th, 15-cm November 30th.
3.December snow cover began with 15-cm on December 1st, 20-cm December 10th, 29-cm December 20th, 39-cm December 30th
4. January snow cover began with 38-cm January 1st, 40-cm January 10th, 54-cm January 20th, 52cm January 30th
5. February snow cover began with 52-cm, February 10th 50 -cm, February 20th60-cm, February 28th 60-cm
6. March snow cover began with 60-cm, March 10th 51-cm, March 20th 49-cm, March 30th 48-cm
7. April snow cover began with 45-cm, April 10th 25-cm and start of consistently decreasing snow cover, April 15th 24-cm, April 20th 22-cm, April 21st 21-cm, April 22rd 18-cm, April 23rd 16-cmm April 24th 1-cm.

Environmental data for April is illustrated in Figure A.3.i below.

After snow cover melted, noteworthy temperatures for April were as follows:

- April 24th -1°C,
- April 25th **- 5°C**
- April 26th **-4.9°C**
- April 27th +0.3 °C
- April 28th -0.6°C
- April 29th +2.9°C
- April 30th +1.7°C

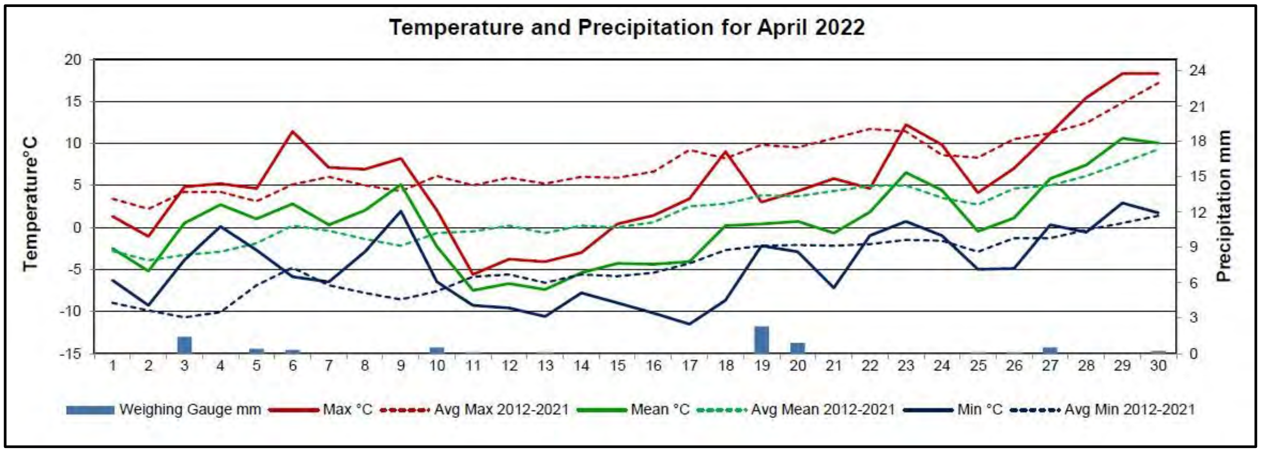

Figure A.2.a: Temperature and Precipitation, Conservation Learning Centre, Prince Albert, SK April 2022
Source: SRC CLIMATE REFERENCE STATION DAILY DATA REPORT available for download at: May 2022 Weather Summary Conservation Learning Centre

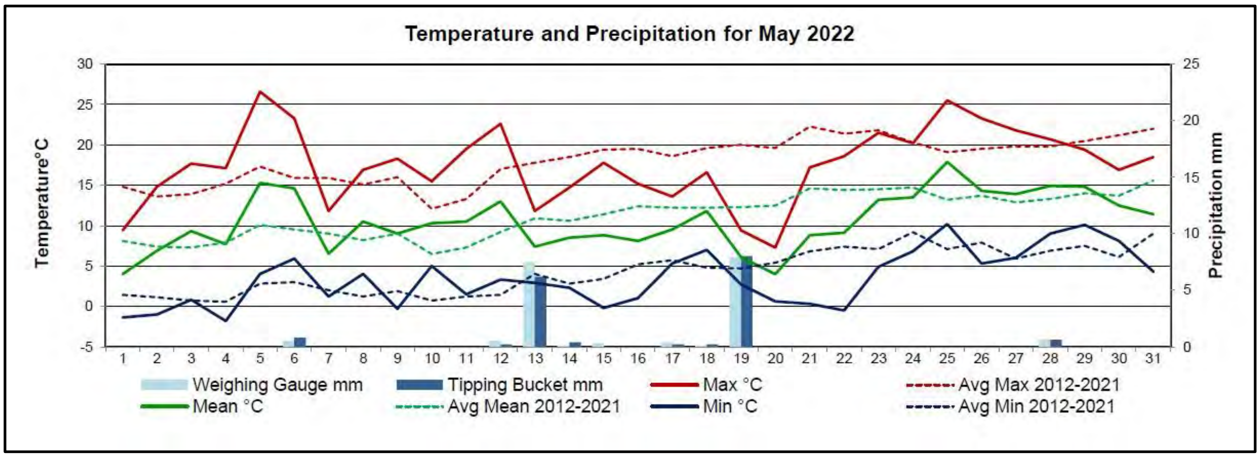

Figure A.2.b: Temperature and Precipitation, Conservation Learning Centre, Prince Albert, SK May 2022
Source: SRC CLIMATE REFERENCE STATION DAILY DATA REPORT available for download at: May 2022 Weather Summary Conservation Learning Centre

Table A.2.c: Average monthly air temperature and precipitation for May and June, plus long-term averages, at Conservation Learning Centre, Prince Albert, SK. 2022.[1]

	May	June	Average
	--- Mean Temperature (°C) ---		
2022	10.5	15.5	-
2012-2021	11.3	16.2	-

	May[2]	June	Cumulative Precipitation
		--- Precipitation (mm) ---	
2022	17.9	75.7	143.8
2012-2021	38.3	77.6	177.3

1.Data collected from the SRC Climate Station.
2.Daily environmental data for May is illustrated in Figure A.3.i below.

- Low (<0 ºC) temperatures: 1st May -1.4 ºC, 2nd May -1.0 ºC, 4th May -1.8 ºC, 9th May -0.3ºC, 15th May -0.2 ºC, 22nd May -0.5 ºC.
- High (>23 ºC) temperatures: 5th May 26.6ºC, 6th May 23.3 ºC,25th May 25.5 ºC, 26th May 23.3 º

A.3 Early growth stage performance of intercropped oat and perennial ryegrass, Prince Albert, 2021, 2022

Table A.3.a: Oat plant densities when intercropped with perennial ryegrass, Prince Albert, SK, spring, 2021.

Oat Placement	Oat Seeding Rate	N	Plant Density (plants/m^2)
Side-band and deeper than perennial ryegrass	0.25 X	2	68
	0.5X	3	106
	0.75 X	4	112
	1.0X	3	161
Same row as perennial ryegrass	0.25 X	4	64
	0.5X	3	92
	0.75 X	3	119
	1.0X	3	140
Monocrop perennial ryegrass	0X	4	16
Mono-crop oat	1.0X	3	153

Table A.3.b: Oat plant densities influenced by seeding rates when intercropped with perennial ryegrass, Prince Albert, SK, spring, 2021.[1.]

Oat Seeding Rate	N	Plant Density (oat plants/m^2)
0.25 X	6	65 c
0.5 X	6	99 b
0.75 X	7	115 b
1.0 X	9	151 a
P-value		<0.05

1.Multiple comparisons were completed using the Least Significant Difference method, Statistix™ v10.

Table A.3.c: Oat plant densities influenced by seed placement when intercropped with perennial ryegrass, Prince Albert, SK, spring, 2021.[1.]

Oat Placement	N	Plant Density (oat plants/m^2)
Side-band	12	115
Same row	13	101
Monocrop oat	3	153
P-value		0.0637

1.Multiple comparisons were completed using the Least Significant Difference method, Statistix™ v10.

Table A.3.d: Perennial ryegrass early spring plant growth when intercropped with oat, Prince Albert, SK, spring, spring, 2022.[1.]

Oat Placement	N	Plant Density (plants/m^2)

Oat Placement	Oat Seeding Rate	N	Perennial ryegrass	Weedy species
			(% ground cover)	
Side-band and deeper than perennial ryegrass	0.25 X	2	43	20 ab
	0.5X	3	26	33 ab
	0.75 X	4	31	28 ab
	1.0X	3	27	8 ab
Same row as perennial ryegrass	0.25 X	4	29	17 ab
	0.5X	3	14	27 ab
	0.75 X	3	39	22 ab
	1.0X	3	48	65 a
Monocrop perennial ryegrass	0X	4	29	5 b
Monocrop oat	1.0X	3	-	-
p value			0.5872	0.0027

1.Multiple comparisons were completed using the Least Significant Difference method, Statistix™ v10. ANOVA was used for parametric data and Krusal-Wallis test for non-parametric data.

A.4 Agronomic performance data of oat and perennial ryegrass when planted as intercrop, Prince Albert, 2021 and 2022

Table A.4.a: Agronomic performance of oat when intercropped with perennial ryegrass, Prince Albert, SK, spring, 2021.

Oat Placement	Oat Seeding Rate	N	Lodging (0-9)	Height (cm)	Biomass (kg/ha)	Yield (kg/ha)	Yield[1] (bu/ac)	Seed Weight[2] (g/1000 seeds)
Sideband and deeper than perennial ryegrass	0.25 X	2	0.2	93	16,780	472	13.2	37
	0.5X	3	0.1	89	15,365	776	21.6	40
	0.75 X	4	0.2	83	14,561	1006	28.0	36
	1.0X	3	0.1	90	17,140	1435	40.0	39
Same row as perennial ryegrass	0.25 X	4	0.7	91	21,325	779	21.7	43
	0.5X	3	1.5	90	23,731	1138	31.7	45
	0.75 X	3	1.1	89	18,881	813	22.7	39
	1.0X	3	1.2	86	15,837	1,198	33.4	38
Monocrop perennial ryegrass	0X	4	-	-	-	-	-	-
Monocrop oat	1.0X	3	0.6	81	15,936	1,221	34.0	38

1.Conversion kg/ha to bu/ac based on oat standard weight 14.515 kg/bu.
2.The seed weight for each treatment was within the typical range for oat at 30 to 40-g.

Table A.4.b: Agronomic performance of oat at different oat seed placements when intercropped with perennial ryegrass, Prince Albert, SK, spring, 2021.[1.]

Oat Placement	N	Lodging	Height	Biomass	Yield[2]	
		(0-9)	(cm)	(kg/ha)	(kg/ha)	(bu/ac)
Sideband	12	0.1 b	88	15,777	967	27.0
Same row	13	1.1 a	89	20,050	966	26.9
Monocrop oat	3	0.6 ab	81	15,936	1,221	34.0
P-value		0.0012	0.149	0.2111	0.6361	0.6364

1.Different letters indicate significant differences (p<0.05). Multiple comparisons were completed using the Least Significant Difference (LSD method using Statistix™ v10 software).
2.Conversion kg/ha to bu/ac based on oat standard weight 14.515 kg/bu.

Table A.4.c: Agronomic performance of oat at different oat seeding rates when intercropped with perennial ryegrass, Prince Albert, SK, spring, 2021.[1.]

Oat Seeding Rate	N	Lodging	Height	Biomass	Yield	
		(0-9)	(cm)	(kg/ha)	(kg/ha)	(bu/ac)
0.25 X	6	0.5	91	19,810	676 bc	18.8
0.5 X	6	0.8	89	19,548	957 ab	26.7
0.75 X	7	0.6	85	16,413	924 ab	25.8
1.0 X	9	0.6	86	16,304	1,285 a	35.8
P-value		0.9578	0.2245	0.6136	0.0001	0.0001

1.Different letters indicate significant differences (p<0.05). Multiple comparisons were completed using the Least Significant Difference (LSD method using Statistix™ v10 software).
2.Conversion kg/ha to bu/ac based on oat standard weight 14.515 kg/bu.

A.5 Fertilizing for perennial ryegrass seed production

Table A.5.a Oat yield and post-harvest nutrient availability data based on a composite sample prepared by collecting soil samples from each replicate of each treatment and depth, fall 2021.

Treatment	Oat Yield (bu/ac)	Soil sample depth (inches)	Management factors (Placement of oat relative to perennial ryegrass PRG, and seeding rate oat)	Standard Supply Rate (lbs/ac actual nutrients available)			
				N	P	K	S
1	13.2	0 – 6	Side-band oat 0.25 X rate with perennial ryegrass	8.6	2.6	29.6	5.5
1		6 -12		11.4	3.2	17.3	6.7
2	21.6	0 – 6	Side-band oat 0.5 X rate with perennial ryegrass	14.9	2.7	21.4	8.3
2		6 -12		17.2	2.9	15.4	8.4
3	28.0	0 – 6	Side-band oat 0.75 X rate with perennial ryegrass	23.7	5.1	28.6	9.7
3		6 -12		20.4	3.8	15.8	8.5
4	40.0	0 – 6	Side-band oat 1.0 X rate with perennial ryegrass	17.6	2.9	25.2	4.4
4		6 -12		10.5	2.3	16.2	4.9
5	21.7	0 – 6	Same row oat 0.25 X rate with perennial ryegrass	16.3	4.7	16.4	7.4
5		6 -12		12.8	3.3	12.6	8
6	31.7	0 – 6	Same-row oat 0.5 X rate with perennial ryegrass	12.9	4.5	37.3	6.8
6		6 -12		8.2	3.2	16.1	4
7	22.7	0 – 6	Same-row oat 0.75 X rate with perennial ryegrass	18.7	25.4	42	7.2
7		6 -12		18.7	25.7	31.3	9.3
8	33.4	0 – 6	Same-row oat 1.0 X rate with perennial ryegrass	15.5	4	40.7	6.5
8		6 -12		16.2	4.6	25.7	7.8
9	-	0 – 6	Monocrop perennial ryegrass (8 lbs/ac)	60.2	6.7	28.1	10.9
9		6 -12		47.1	4.5	22	9
10	34.0	0 – 6	Monocrop oat 1.0X rate (122 lbs/ac)	14.6	6	41.9	8.4
10		6 -12		16.4	6.3	38.5	8.8
Average				19.1	6.2	26.1	7.5

A.6 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. P2O5 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 averaged $0.78/lb, average yield in the area was 800 lb/ac., for a gross return forage seed sale of $624/ac. Canola, oat, or wheat were used as companion crops.

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

Oat seed placement	Sideband				Seedrow				PRG Monocrop	Oat Monocrop
Oat seeding rate	**0.25X**	**0.5X**	**0.75X**	**1.0X**	**0.25X**	**0.5X**	**0.75X**	**1.0X**		
2021 Yield (kg/ha)	472	776	1006	1435	779	1138	813	1198	0	1221
2021 Yield (bu/ha) kg/ha divided by oat standard weight 14.515 kg/bu	32.5	53.5	69.3	98.9	53.7	78.4	56.0	82.5	0.0	84.1
2021 Yield (bu/ac) = bu/ha divided by 2.4710 (A)	13.2	21.6	28.0	40.0	21.7	31.7	22.7	33.4	0.0	34.0
Oat seed cost ($0.50/lb)	$ 0.50	$ 0.50	$ 0.50	$ 0.50	$ 0.50	$ 0.50	$ 0.50	$ 0.50	-	$ 0.50
Oat seeding rate (lbs/ac)	31	61	92	122	31	61	92	122	-	122
Perennial ryegrass seed cost ($2.50/lb)	$ 2.50	$ 2.50	$ 2.50	$ 2.50	$ 2.50	$ 2.50	$ 2.50	$ 2.50	$ 2.50	-
Perennial ryegrass seeding rate (lbs/ac)	8	8	8	8	8	8	8	8	8	-
mixed intercrop and monocrop seed costs $/ac	$ 35.50	$ 50.50	$ 66.00	$ 81.00	$ 35.50	$ 50.50	$ 66.00	$ 81.00	$ 20.00	$ 61.00
GOS Total Variable expenses/ac GOS, oat black soil zone	$ 352.46	$ 352.46	$ 352.46	$ 352.46	$ 352.46	$ 352.46	$ 352.46	$ 352.46	$ 352.46	$ 352.46
GOS Varible Expenses oats minus ($ 50.35/ac seed cost +innoculant $1.(	$ 301.07	$ 301.07	$ 301.07	$ 301.07	$ 301.07	$ 301.07	$ 301.07	$ 301.07	$ 301.07	$ 301.07
Adjusted for mixed intercrop Total Variable Expenses estimate (B)	$ 336.57	$ 351.57	$ 367.07	$ 382.07	$ 336.57	$ 351.57	$ 367.07	$ 382.07	$ 321.07	$ 362.07
GOS total Oat Other Expenses $/ac (C)	$ 116.87	$ 116.87	$ 116.87	$ 116.87	$ 116.87	$ 116.87	$ 116.87	$ 116.87	$ 116.87	$ 116.87
Adjusted Total Expenses ($/ac) B+C=D	$ 453.44	$ 468.44	$ 483.94	$ 498.94	$ 453.44	$ 468.44	$ 483.94	$ 498.94	$ 437.94	$ 478.94
Field trial yield bu/ac	13	22	28	40	22	32	23	33	0	34
Fall 2021 oat price $4.80 (E)	$ 4.80	$ 4.80	$ 4.80	$ 4.80	$ 4.80	$ 4.80	$ 4.80	$ 4.80	$ 4.80	$ 4.80
Fall 2022 oat price $9.00-$10.00 (F)	$ 9.50	$ 9.50	$ 9.50	$ 9.50	$ 9.50	$ 9.50	$ 9.50	$ 9.50	$ 9.50	$ 9.50
Gross return 2021 $/ac (AE) = G	$ 63.17	$ 103.85	$ 134.63	$ 192.05	$ 104.25	$ 152.30	$ 108.80	$ 160.33	$ -	$ 163.41
Gross return 2022 $/ac (AF) = H	$ 125.02	$ 205.54	$ 266.46	$ 380.09	$ 206.33	$ 301.42	$ 215.34	$ 317.32	$ -	$ 323.41
Net Return 2021 (G-D)	**-$ 390.27**	**-$ 364.59**	**-$ 349.31**	**-$ 306.89**	**-$ 349.19**	**-$ 316.14**	**-$ 375.14**	**-$ 338.61**	**-$ 437.94**	**-$ 315.53**
Net Return 2022 (H-D)	**-$ 328.42**	**-$ 262.90**	**-$ 217.48**	**-$ 118.85**	**-$ 247.11**	**-$ 167.02**	**-$ 268.60**	**-$ 181.62**	**-$ 437.94**	**-$ 155.53**

14 Abstract

At Prince Albert in 2021, the environmental conditions of low precipitation and high temperatures were such that oat, planted as a monocrop yielded 34 bu/ac, or as a mixed intercrop (average 27 bu/ac), fell far short of 145 bu/ac goal used for fertilizer recommendations in northeast Saskatchewan. Nonetheless, mixed intercropping oat and turf-type perennial ryegrass did not significantly reduce oat yield relative to monocrop oat. Economically, monocrop oat had a (negative) net return of -$155.53/ac, whereas a mixed intercrop had fewer losses (-$118.85/ac). Oat placement did not significantly influence yield; however, seeding rate had a highly significant impact on yield (0.25X rates reduced yield by 44%). Conversely, the 1.0X rate mixed intercrop treatments (side-band and same-row) gained 1.8 bu/ac relative to monocrop oat. October drone images did not discern treatment differences in the growth of perennial ryegrass. Although, extensive oat straw and chaff in the plot area likely obscured any green growth. Therefore, a primary inference from this demonstration is that managing the straw/chaff of the companion crop is critical to the successful overwintering of turf-type perennial ryegrass. Available nutrient supply levels were measured to compensate for oats' nutrient use. The perennial ryegrass plants could survive with good snow cover in winter 2021-2022. Fertilizer was spring applied (90 lb N/ac, 35 lbs P_2O_5/ac, 25 lb K_2O/ac and 10 lb S/ac). However, with a rapid loss of snow cover April 23rd, followed immediately by sub-zero temperatures April 24-26th, the now-active crown roots would have been severely impacted by two days of - 5°C temperatures. With this weakened physiological condition and lack of spring rainfall, we conclude that the environmental conditions of 2021-22 had a greater influence on the establishment of the perennial ryegrass than did the presence of, or the seeding rates, or placement of the oat companion crop.

15 Finances

Contract:

Ministry of Agriculture
Project # 20200536
Midas # 000529

17. Budget

- **Please complete this form to summarize how ADOPT funds will be spent. Please carefully check your addition.**

	Total Funds required for the project	ADOPT Funds requested for Year 1	ADOPT Funds requested for Year 2	Total ADOPT Funds Requested
Salaries and Benefits				
Students				
Postdoctoral/Research Associates				
Technical/Professional Assistants				
Consultant Fees & Contractual Services[1]	12,800	6,400	6,400	12,800
Rental Costs				
Materials [2]**/ Supplies**	3,904	2,084	1,820	3,904
Project Travel				
Field Work[3]	500	250	250	500
Collaborations / Consultations				
Other				
Field Days (or other knowledge transfer pending Covid-19 restrictions)	500	250	250	500
Administration	1,000	500	500	1,000
Miscellaneous[4]	884	310	574	884
Total	19,588	9,764	9,764	19,588

1. Contractual Services: Agri-Arm sites @ site $6400 per year
- 10 treatments x $ 500 / treatment = $ 5000 in 2021, $ 5000 in 2022
- Materials and Supplies: $ 500 in 2021, $500 in 2022
- Oat seed quality testing: 9 samples x $ 100 per sample = $ 900 in 2021
- Forage seed quality testing: 9 samples x $ 100 per sample = $ 900 in 2022

2. Materials and supplies
- soil testing 1 composite sample (spring 2021) and 10 treatments (fall 2021) x $120 per sample plus taxes. In year two, soil analysis will be done on all 10 treatments (2022) x $120 per sample plus taxes.
- Biomass measurements using UAV and image analysis, $500 per capture.

3. Travel from Saskatchewan Forage Seed Development Commission office to field trial location, 138 km at provincial mileage rate, currently $0.4535/km, two return trips, $237.63.

4. Miscellaneous includes project management and report writing, 9.5 hours at $32.50/hr 2021 and 17.6 hours 2022 (same rate).

Payments were issued by SFSDC to the CLC upon receiving the Year One Interim Report and spring payment for trial expenses.

Ministry of Agriculture
Project # 20200536
Midas # 000529

APPENDIX "B"

The total approved funding for this project is up to $19,588.00.

APPROVED BUDGET

	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total ($)
Salaries and Benefits				
•Students				
•Postdoctoral / Research Associates	6,400	6,400		12,800
•Technical / Professional Assistants				
Consultant Fees & Contractual Services				
Rental Costs				
•Rentals				
Materials / Supplies	2,084	1,820		3,904
Project Travel				
•Field Work	250	250		500
•Collaborations/consultations				
Other				
•Field Day	250	250		500
•Administration	500	500		1,000
• Miscellaneous	310	574		884
Total	9,794	9,794		19,588

PROJECT REPORT AND EXPENDITURE STATEMENT DUE DATES SCHEDULE

1. The Ministry shall make the following contributions:

			Project Report and Expenditure Statement Due Date
a) up to	$7,835	on signing	
b) up to	$9,794	on approval of final report and expenditure statement	December 1, 2021
c) up to	$1,959	on approval of final report and expenditure statement.	December 1, 2022
Total	19,588		

Saskatchewan

Date 2021 04 13
YYYY MM DD

General Revenue Fund 5600647516

MINISTRY	INQUIRY	INVOICE	PAYMENT DESCRIPTION	AMOUNT
griculture	(306) 787-7450	20200535-1	20200535/JO-ANNE RELF-ECKSTEIN/ADOP	8,000.00
griculture	(306) 787-7450	20200536-1	20200536/JO-ANNE RELF-ECKSTEIN/ADOP	7,835.00
griculture	(306) 787-7450	20200537-1	20200537/JO-ANNE RELF-ECKSTEIN/ADOP	7,915.00
			Total	$23,750.00

4314064

Saskatchewan

Date 2022 03 02
YYYY MM DD

General Revenue Fund 5600686807

MINISTRY	INQUIRY	INVOICE	PAYMENT DESCRIPTION	AMOUNT
Agriculture	(306) 787-7450	20200535-2	20200535/J RELFOECKSTEIN/ADOPT PROG	10,000.00
Agriculture	(306) 787-7450	20200536-2	20200536/J RELF-ECKSTEIN/ADOPT PROG	9,794.00
			Total	$19,794.00

Expenditure Statement

Year 1 May 01, 2021 – December 31, 2022

Amount		Report / Payment Due Dates
$4,800.00	Initial Payment	On signing of contract
$1,600.00	Year 1 Final Payment (on or before December 01, 2021 pending Ministry approval of Final Report and Expenditure Statement, and receipt of **SFSDC** year 1 payment from Government of Saskatchewan)	Typically, within 30 days of submission December 01, 2021 and approval of Final Report Year 1 - approximately December 31, 2021
$6,400.00	Total amount of payments by **SFDC** to **CLC**	

Year 2 January 01, 2022 – December 31, 2022

Amount		Report / Payment Due Dates
$4,800.00	Year 2 Spring Payment (on receiving payment from Ministry)	June 30, 2022
$1,600.00	Year 2 Final Payment (on or before December 01, 2021 pending Ministry approval of Final Report and Expenditure Statement, and receipt of **SFSDC** year 2 payment from Government of Saskatchewan)	Typically, within 30 days of submission December 01, 2022 and approval of Final Report Year 2 - approximately December 31, 2022
$6,400.00	Total amount of payments by **SFDC** to **CLC**	

Excel spreadsheet attached using the format requested by the Ministry.