INTERIM REPORT

ADOPT 20200537

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

Saskatchewan Forage Seed Development Commission in collaboration with the Northeast Agriculture Research Farm, Melfort, Saskatchewan

SFSDC

NARF
Northeast Agriculture Research Foundation

Contents

Abstract

Intercropping is used in the forage seed-producing regions of Saskatchewan to provide cash income from the annual seed crop planted simultaneously with a short-lived perennial crop grown for forage seed production. This approach saves on input costs and time by planting two crops at once, reducing emissions, keeping roots in the soil for an extended period while the annual crop stubble provides overwintering protection for the forage seed crop harvest the subsequent year. At pre-planting or during seeding, fertilizer is applied based on the yield expectations of the companion crop. Depending on the seeder, the two crops are planted in the same row or, using the fertilizer shoot and side-banding, the annual crop is sown deeper relative to the forage seed crop. To demonstrate the potential benefits of an oat-perennial ryegrass (PRG) intercrop, the demonstration featured different seed placement of oat in relation to PRG (same row vs. sideband) and four oat seeding rates (1X, 0.25X, 0.5X, and 0.75X). Agronomic performance data was collected from a 4-replicate, 1-acre-sized trial planted at a research farm in the northeast Saskatchewan region. Drone imagery measured vegetative growth post-harvest of the oat crop. Fall soil sampling assessed plant nutrient availability for the PRG going into winter. Comparing oat seed placement, side-banded oat (45 PRG plant/m2) treatments had a significantly higher ($p<0.05$) PRG plant density than seed row-placed oat (40 PRG plant/m2). Among different oat seeding rates, high seeding rates had a significantly ($p<0.05$) higher oat plant density, fewer weeds, shorter oat plants, higher lodging, and matured earlier than lower seeding rates. There was no difference in the oat yield between different oat placements or seeding rates. Based on this demonstration at Melfort, a 0.5-0.75X seeding rate of oat placed in the sideband may be favourable to establish PRG for seed production due to the oat production characteristics of adequate grain yield, moderate maturity, and minimal lodging. However, results from year two will be necessary to determine the treatment effects on PRG overwintering and PRG seed yield.

1.Project Title:

Demonstration of intercropping perennial ryegrass (*Lolium perenne* L.) with oat *(Avena sativa*) using different seed placements and seeding rates.

2.Project Number: ADOPT 20200537

3.Producer Group Sponsor: Saskatchewan Forage Seed Development Commission SFSDC

4.Project Location(s): Northeast Agriculture Research Foundation NARF, AAFC Research Farm, Melfort, Saskatchewan

5.Project start and end dates (month & year): May 2022 – December 2023

6.Project contact person & contact details:

Executive Director
Saskatchewan Forage Seed Development Commission
office@saskforageseed.com 306-341-1347

Operations Manager, Northeast Agriculture Research Foundation
neag.agro@gmail.com 306-920-9393
Associate Research Manager, Northeast Agriculture Research Foundation
research.narf@gmail.com

Objectives and Rationale

7.1 Project objectives:

The project will demonstrate the technology of intercropping and the use of a companion crop (oat) with a forage seed crop (perennial ryegrass-PRG) during the year of establishment.

This two-year project aims to assess the economic feasibility of intercropping oat with PRG. We will also assess the establishment and winter survival of the PRG, the seed yield and the quality of both oat and PRG. Given the type of seeding equipment available to growers, we compare two methods of seed placement of the companion crop in relation to forage seed crop - oat as sideband and deeper than PRG and planting both crops in the same row. Based on grower interest in selecting an optimum seeding rate for intercropping, we assess the effect of four different oat seeding rates, 0.25X, 0.5X, 0.75X and 1.0X. The economic feasibility of the two-year intercropping strategy will be determined in year two, based on input costs in 2022 and 2023 and the farmgate value of the two crops at the time of harvest.

In year one, 2022, our objective is to assess the agronomic performance of the companion crop planted with and without the forage seed crop, the nutrient availability following the harvest of the oat plots and the plant stand of the PRG before winter.

7.2 Rationale:

Intercropping and using a companion crop such as an annual cereal, pulse, or oilseed, help establish a short-lived perennial seed crop. This approach is becoming a management strategy producers use in the forage seed-producing regions of Saskatchewan, Manitoba, and the Peace Region of Alberta-British Colombia. When viewed from the lens of forage seed growers, intercropping means that the seeding of both crops coincides but harvest time is separated by several months. At pre-planting or during seeding, fertilizer is applied based on the yield expectations of the companion crop. The annual crop is harvested in the fall of year one; the standing stubble provides overwintering protection for the forage seed crop harvested in the late summer of the following year. This intercropping strategy creates the opportunity to save input costs and time by planting two crops at once, saving fuel costs and reducing emissions while keeping roots in the soil for an extended period. The forage seed grass and legume crops on the prairies are typically treated as a biennial. However, with good stand establishment, sufficient moisture reserves, reasonable weed control and a 4R fertility management approach, the forage seed crop is harvested for seed for another two to five more years. Typical companion crops used in the forage seed-producing regions of the prairies include canola (e.g., Liberty® and Clearfield® systems) and cereal crops such as barley, wheat, and oat, all proven to be particularly well suited to production in moister parts of the grey-wooded and black soil zones. [1]

[1] Jefferson, P. G., Lyons, G., Pastl, R., & Zentner, R. P. (2005). Companion crop establishment of short-lived perennial forage crops in Saskatchewan. 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. Cattani, Douglas. (2007). Perennial Ryegrass Seed Production. Available for download on Research Gate link.

In the northeast Saskatchewan region, the Melfort area is known for high yield potential in cereal crops, particularly oat. An n oat intercrop has excellent potential for success.[2] Turf-type PRG is in demand, and Saskatchewan production is trending upward. Compared to the past 17 years of production data, in 2021-2022, PRG deliveries exceeded red clover, the traditional top-ranked forage seed crop produced based on deliveries documented by the Saskatchewan Forage Seed Development Commission (SFSDC).[3] Yet, local producers may be hesitant in attempting to grow PRG. Perennial ryegrass is vegetative in its first year, and winterkills more frequently without a companion crop; producers may find it uneconomical to plant alone (Bezan, 2021).

When PRG is planted with oat, the cereal stubble following harvest may minimize the risk of winterkill in the perennial ryegrass due to the ability of the oat straw to trap snow, conserve moisture and offer protection from wind and severe cold. Also, when PRG is established under a companion crop, the plants are physiologically younger than those grown in straight-seeded stands. As a result, less vegetative matter with the companion cropped PRG can reduce disease and insect pressure (Alberta Agriculture, 2004). But there is also a need to demonstrate the suitability of a PRG/oat intercrop since there is the potential that the oat crop could out-compete the PRG. Determining if PRG can be established in an oat intercrop system and what agronomic practices work best, such as seed placement and seeding rates, will greatly benefit forage seed growers and, potentially, oat growers who wish to diversify their crop rotations. Our demonstration considered alternative row arrangements and the seeding rate of the oat crop in relation to the perennial ryegrass.

Methodology and Results

8.Methodology

The demonstration trial consists of four replicates of 10 treatments (40 plots). Each plot is approximately 9-meter (m) long and 1.830-m wide (for treatment list, please see Appendix Table A.1). The oat variety planted in 2022 was 'CDC Arborg' a high-yielding, white-hulled milling oat with good quality, standability and maturity and improved disease resistance compared to standard industry varieties.[4] The turf-type perennial ryegrass variety 'CE1' was selected based on industry recommendations as a good fit for Saskatchewan's forage seed production areas.

---

[2] Final Crop Reports. Saskatchewan Agriculture. In 2021 northeast region oat yields were estimated on October 4th as second highest in the province at 11 bu/ac above the provincial average of 49 bu/ac. In 2022, October 17th, estimates of northeast region oat yields are 100 bu/ac - the highest yielding area in the province - 19 bu/ac above the 10-year provincial average Accessed online 2022 Saskatchewan Crop Report. Comparable seed yield and performance data for forage seed crops are unavailable for Saskatchewan.

[3] Alfalfa seed production is recognized to be greater than perennial ryegrass or red clover. However, that crop does not fall within the scope of SFSDC activities. Please see website for crop data in the Annual Reports Sask Forage Seed Development Commission Annual Reports

[4] 2022 Sask Seed Guide. *Varieties of Grain Crops 2022.* Saskatchewan Agriculture. In Zone 3 and 4 (RM 429 in Zone 4), over 7 years of evaluation, the seed yield of CDC Arborg is 106% check variety CS Camden. CDC Arborg has high test weight (250 g/0.5L), 20.1% hull, 85% plump kernels, medium maturity (<98 days maturity rate L), very good resistance to lodging, and has improved disease resistance over CS Camden with R (resistant) ratings for smut disease, I (intermediate resistance) for crown rust; both varieties are susceptible to stem rust. Accessed online Varieties of Grain Crops 2022.

8.1 Changes from the originall proposal

Our demonstration was first planted in spring 2021 with completion anticipated by December 2022. The plots were seeded at a location allocated to NARF by Agriculture and Agri-Food Canada (AAFC) in 2021. Due to the environmental conditions (drought and high temperatures in spring) and very high weed pressure at the field site, the demonstration did not proceed as proposed in the original plan. The infestation of wild oat and other weedy species was too high to control manually without severely damaging the tame oat and/or perennial ryegrass plants. Consequently, neither planted crops could establish a sufficient stand essential for a successful demonstration. With approval from the Ministry of Agriculture to defer the demonstration one year and the seeded area was mowed and tilled under.

The full economic analysis including the cost of inputs was not yet complete at the time of submitting the interim report. The economic feasibility of using oat as a companion crop to establish a forage seed crop will be determined based on input costs and the farmgate value of the oat crop at the time of harvest in October 2022. Upon reviewing the December 2022 interim report, errors were discovered. The methodology we used is described in Section 9.4.

Regarding communications and knowledge transfer methods, ADOPT 20200537 was not featured as planned at the 2022 NARF AAFC combined field day in July. Upon approval of the interim report by the Ministry, an article will be published in the Spring/Summer 2023 issue of the Forage Seed News and circulated to the forage seed industry and growers in the three prairie provinces and British Columbia. The report will also be sent to the Saskatchewan Prairie Oat Growers Association. A field day is planned for early July 2023. We will use the group text system to communicate the event directly to forage seed growers and will QR-code tagged information linking readers to the interim report posted on Sask Forage Seed Development Commission website. In addition to in-person field talks about the demonstration, we aim to create a video in 2023 of the trial to share on the NARF social media and YouTube channel.

8.2 Field demonstration 2022 - 2023

In spring 2022, the demonstration was seeded in a different field location at the AAFC Melfort Research Farm. Soil samples were drawn from the trial area, and we used the reserve seed sources provided by the seed industry as an in-kind contribution to the project. FP Genetics supplied CDC Arborg, and Brett Young Seeds supplied CE1 turf-type perennial ryegrass. A chronological list of activities for the demonstration is listed in Table 1 below. Additional information on project activities is available in Appendix Tables A.1, A.2, and A.3.

Weather conditions enabled both crops to establish well and develop over the growing season. May and June were characterized by cooler to near-average daily temperatures and above-average precipitation. July to October was warmer than average temperatures and lower than average precipitation. The 2002 and long-term average for air temperature and precipitation is reported in Appendix Table A.4.

Table 1: Description of demonstration project activities at Melfort, SK. May to November 2022.

Activity	Timing	Outcome
Soil test 1	Pre-seed	Agvise Laboratories fertilizer recommendations were used for a typical oat yield goal for the area of 150 bu/ac (see Appendix Table A.2 soil test results)
Fertility requirements companion crop	Pre-seed	Potash (0-0-60) and AMS (21-0-0-24) were broadcast before seeding to deliver rates of 11 kg K2O /ha and 6 kg S/ha, respectively.
Planting method	25 May	Plots seeded into canola stubble using a no-till, Fabro plot seeder, double disc openers, 12 in row spacing.
Seeding rates based on seed supplier recommendations and treatment rates	25 May	Perennial Ryegrass: 8 lbs/ac Oat 1.0X: 128 lbs/ac Oat 0.75X: 96 lbs/ac Oat 0.5X: 64 lbs/ac Oat 0.25X: 32 lbs/ac
Seeding depth based on seed supplier recommendations	25 May	Perennial Ryegrass @ 0.5 inch Oat @ 0.5 inches (same row placement) 1.5-2 inch (side-band placement)
Fertility requirements companion crop	25 May	Urea (46-0-0) mid-row banded to apply 94 kg N/ha. Monoammonium phosphate MAP (11-52-0) side banded to apply 43 kg P_2O_5/ha
Pre-emergent weed control	May 27	Glyphosate @1 L/ac water rate 40 L/ac
Emergence evaluation	20 June	Plant density for the oat and PRG seedlings was determined three weeks after seeding by counting two 1-m sections of crop row in both the front and back of each plot. This provided a total of four 1-m areas per plot. Percent plant coverage will be used in year 2 to document the establishment of the perennial ryegrass.
In crop weed control	15 August	Mechanical: hand-rogueing
Crop growth evaluations	August 10, 23, 20 October 20	Plant height was measured 10 August 10. Plant biomass determinations 23 August 23 were done by hand harvest and weight measurements. Maturity oat plots and lodging evaluated at harvest (7 September). The perennial ryegrass stand was evaluated post-harvest of oat crop by aerial drone imaging using a DJI Matrice 200 V2 UAV platform and a MicaSense RedEdge-MX multispectral sensor, 20 October. For additional information, see Appendix A.3 and A.4.
Harvest method	7 September	Five rows/plot combined using a Wintersteiger Quantum combine.
Seed yield evaluation	7 September	The oat crop was ready for harvest7 September 20222022 (105 days from planting). Each plot was harvested, weighed, and reported based on 10.2% moisture. Seed weight is reported by measuring the weight of 500 seeds and reporting on the basis of 1000-seed weight (TKW).

Table 1 (continued): Description of demonstration project activities at Melfort, SK. May to November 2022.

Activity	Timing	Outcome
Soil test 2	Post-harvest oat	Western Ag fertilizer recommendations using PRS probe ® analysis to determine plant available nutrients for perennial ryegrass. One composite was created by mixing four replicates of soil samples taken at 0 to 6-inch depth from each plot.
Fertility requirements forage seed crop.	31 October	Bare urea (46-0-0) was broadcast on all plots with PRG on 31 October 2022 at, a rate of 67 kg N/ha (146 kg product/ha).
Draw conclusions from the data collected	November	Data were analyzed by ANOVA using Statistix 10 software. Comparisons were completed between treatments, oat seeding rates, and oat placement. Multiple comparisons were determined by Tukey's HSD method. Significance was determined at $p<0.05$.

9.Results

Year one of the demonstration achieved all its objectives. Although the demonstration was planted on a research farm, the trial site manager and research program staff at the Northeast Agriculture Research Foundation could simulate comparable field operations as in commercial fields. Soil testing before seeding was completed. Fertilizer was applied pre-plant and at seeding using recommendations based on yield goal for the companion oat crop, 150 bu/ac oat, high for the long-term provincial crop average of about 80 bu/ac, yet achievable in the northeast Saskatchewan region. Both crops were planted at rates and depths advised by the seed suppliers, and there were no technical issues encountered during the planting operation. Control of the first flush of weeds was accomplished using nonselective herbicide (glyphosate) applied before emergence. Subsequent weed control methods differed from commercial fields in that manual rogueing was done instead of application of herbicides. Timing and method of harvest was managed similar to commercial fields. Mimicking common practices for forage seed growers, after the oat harvest in 2022, the oat straw and was removed by being cut with a swather, baled and removed from the field site.

9.1 Environmental conditions

Forage seed production tends to be concentrated in regions that receive ample moisture, particularly at seeding time. This was indeed the situation for 2022 in northeast Saskatchewan. Melfort received approximately 280 mm (about 11 inches) of rainfall from May to October (see Table A.4). Approximately 170 mm (about 60%) of precipitation was received as May and June rainfall.

The average growing season air temperature was 13.6°C, with slightly cooler spring daily temperature conditions (0.8°C less in May 2022) compared to the long-term average. There was no severe frost in either spring or late summer. The second part of the growing season, July-October, was characterized by warmer-than-average temperatures and lower-than-average precipitation. The greatest deviation from the long-term average daily mean temperature from July-October occurred in September which was 2.9°C warmer than usual. The driest month compared to the long-term average was July which received 41.8-mm less precipitation than the long-term monthly total. The influence of the July-September period being warmer and dryer than the long-term average led to the growing season (May-October) being 1.1°C warmer than the long-term average and receiving 11.1-mm less precipitation than the long-term average. Furthermore, from Table A.4, in 2022, there is evidence of a shift in the timing of the rain. Compared to the long-term average of 97 mm (or 33% precipitation) that would typically be available for crop growth in the first two months, in 2022, 60% of growing season precipitation was received during the early stages of crop emergence and development, coinciding with cool temperatures.

Based on the results for environmental conditions at Melfort in 2022, and also considering the context of 2021 field conditions for the other two ADOPT projects planted at Redvers (southeast Saskatchewan) and Prince Albert (north central Saskatchewan), the environmental conditions are crucial variables for the successful establishment and growing season development of two crops grown simultaneously. In 2022, the ecological conditions at Melfort supported the crop growth potential for both intercrops. Similar results were reported from Redvers ADOPT 20200535 in 2021. The reduced precipitation and higher temperatures at Prince Albert in 2021 did not support the oat companion crop's crop growth and yield potential.[5]

9.2 Agronomic performance

Agronomic data were analyzed by ANOVA using Statistix 10 software. Comparisons were completed between treatments, oat placement, and oat seeding rates. However, due to the experimental design, the interaction between oat placement and seeding rate could not be explicitly examined. Multiple comparisons were determined by Tukey's HSD method. Significance was determined at $p<0.05$. Plant establishment and early growth are reported as plant density per square meter based on plant count data collected for both crops on June 20. As shown in Table 2, there were significant differences in oat plant density across all treatments. There were no significant differences for PRG.

[5] See also the interim report for ADOPT 20200535 where oat and perennial ryegrass were intercropped at Redvers. Above-average spring (May and June) precipitation of 137 mm (48% of total growing season precipitation May to October) was recorded for southeast Saskatchewan in 2021 and oat yields were above the provincial average (average over all treatments and control monocrop oat of 65 bu/ac). May 2021 temperatures at Redvers were similar to Melfort in 2022, although June was much hotter. In comparison, in Prince Albert 2021 where ADOPT 2020536 was planted, 114 mm rainfall (or 63% for the total growing season) came in May and June but temperatures were far above average and total growing season precipitation was about 25% below the long-term average of 248 mm and the oat yield in the intercrop combination was low (average over all treatments and control monocrop oat of 26 bu/ac).

Table 2: Plant establishment of intercropped oat and perennial ryegrass, Melfort, June 2022 [1,2]

Placement	Seeding rate	Plant Density (plants/m^2)	
	Oat	Oat	Perennial ryegrass
Oat as sideband and deeper than perennial ryegrass	0.25X	53 e	42 a
	0.5X	129 cd	56 a
	0.75X	163 abc	41 a
	1.0X	197 ab	51 a
Oat same row as perennial ryegrass	0.25X	77 de	36 a
	0.5X	147 bc	29 a
	0.75X	178 abc	32 a
	1.0X	217 a	24 a
Monocrop perennial ryegrass[3]	0 X	-	46 a
Monocrop oat[3]	1.0X	208 a	-
Grand Mean		152	40
Coefficient of Variation (%)		16	62.3
p-value		<0.001	0.67

1. Plant density was determined 26 days after planting by counting two 1-m sections of crop row in both the front and back of each plot. This provided a total of four 1-m areas per plot and the average value calculated as representative of the plot.
2. Letters indicate significant differences between treatments ($p<0.05$).
3. Seeding rate perennial ryegrass variety CE-1 = 8 lbs/ac. Seeding rate oat variety CDC Arborg 1.0X =128 lbs/ac (0.25X 32 lbs/ac, 0.5X 64 lbs/ac, 0.75X 96 lbs/ac)

When analyzed for the effects of oat placement over all four seeding rates, and the impact of oat seeding rate over both sideband and same row placement, we can glean additional information presented in Tables 3 and 4. Figures 1 and 2 illustrate the differences, using a log scale to visualize the smaller values more easily on a chart. There were no significant differences ($p<0.05$) in oat plant density based on oat seed placement (Table 3), yet there were highly significant differences ($p<0.001$) based on oat seeding rate (Table 4). The highest oat plant density was 207 plants/m2 at the 1.0X rate (128 lbs/ac), decreasing by 17% to 171 plants/m2 at 0.75X (96 lbs/ac), 138 plants/m2 at 0.5X (64 lbs/ac) The opposite effect was observed for PRG. Placement of the companion crop significantly impacted PRG plant density - side-band oat had greater PRG density than when sown in same-row oat, 47 PRG plants/m2 and 30 PRG plants/m2, respectively (Table 3). Oat seeding rate did not have a significant effect on PRG plant density. However, the high C.V. of 66% suggests substantive variation and therefore less predictive power of the observation (Table 4). Figures 1 and 2 illustrate the differences, using a log scale to visualize the smaller values more easily on a chart.

Table 3: Seed placement effect on plant establishment intercropped oat and perennial ryegrass, Melfort, June 2022[1,2]

Placement	Plant Density (plants/m^2)	
	Oat	Perennial ryegrass
Oat as sideband and deeper than	165 a	47 a
Oat same row as perennial ryegrass	136 a	30 b
Grand Mean	151	39
Coefficient of Variation (%)	40	60
p-value	0.15	0.04

1. Establishment (plant density at 26 days after planting) was measured by counting two 1-m sections of crop row in both the front and back of each plot. This provided a total of four 1-m areas per plot, the calculated average value representing the plot.
2. Letters indicate significant differences between treatments (p<0.05).

Table 4: Seeding rate effect on plant establishment of intercropped oat and perennial ryegrass, Melfort, 2022[1,2]

Seeding rate	Plant Density (plants/m^2)	
Oat[3]	Oat	Perennial ryegrass
0.25X	65 c	44 a
0.5X	138 b	42 a
0.75X	171 b	41 a
1.0X	207 a	52 a
Grand Mean	145	39
Coefficient of Variation (%)	16.6	66.6
p-value	<0.001	0.97

1. Establishment (plant density at 26 days after planting) was measured by counting two 1-m sections of crop row in both the front and back of each plot. This provided a total of four 1-m areas per plot, the calculated average value representing the plot.
2. Letters indicate significant differences between treatments (p<0.05).
3. Seeding rate oat variety CDC Arborg 1.0X =128 lbs/ac (0.25X 32 lbs/ac, 0.5X 64 lbs/ac, 0.75X 96 lbs/ac). Seeding rate perennial ryegrass variety CE-1 = 8 lbs/ac

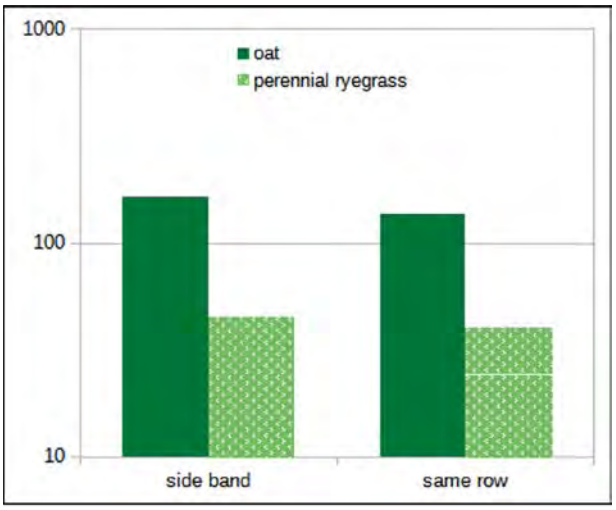

Figure 1: Seed placement effect on plant establishment of intercropped oat and perennial ryegrass, Melfort, June 2022

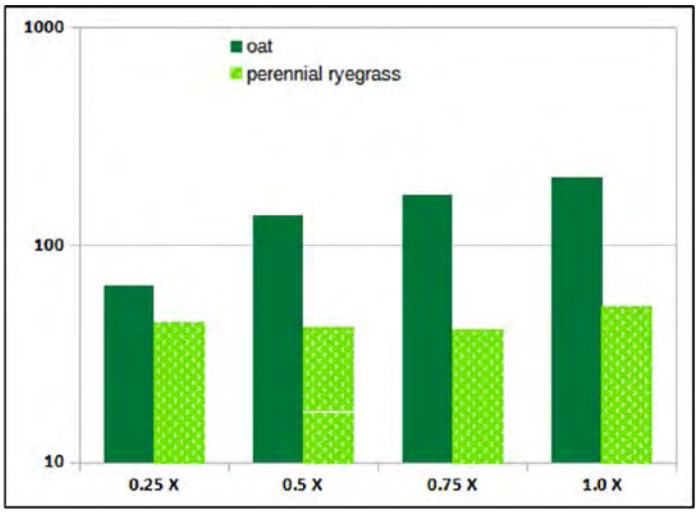

Figure 2: Seeding rate effect on plant establishment of intercropped oat and perennial ryegrass, Melfort, June 2022

Crop growth is reported as plant biomass. Oat, perennial ryegrass, and weedy species were cut separately from each plot at the oat swathing stage (kernel moisture ~30-36%) and dried at ambient temperatures. Dry weight was recorded and reported as grams per m^2 (g/m^2). There were no significant differences ($p<0.05$) in oat or weed biomass when examined across all treatments (Table 5). Highly significant ($p<0.001$) differences are observed for PRG biomass when compared over all treatments, the statistical significance influenced by the high biomass of the PRG monocrop. Among all nine treatments containing PRG, PRG biomass ranged from 0 g/m^2 (sideband 1.0X, same row 0.75X and 1.0X) to 124 g/m^2 (PRG monocrop).

Table 5: Plant biomass of intercropped oat and perennial ryegrass, Melfort, August 2022 [1,2]

Placement	Seeding	Plant Biomass (grams/m^2)		
	Oat	Oat	Perennial ryegrass	Weeds
Oat as sideband and deeper than perennial ryegrass	0.25X	1859.2 a	4.1 b	102.3 a
	0.5X	2177.0 a	3.5 b	36.1 a
	0.75X	2142.2 a	1.0 b	64.8 a
	1.0X	2201.6 a	0.0 b	15.2 a
Oat same row as perennial ryegrass	0.25X	2050.8 a	2.7 b	74.3 a
	0.5X	2306.8 a	0.9 b	18.1 a
	0.75X	2095.8 a	0.0 b	61.6 a
	1.0X	2174.8 a	0.0 b	30.1 a
Monocrop perennial[3]	0 X	-	124.0 a	130.2 a
Monocrop oat[3]	1.0X	2067.8 a	-	39.3 a
Grand Mean		2119.6	15.1	57.2
CV (%)		11.4	219.2	87.2
p-value		0.42	<0.001	0.05

1. Plant biomass was determined at the oat swathing stage, with kernel moisture ~30-36%.

2. Letters indicate significant differences between treatments ($p<0.05$).

3. Seeding rate oat variety CDC Arborg 1.0X =128 lbs/ac (0.25X 32 lbs/ac, 0.5X 64 lbs/ac, 0.75X 96 lbs/ac). Seeding rate perennial ryegrass variety CE-1 = 8 lbs/ac

The effect of seed placement and seeding rate are reported in Tables 6 and 7. Oat biomass was not affected by either seed placement (Table 6) or oat seeding rate (Table 7). Significant differences for weed biomass are reported based on oat seeding rate. While differences are noted for PRG, the p-value 0.08 is slightly greater than the 95% probability ($p<0.05$) of detecting a real difference due to oat seeding rate. Figures 3 and 4 illustrate the differences, using a log scale.

Table 6: Seed placement effect on plant biomass of intercropped oat and perennial ryegrass, Melfort, August 2022[1,2]

Placement	Plant Biomass (g/m^2)		
	Oat	Perennial ryegrass	Weeds
Oat as sideband and deeper	2095.0 a	2.2 a	54.6 a
Oat same row as perennial	2139.2 a	1.5 a	44.7 a
Grand Mean	2117.2	1.5	49.6
Coefficient of Variation (%)	11.7	195.0	106.4
p-value	0.60	0.24	0.58

1. Plant biomass was determined at the oat swathing stage, kernel moisture ~30-36%. 2. Letters indicate significant differences between treatments ($p<0.05$).

Table 7 Seeding rate effect on plant biomass of intercropped oat and perennial ryegrass, Melfort, August 2022[1,2]

Seeding rate	Plant Biomass (g/m^2)		
Oat[3]	Oat	Perennial ryegrass	Weeds
0.25X	1955.0 a	3.4 a	88.3 a
0.5X	2242.0 a	1.8 ab	27.1 b
0.75X	2119.0 a	0.3 ab	63.2 ab
1.0X	2148.0 a	1.1 b	28.2 b
Grand Mean	2116.0	1.5	51.7
Coefficient of Variation (%)	10.96	181.6	91.2
p-value[2]	0.12	0.08	0.029

1. Plant biomass was determined at the oat swathing stage, with kernel moisture ~30-36%.
2. Letters indicate significant differences between treatments (p<0.05).
3. Seeding rate oat variety CDC Arborg 1.0X =128 lbs/ac (0.25X 32 lbs/ac, 0.5X 64 lbs/ac, 0.75X 96 lbs/ac). Seeding rate perennial ryegrass variety CE-1 = 8 lbs/ac

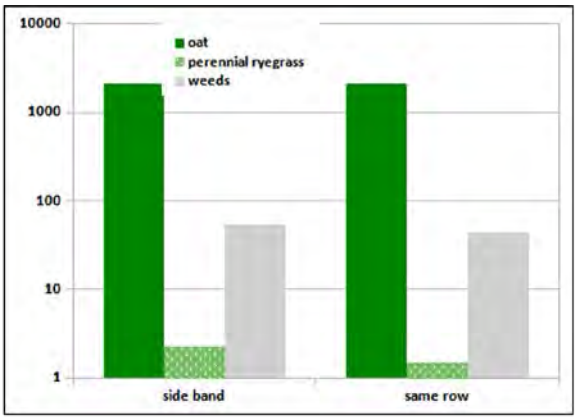

Figure 3: : Seed placement effect on plant biomass of intercropped oat, perennial ryegrass and weedy species, Melfort, August 2022

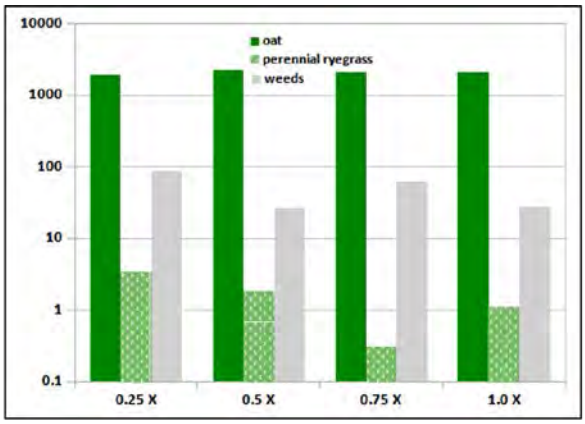

Figure 4: Seeding rate effect on plant biomass of intercropped oat, perennial ryegrass and weedy species, Melfort, August 2022

Agronomic performance of oat when intercropped with PRG is reported based on several attributes. Average plant height is determined from three measurements per plot on August 10. Lodging is ranked using a 0 to 10 scale where 0 = no lodging and 10 = full lodged on ground as observed in a plot at harvest time and based on the percentage of the plot area experiencing lodging. Maturity is ranked based on the number of days between seeding to when the majority of oat plants in the plot reached the hard dough stage (Zadoks 87). Oat seed yield for each plot was measured on the Wintersteiger Quantum plot combine on September 7 and reported on the basis of 10.2% moisture content. Seed weight was determined on a per plot basis by measuring the weight of 500 seeds and then multiplying it by two.

As reported in Table 8 below, there were significant differences in the plant height across all nine treatments (p<0.05). Heights ranged from 109-cm (sideband oat 1.0X) to 116-cm (sideband oat 0.25X). Side-banded oat at 1.0X (109-cm) and 0.75X (110-cm) seeding rates were significantly

shorter than side-banded oat at a 0.25X seeding rate. Plant height was the only agronomic attribute evaluated for which there were significant differences over all treatments.

There were no significant differences ($p<0.05$) in oat lodging across the nine treatments containing oat (Table 8). With a grand mean of 2.0 out of a ten-point scale for lodging across the nine treatments, the severity of lodging was relatively low in 2022. There were no significant differences ($p<0.05$) in oat days to maturity (DTM) across the nine treatments, ranging from 98 days at sideband placement and 0.25X, to 91 DTM at highest rate 1.0X. When examining grain (seed) yield, there were no significant differences across the nine treatments containing oat and similarly, no significant differences for seed weight ($p<0.05$). With a grand mean of 5325 kg/ha (140 bu/ac) intercropping oat with PRG, did not significantly impact seed yield compared to monocrop oat (5195 kg/ha, 136 bu/ac).. Seed placement and seeding rate were analyzed separately and reported in Tables 9 and 10, respectively.

Of the five agronomic attributes assessed, no significant differences were revealed for oat placement (Table 9) – neither oat-placed side band relative to the PRG intercrop, nor oat seeded in the same row as PRG intercrop were statistically different for plant height, lodging, seed yield or weight. Furthermore, for assessing agronomic performance, the coefficient of variation is reasonably low at < 10%, giving confidence that the trial was of sufficient quality to detect differences due to treatment effect rather than random chance. The exception is lodging, a subjective ranking rather than a direct quantitative measurement. With a grand mean of 5324 kg/ha (140 bu/ac) comparing seed placement, oat seed placed either as a sideband yielded 5344 kg/ha (140 bu/ac) or in the same row with PRG (5305 kg/ha, 139 bu/ac), did not significantly impact seed yield when compared to monocrop oat (5195 kg/ha, 136 bu/ac).

Table 8 Agronomic performance of oat when intercropped with perennial ryegrass, Melfort, 2022[1]

Placement	Seeding rate (lbs/ac)	Plant Height (cm)	Lodging (0-10)	Maturity (days)	Seed yield (kg/ha)	Seed yield (bu/ac)	Seed weight (g/1000 seeds)
Oat as sideband and deeper than perennial ryegrass	0.25X	116 a	0.25 a	98 a	4951 a	130 a	37.4 a
	0.5X	112 ab	0.50 a	96 a	5442 a	143 a	36.8 a
	0.75X	110 b	3.00 a	94 a	5346 a	140 a	36.8 a
	1.0X	109 b	2.25 a	91 a	5638 a	148 a	37.4 a
Oat same row as perennial ryegrass	0.25X	114 ab	0.25 a	97 a	5263 a	138 a	36.8 a
	0.5X	111 ab	2.25 a	94 a	5366 a	141 a	37.0 a
	0.75X6	115 ab	2.00 a	94 a	5277 a	138 a	37.5 a
	1.0X	110 ab	3.50 a	93 a	5422 a	142 a	37.8 a
Monocrop oat[2]	1.0X	111 ab	3.75 a	93 a	5195 a	136 a	36.5 a
Grand Mean		112	1.97	94	5322	140	37.1
CV (%)		2	106.39	3	8	8	2.7
p-value[2]		0.01	0.15	0.05	0.68	0.68	0.69

1. Letters indicate significant differences between treatments ($p<0.05$).

2. Seeding rate oat variety CDC Arborg 1.0X =128 lbs/ac (0.25X 32 lbs/ac, 0.5X 64 lbs/ac, 0.75X 96 lbs/ac). Seeding rate perennial ryegrass variety CE-1 = 8 lbs/ac.

Seeding rates influenced the agronomic performance of the oat crop (Table 10). Plant height was significantly ($p<0.05$) influenced by oat seeding rate - higher oat seeding rates produced shorter oat plants. Plant height ranged from 110 cm (128 lb/ac or 1.0X seeding rate) which was significantly shorter compared to 115 cm recorded for the 32 lbs/ac (0.25X) oat seeding rate. Similarly, significant differences ($p<0.05$) are reported for maturity. Higher oat seeding rates reduced the days to maturity with a 1.0X rate maturing in 92 days compared to 97 days with the 0.25X oat seeding rate. Lodging followed the same trend with significantly more lodging reported at the highest seeding rate and the lowest percentage of lodging reported at the lowest seeding rate, with values of 3.2 (high seeding rate) and 0.3 (lowest seeding rate).

Yield and seed weight are important indicators of overall agronomic performance. As reported in Table 10, the four different seeding rates of oat planted at the same time as PRG did not have a significant effect on either oat seed yield or seed weight (g/1000 seeds). When comparing the effect of oat seeding rates, oat planted at the lowest rate (0.25X or 32 lbs/ac) with PRG yielded 5107 kg/ha (134 bu/ac) versus planting oat at the highest rate (1.0X or 128 lbs/ac) with PRG which produced oat yields of 5419 kg/ha (142 bu/ac), demonstrating that oat seeding rate did not significantly impact seed yield when compared to monocrop oat (5195 kg/ha, 136 bu/ac), see Table 8.

Table 9: Seed placement effect on agronomic performance of the companion crop oat, when intercropped with perennial ryegrass, Melfort, 2022[1]

Placement	Plant Height	Lodging	Maturity	Seed Yield		Seed Weight
	(cm)	(0-10)	(days)	(kg/ha)	(bu/ac)	(g/1000 s)
Oat as sideband and	112 a	1.5 a	95 a	5344 a	140 a	37.1 a
Oat same row as perennial ryegrass	112 a	2.4 a	94 a	5305 a	139 a	37.1 a
Grand Mean	112	1.9	94	5324	140	37.1
CV (%)	3	117.5	3	8	8	2.7
p-value	0.62	0.27	0.58	0.79	0.79	0.96

1.Letters indicate significant differences between treatments ($p<0.05$).

Table 10 Seeding rate effect on agronomic performance of the companion crop oat, when intercropped with perennial ryegrass, Melfort, 2022[1,2]

Seeding rate[2]	Plant Height	Lodging	Maturity	Seed Yield		Seed Weight
	(cm)	(0-10)	(days)	(kg/ha)	(bu/ac)	(g/1000 s)
0.25X	115 a	0.3 b	97 a	5107 a	134 a	37.1 a
0.5X	112 ab	1.4 ab	95 ab	5404 a	142 a	36.9 a
0.75X	112 ab	2.5 ab	94 ab	5311 a	139 a	37.1 a
1.0X	110 b	3.2 a	92 b	5419 a	142 a	37.2 a
Grand Mean	112	1.8	95	5310	139	37.1
CV (%)	2.57	111.1	2.83	8	8	2.7
p-value	0.0092	0.022	0.0023	0.43	0.43	0.95

1.Letters indicate significant differences between treatments ($p<0.05$).

2.Seeding rate perennial ryegrass variety CE-1 = 8 lbs/ac. Seeding rate oat variety CDC Arborg 1.0X =128 lbs/ac (0.25X 32 lbs/ac, 0.5X 64 lbs/ac, 0.75X 96 lbs/ac)

9.3 Overwintering Assessment and Nutrient Availability

For good winter survival, PRG plants should be relatively small – about 4 to 8 tiller) going into winter and a six-inch stubble height helps trap snow and insulates the crown throughout the winter (Cattani, 2007). Information about the amount of growth of the PRG plants going into winter were collected using multispectral aerial survey mapping. Drone imagery was done on October 20, 2022, using a DJI Matrice 200 V2 UAV platform and a MicaSense RedEdge-MX multispectral sensor. Images were recorded at an altitude of 15-m above ground level and a speed of 0.7m/s. Normalized Difference Vegetation Index (NDVI) data is presented in Table 11.[6] Average NDVI ranged from 0.027 (oat 1.0X sideband) to 0.18 (PRG monocrop). The plot average NDVI for the PRG monocrop was highly significantly (<0.001) greater than the other nine treatments. As noted by the drone pilot, the swathing and bailing of the oat filler areas from the trial area reduced the height of the oat stubble compared to a commercial field. This may need to be considered when examining the winter survival of PRG.

Table 11 Perennial ryegrass growth and fall soil nutrient supply rates by PRS probe ® analysis for perennial ryegrass plots grown for seed production in 2023 and established under oat varying by oat seed placement and oat seeding rate, Melfort, October 2022[1,2]

Placement	Seeding rate oat	NDVI	N	P	K	S	pH
Oat as sideband and deeper than perennial ryegrass	0.25X	0.045 a	58	6	49	94	6.14
	0.5X	0.039 a	38	8	41	57	6.18
	0.75X	0.035 a	56	5	54	52	6.05
	1.0X	0.027 a	66	8	49	64	6.05
Oat same row as perennial ryegrass	0.25X	0.043 a	91	6	39	88	5.98
	0.5X	0.036 a	73	7	40	51	5.98
	0.75X	0.04 a	80	5	41	53	6
	1.0X	0.045 a	65	8	54	77	6.03
Monocrop perennial ryegrass[3]		0.18 b	268	5	49	69	5.78
Monocrop oat[3]		0.039 a	69	10	51	61	5.99
Grand Mean		0.1					
CV (%)		42.7					
p-value		<0.001					

1.Imagery of overwintering PRG plant population is measured by Normalized Difference Vegetation Index (NDVI). Supply rate by nutrient is listed in micro grams/10cm2/burial length of the PRS probe® 2. Letters indicate significant differences between treatments (p<0.05). 3. Seeding rate perennial ryegrass variety CE-1 = 8 lbs/ac. Seeding rate oat variety CDC Arborg 1.0X =128 lbs/ac (0.25X 32 lbs/ac, 0.5X 64 lbs/ac, 0.75X 96 lbs/ac)

[6] Healthy vegetation (left) absorbs most of the visible light that hits it and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation (right) reflects more visible light and less near-infrared light. Vegetation Indices employ this difference formula to quantify the density of plant growth on the Earth — near-infrared radiation minus visible radiation divided by near-infrared radiation plus visible radiation. The result of this formula is called the Normalized Difference Vegetation Index (NDVI). Written mathematically, the formula is: NDVI = (NIR — VIS)/(NIR + VIS). Calculations of NDVI ranges from minus one (-1) to plus one (+1). In absence of green leaves, NDVI would have s a value close to zero. A zero means no vegetation. An NDVI value close to +1 (0.8 - 0.9) indicates the highest possible density of green leaves. Source: Earth Observatory, part of the EOS Project Science Office at NASA Goddard Space Flight Center. August 2020. NDVI explanation

Figures 5 and 6 illustrate the standardized differences for the effects of oat seed placement and oat seeding rate on PRG vegetative growth going into winter. A log scale is used to visualize the smaller values more easily on the chart. The data values are reported in Appendix Tables A.5 and A.6.

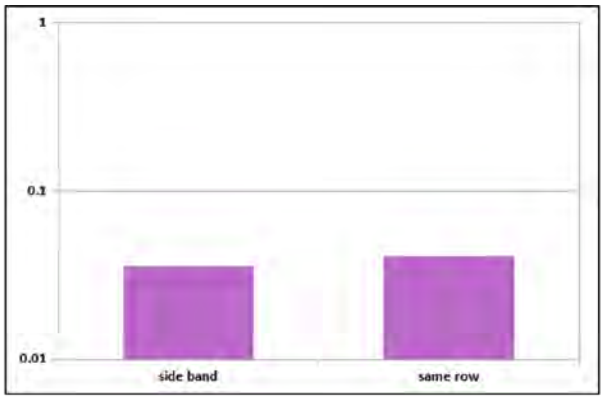

Figure 5: Seed placement effect on vegetative cover (NDVI) oat and perennial ryegrass plot means, Melfort, October 2022

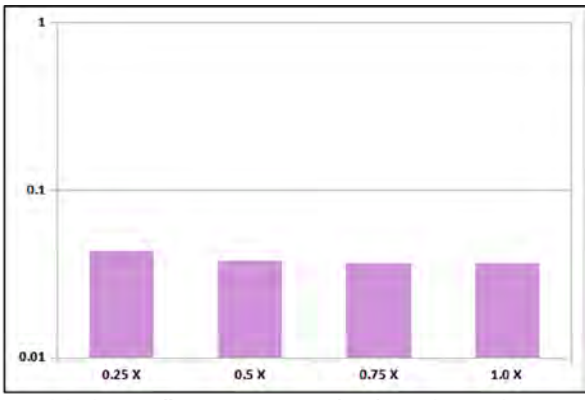

Figure 6: Seeding rate effect on vegetative cover (NDVI) oat and perennial ryegrass plot means, Melfort, October 2022.

Fall soil samples were collected to assess nutrient removal based on oat seed placement and seeding rate. One sample was prepared for each treatment by creating a composite from samples collected from all four replicates of each treatment. One depth was collected from 0-6 inches. Industry sources report that soil test calibration curves are not available in western Canada to accurately recommend fertilizer application rates for forage seed crops, especially fertilizer recommendations after the harvest of the companion crop. 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 PRG to overwinter and continue growth in the spring. Samples were submitted to Western Ag in Saskatoon and processed using PRS probe ® analysis and PRS Cropcaster® service. Using these results, individual treatments are fertilized based on the 4-replicate average value of plant nutrient availability. Canary seed fertilizer recommendations as used a proxy for PRG.

Soil test results are presented in Table 11 (above). Nutrient supply rate is expressed as micrograms/10cm2/burial length of the PRS probe. The nitrogen (N) supply rate (combined NO_{3-} and NH_{4+} supply rates) ranged from 38 (sideband 0.5X oat) to 268 (PRG monocrop). The standard supply rate for nitrogen for the perennial ryegrass treatment was higher than the remaining treatments with the next highest value being 91 (seed row 0.25X oat). The higher fall N supply rate in the PRG monocrop is likely due to no oat crop being grown there in 2022. The phosphorus (P) supply rate had an average of 7 across the ten treatments and ranged from 5 (sideband 0.75X oat, seed row 0.75X oat, PRG monocrop) to 10 (oat monocrop). The potassium (K) supply rate had an average of 47 across the ten treatments and ranged from 39 (seed row 0.25X oat) to 54 (sideband 0.75X oat, seed row 1.0X oat). The sulfur (S) supply rate had an average of 66 across the ten treatments and ranged from 51 (seed row 0.5X oat) to 94 (sideband 0.25X oat).

Nitrogen supply by seed placement ranged from 55 when the companion crop oat is placed sideband and deeper than the PRG crop, to 77 for oat planted in the same row as PRG. Nitrogen supply by seeding rate ranged from 56 (0.5X oat) to 74 (0.25X oat). Phosphorus supply by seeding rate ranged from 5 (0.75X oat) to 8 (0.5X oat and 1.0X oat). Side banded and seed-placed oat treatments had the same P supply rate of 7. Potassium supply by seeding rate ranged from 40 (0.5X oat) to 52 (1.0X oat). Side-banded oat had a K supply rate of 48 while seed-placed oat treatments had a K supply rate of 43. Sulfur supply by seeding rate ranged from 52 (0.75X oat) to 91 (0.25X oat) Side banded, and seed-placed oat treatments had the same S supply rate of 67. Figures 7 and 8 illustrate the standardized differences in the effects of oat seed placement and oat seeding rate on N, P, K, and S availability. A log scale is used to visualize the smaller values more easily on the chart. The data values are reported in Appendix Tables A.7 and A.8. Statistical analysis was not done on the nutrient availability due to the budget restrictions for testing 40 plots, therefore the PRS analysis is based on 9 samples, i.e., no replication to accurately discern plot-by-plot variation or treatment effects.

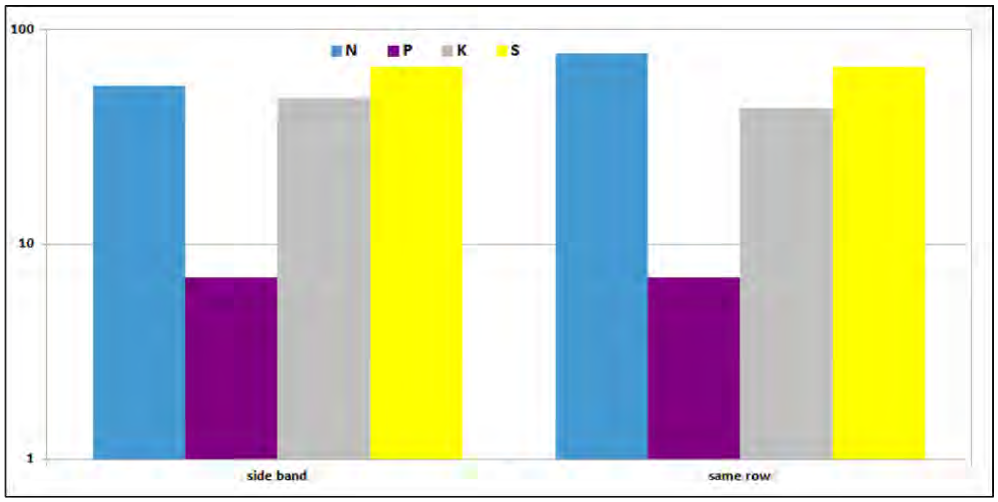

Figure 7: Seed placement effect on plant nutrient availability in oat-perennial ryegrass intercrop, Melfort, October 2022

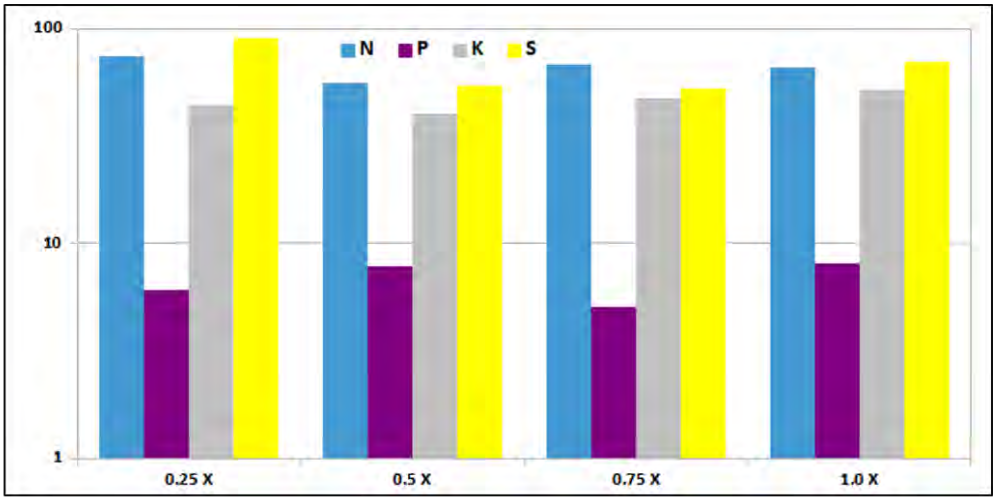

Figure 8: Seeding rate effect on plant nutrient availability in oat-perennial ryegrass intercrop, Melfort, October 2022

9.4 The economic feasibility of using oat as a companion crop to establish perennial ryegrass

Economic analysis, currently in process, will compare the marginal economic return by treatment oat seed placement, and oat seeding rate in the first year of this two-year project.

Costs are derived from quotes from agricultural retailers near Melfort and the Crop Planning Guide, Saskatchewan Ministry of Agriculture. The following assumptions were made when using the 2022 publication.

1. We used local area (industry) values for seed, fertilizer, and herbicide.
2. No seed treatment was used (2022 Crop Planning Guide adjusted by -$1.04/ac).
3. No fungicide was applied (2022 Crop Planning Guide adjusted by -$19.35/ac).
4. Insecticide was applied as aphids were an issue at the Melfort Research Farm in 2022 (2022 Crop Planning Guide by +$21.89/ac).
5. Crop insurance was purchased (2022 Crop Planning Guide adjusted by +$8.11/ac).
6. Hail insurance was purchased (2022 Crop Planning Guide adjusted by +$12.25/ac).
7. All other variable and fixed costs from the Black soil zone in the 2022 Crop Planning Guide (Saskatchewan Ministry of Agriculture) were added into the total costs amount.

10.Interim Conclusions

In year one of our demonstration, we found that establishing perennial ryegrass for seed production using oat as a companion crop does not have a negative impact on oat seed yield.

As a recommendation based on 2022 results and the oat variety CDC Arborg, an oat seeding rate of 0.5X (68 lb/ac) placed sideband may be favourable to maintain oat grain yield, reduce lodging, not significantly delay maturity, and prevent excess nitrogen available in the fall that could be vulnerable to loss. However, a year with different moisture and temperature conditions may impact these results. The success of this two-year rotation will be confirmed in year two with the overwintering and seed production of the PRG

Oat and perennial grass : (above) June 2022 early emergence (right) August 2022 oat near swathing maturity. Source: NARF photos, 2022.

The agronomic data gathered and analyzed from our demonstration supports the feasibility of intercropping an annual cereal crop, oat, with a short-lived perennial forage seed crop, perennial ryegrass PRG. Based on the field demonstration site at Melfort SK, in 2022 we found:

- no significant differences in oat seed yield or thousand kernel weight (TKW grams per 1000 seeds)) were observed at a probability level of $p<0.05$, when comparing the nine treatments assessing oat seed placement and planting rates.
- the data may be viewed as a reliable estimate of agronomic performance of the companion crop, specifically oat seed yield with a coefficient of variation (C.V.) of <10%.
- The top four intercrop combinations of milling oat CDC Arborg co-planted with turf-type CE-1 perennial ryegrass are:
  - oat sideband, 1.0X rate (128 lb/acre) 148 bu/ac TKW 37.4 g
  - oat sideband, 0.5X rate (64 lb/acre) 143 bu/ac TKW 36.8 g
  - oat in same seed row, 1.0X rate 142 bu/ac TKW 37.8 g
  - oat in same seed row, 0.5X rate 141 bu/ac TKW 37.0 g

Over all the treatments, intercropping did not have a significant effect on oat maturity. Days to maturity ranged from 91 days (oat sideband 1.0X) to 98 days (oat sideband 0.25X).

Oat placement led to significant differences ($p<0.05$) in the early establishment of the perennial ryegrass as measured by plant density measured 26 days after planting.

- 47 perennial ryegrass plants/m2 when oat placed as sideband relative to perennial ryegrass
- 30 perennial ryegrass plants/m^2 when oat seeded in the same row
- there were no significant differences in plant height, lodging, maturity, seed yield or seed weight based on oat sown in the same row or as sideband relative to the perennial ryegrass.

Oat seeding rates led to significant differences in oat plant height, lodging and days to maturity (DTM). Biomass of weeds and the perennial ryegrass were also affected.

- oat 1.0X (128 lb/ac) 110 cm height 3.2 lodging 92 DTM
- oat 0.25X (32 lbs/ac) 115 cm height, 0.3 lodging 97 DTM

- oat 1.0X: biomass weeds 28.2 g/m^2, perennial ryegrass 1.1 g/m^2
- oat 0.25X: biomass weeds 88.3 g/m^2, perennial ryegrass 3.4 g/m^2
- there were no significant differences in seed yield or seed weight based on the four seeding rates: 0.25X (32 lbs/ac), 0.5X (64 lbs.ac), 0.75X (96 lbs/ac) or 1.0X (128 lbs/ac).

Drone imagery technology and Normalized Difference Vegetation Index (NDVI) based data collection and analysis was a useful, quantitative measure of plant growth as the different treatments move into their dormant (winter) growth phase. The post-oat-harvest imagery revealed that the PRG monocrop had a significantly higher NDVI value, but there were no significant differences based on oat seeding rate or oat seed placement. NDVI values ranged from 0.027 (oat 1X sideband) to 0.18 (perennial ryegrass as monocrop).

After the harvest of the oat crop, fall 2022 soil samples from the 0 to 6-inch depth indicate that the PRG monoculture had a higher N supply rate than the other nine treatments.

When comparing oat that is sown as sideband or in the same seed row as perennial ryegrass:

- same row oat- perennial ryegrass had higher supply N (77 vs 55), lower K (43 vs 48) and similar P (7) & S (67)

When comparing oat seeding rates:

- the lowest oat rate 0.25X (32 lbs/ac) had the highest supply N (74) and S (91);
- there was no linear relationship nutrient availability for N, P, K or S from lowest to highest seeding rate; and
- the lowest available levels of K (40 and 44) coincided with the two lowest oat planting rates, both below the treatment mean value of 46 and the highest seeding rate treatments had the highest levels of K.

11.Supporting Information

Appendices

Table A.1: List of treatments demonstrating seed placement of the companion crop in relation to PRG seed and assessing the effect of four seeding rates of the companion crop.

Treatment	Seeded as Main Crop	Factor 1: Placement of companion crop (oat) in relation to forage grass perennial ryegrass (PRG)	Factor 2: Seeding rate of companion crop (oat)
1	perennial ryegrass	side band and deeper than PRG	0.25X
2	perennial ryegrass	side band and deeper than PRG	0.5X
3	perennial ryegrass	side band and deeper than PRG	0.75X
4	perennial ryegrass	side band and deeper than PRG	1.0X
5	perennial ryegrass	same row as PRG	0.25X
6	perennial ryegrass	same row as PRG	0.5X
7	perennial ryegrass	same row as PRG	0.75X
8	perennial ryegrass	same row as PRG	1.0X
9	perennial ryegrass	monocrop PRG	0X
10	oat	monocrop Oat	1.0X

Table A.2: Soil fertility determinations at the planting site, Melfort SK, May 2022.

Soil Depth	Nutrient				OM	pH	Salts
(cm)	N (lb/ac)	P (ppm)	K (ppm)	S (lb/ac)	(%)		(mmho/cm)
0-15	21	9	309	24	9.4	6.4	0.67
15-30	23			16		6.1	0.29

Soil test results derived from AgVise Laboratories based on a composite soil sample collected from the trial area.
For additional details on the methodology for soil nutrient analysis, please see Ag Vise Laboratories methods

Table A.3: Agronomic performance measurements. Melfort SK, May to November 2022.

Metric	Plant type	Timing	Measurement
Density	oat	3 weeks after seeding	counting of two 1m sections of crop row row in both the front and back of each plot
Density	perennial ryegrass		
Biomass	oat	oat swathing stage (kernel moisture ~30-36%)	plants cut within a 0.5m^2 quadrant, fresh weight recorded, samples dried ambient temperature, dry weight recorded, reported as g/m^2
Biomass	perennial ryegrass		
Biomass	weedy species		
Height	oat	August 10	per plot was measured by taking the average height from a measurement in the front, middle, and back of each plot
Lodging	*oat*	September 7	0-10 lodging rating scale based on the percentage of the plot area experiencing lodging
Maturity	oat	September 7	days between seeding to when the majority of the plot reached hard dough stage (Zadoks 87)
Seed yield	oat	September 7	5 rows of each plot harvested, weighed with a Wintersteiger Quantum combine.
	adjusted for moisture		Weight adjusted to 10.2% mc moisture
Stand before winter	perennial ryegrass	October 20	Drone imagery was collected on October 20, 2022 using a DJI Matrice 200 V2 UAV platform and a MicaSense RedEdge-MX multispectral sensor. Images were recorded at an altitude of 15-m above ground level and a speed of 0.7m/s.

Table A.4: Environmental conditions during the 2022 growing season, AAFC Melfort Research Farm

	May	June	July	August	September	October	Average /Total
	--- Mean Temperature (°C) ---						
2022	9.9	15.2	18.2	18.7	13.7	5.6	13.6
Long-term	10.7	15.9	17.5	16.8	10.8	3.3	12.5
	--- Precipitation (mm) ---						
2022	90.8	78.1	34.9	36.5	29.6	11.9	281.8
Long-term	42.9	54.3	76.7	52.4	38.7	27.9	292.9

Table A.5: Seed placement effect on normalized differential vegetative index NDVI, Melfort, October 2022[1]

Placement	NDVI (plot mean)
Oat as sideband and deeper than perennial ryegrass	0.036 a
Oat same row as perennial ryegrass	0.041 a
Grand Mean	0.039
Coefficient of Variation (%)	31.8
p-value[2]	0.3

1.NDVI measured by drone imagery.

2. Letters indicate significant differences between treatments ($p<0.05$).

Table A.6: Seeding rate effect on normalized differential vegetative index NDVI, Melfort, October 2022[1]

Seeding rate Oat[3]	NDVI (plot mean)
0.25X	0.044 a
0.5X	0.038 a
0.75X	0.037 a
1.0X	0.037 a
Grand Mean	0.039
Coefficient of Variation (%)	32.03
p-value[2]	0.6

1.NDVI measured by drone imagery.

2. Letters indicate significant differences between treatments ($p<0.05$).

3. Seeding rate oat variety CDC Arborg 1.0X =128 lbs/ac (0.25X 32 lbs/ac, 0.5X 64 lbs/ac, 0.75X 96 lbs/ac). Seeding rate perennial ryegrass variety CE-1 = 8 lbs/ac

Table A.7: Fall soil nutrient supply rates by PRS probe ® analysis for perennial ryegrass plots established under oat varying by oat seed placement, Melfort, October 2022

Placement	N	P	K	S
Oat as sideband and deeper than perennial ryegrass	55	7	48	67
Oat same row as perennial ryegrass	77	7	43	67

Table A.8: Fall soil nutrient supply rates by PRS probe ® analysis for perennial ryegrass plots established under oat varying by oat seeding rate, Melfort, October 2022

Seeding rate oat	N	P	K	S
0.25X	74	6	44	91
0.5X	56	8	40	54
0.75X	68	5	47	52
1.0X	66	8	52	70

A.9 Relative profitability assumptions

Costs that Varied between Treatments

- Oat seed costs
- Perennial ryegrass seed costs (Treatment 10 was a oat monocrop)
- Fall fertility

Assumptions When Using Costs from the 2022 Guide to Crop Protection

- We used our own values for seed, fertilizer, and herbicide
- No seed treatment was used (-1.04/ac)
- No fungicide was sprayed (-19.35/ac)
- Insecticide was sprayed (+21.89/ac): Aphids were an issue in 2022 at the Melfort Research Farm
- Crop insurance was purchased (+$8.11/ac)
- Hail insurance was purchased (+$12.25/ac)
- All other variable and fixed costs from the Black soil zone in the 2022 Crop Production Guide (Saskatchewan Ministry of Agriculture) were added into the total costs amount

A.10 Bibliography

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

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.

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

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.

Government of Saskatchewan. 2021. Crop Report. Retrieved November 28, 2021 from https://www.saskatchewan.ca/crop-report.

Government of Saskatchewan. 2022. Crop Planning Guide 2022. Available for download at SK Crop Planning Guide

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.

A.11 Acknowledgements

The Saskatchewan Forage Seed Development Commission and the project collaborators at eh Northeast Agriculture Research Foundation (NARF) would like to thank all the NARF research staff who helped make this project possible in 2022. Thank you to the seed industry agronomists and soil test providers for their guidance on the project. David MacTaggart is acknowledged for services as a drone pilot and providing statistical analysis of the NDVI data and the economic evaluations for marginal rate of return. We would also like to thank the ADOPT program funded by the Ministry of Agriculture.