2022 Annual Report
for the
Saskatchewan Ministry of Agriculture's
Agricultural Demonstration of Practices & Technologies (ADOPT) Program
Project Title: 4R Management: Right Rate and Placement for Fertilizer in Oats
Project # ADOPT20211039

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<u>Project Identification</u>

1. **Project Title:** 4R Management: Right rate and Placement for fertilizer in Oats
2. **Project Number:** ADOPT20211039

3. **Producer Group Sponsoring the Project:** Saskatchewan Oat Development Commission
4. **Project Location(s):** Melfort (RM #428), and Scott (RM #380)
5. **Project Start and End Dates (Month & Year):** March 2022 to February 1, 2023
6. **Project Contact Person & Contact Details:**

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Objectives and Rationale

7. **Project Objectives:**
The objective of the demonstration was to highlight the impact of fertilizer placement and rate on oat establishment, seed yields, and quality

8. **Project Rationale:**
Oat response to macronutrients has been investigated in previous research and has concluded that oats are responsive to additions of nitrogen and sometimes phosphorus fertilizer (Mohr et al. 2007). Increased nitrogen rates are known to increase seed yields, however high nitrogen rates have the potential to increase crop lodging and decrease test weights (Mohr et. al. 2007). A 100 bu/ac oat crop requires anywhere from 97-117lbs/ac of soil and applied nitrogen (Top Crop Manager 1999). Typical oat yields in the northeast growing region of Saskatchewan often exceed 100 bu/ac, and therefore high supplies of nitrogen are required to maximize yield potential. In contrast, while phosphorus supplementation is recommended in oats, yield responses have been less consistent and effects to quality have not been detected (Mohr et al. 2007). When evaluating phosphorus placement Miller et al. found that phosphorus fertilizer absorption in oats was increased as the distance of phosphorus placement increased from the seed by 1-inch. The only instance where more phosphorus was taken up by the plant with seed placement was during the very early growth stages (Miller et al. 1960). Phosphorus absorption was also increased in oats with increasing supply of nitrogen (Miller et al. 1960). Although, yield responses were not always found to be consistent with phosphorus supplementation, 80% of Saskatchewan soils are deficient in

phosphorus, and thus some amount of supplementation is likely to effect oat emergence and seed yields where phosphorus is limiting.

While macronutrient supplementation has been investigated in prior research, demonstration of different placement methods is lacking in oats. Karamonas et al. 2014 evaluated phosphorus rates and placement options in canola, wheat and barley and found wheat and barley were not significantly impacted by fertilizer placement; however, it is acknowledged in the report that wheat plant stands were only evaluated at one site, and thus different soil types and conditions were not compared. There was one instance throughout the duration of this study where spring wheat yields responded positively to side-banded phosphorus as compared to seed-placed (Karamonas et. al. 2014). The reasoning for this was uncertain; however, possible causes for this may be reduced plant stands from seed-placed P as plant stands were not evaluated under this occurrence, or that side-band placement allowed for better positioning for root uptake (Karamonas et. al. 2014). Mooleki et. al. 2010 compared midrow-banding and side banding of nitrogen sources in wheat, and found a tendency for wheat plant stands to decrease with side-banding as compared to midrow banding; however, targeted plant densities were met with both placements. Lower plant densities were also found under dry conditions when N was placed closer to the seed (Mooleki et al. 2010). When comparing phosphorus fertilizer placement, in all years Scott demonstrated lower average plant stands with seed placed phosphorus and lower average seed yields as compared to side-banded phosphorus (Mooleki et al. 2010). At sites with finer texture soils, such as Melfort, differences in plant stands and seed yields were relatively inconsistent and small, and when averaged across sites no significant difference in plant stands and seed yields occurred due to phosphorus placement in wheat. The greatest limitation with phosphorus placement in this study, was that very low rates of 7 and 10 kg/ha of phosphorus were tested, which diminished the likelihood of a phosphorus placement response.

Depending on drill capabilities, farmers may choose different fertilizer placements when seeding oats. In other cereal crops placing high rates of fertilizer close to the seed has proven to decrease plant stands; however, effects to plant establishment begin to diminish as seed-bed utilization(SBU) increases. Seedbed utilization is greater when nitrogen is midrow banded as compared to side-banded, as fertilizer is placed further from the seed. Furthermore, seed bed utilization is also increases when phosphorus is placed in the side-band as compared to with the seed-row. Greater seed bed utilization diminishes the risk of fertilizer burn and reduced plant emergence. Keeping plant stands high is important for weed competition, insect pressure, and preserving yield potential. This demonstration was intended to demonstrate to oat grower's different fertilizer placements at seeding and whether or not these different placements would affect plant stands, yield and/or quality of their oat crop. Rates that would be used by Saskatchewan producers will be used to simplify the design, and demonstrate whether there is any effect of placement when using typical fertilizer rates in oats within the province.

Literature Cited

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Methodology and Results

9. **Methodology:**

The demonstration was arranged as an unbalanced split-plot with four replications. The unbalanced design was selected due to seeder capabilities at the participating locations. Three factors were used which included nitrogen placement, nitrogen rate, and phosphorus placement to create a total of 12 treatments (Table 1). There were three factors within the main plot that consisted of no nitrogen, nitrogen in the midrow-band, or nitrogen in the side-band. To provide better randomization in the field, the midrow-band and no nitrogen main-plots were completely randomized within the first half of the split-plot (treatments 1-6), and the side-band treatments for nitrogen placement (treatments 7-12) were completely randomized within the second half of the split-plot. The sub-plot factors were also not consistent between the main plot groupings. For the no nitrogen main plot the subplot was no phosphorus, phosphorus in the seed-row or phosphorus in the side-band, and for the midrow-band nitrogen main plot the sub plot was a nitrogen rate of 75, 100, or 125 kg/ha of applied nitrogen. Phosphorus placement remained consistent in all the midrow-band nitrogen treatments. For the side-band nitrogen placement, there were two sub-plot factors of a nitrogen rate of 75, 100, or 125 kg/ha of applied nitrogen, with phosphorus placement in the seed-row or sideband.

Table 1. Treatments used in 4R Management: Right Rate and Placement for Fertilizer in Oats at Melfort and Scott, SK in 2022.

Treatment #	Nitrogen Placement	Nitrogen Rate (kg/ha)	Phosphorus Placement[z]
1	N/A	0	No P
2	N/A	0	Seed Row
3	N/A	0	Side-Band
4	Mid-Row	75	Seed Row
5		100	
6		125	
7	Side-Band	75	Seed Row
8		100	
9		125	
10	Side-Band	75	Side-Band
11		100	
12		125	

[z]phosphorus to be applied at 45 kg/ha of P_2O_5

The demonstration was conducted at two locations including Melfort and Scott, SK in 2022. The site at Scott is in the brown soil zone while the site at Melfort is in the black soil zone. These two locations represent different soil conditions, most notably in texture and organic matter content, while also experiencing different environmental conditions to demonstrate oat response across different environments.

Seeding equipment and crop management varied by location (Table 2). The oat variety used was CDC Arborg, which was seeded at 143kg/ha to target 350 plants/m^2. Oats were seeded into canola stubble on May 16th at Scott and May 23rd at Melfort. Weeds, insects, and disease were controlled using registered products at each participating site at the discretion of each site manager for best management practices. All fertility was applied as per treatment aside from potassium and sulphur, which were applied based on soil sample results at each site to be non yield limiting (Table 3). All plots were harvested with a plot combine on August 23rd at Scott and September 6th at Melfort.

Table 2. Agronomic information and dates of operation for 4R Management: Right Rate and Placement for Fertilizer in Oats at Melfort and Scott, SK in 2022.

Factor/Operation	Melfort	Scott
Previous Crop	Canola	Canola
Pre-Emergent Weed Control	Glyphosate 540 at 0.67L/ac May 21	Glyphosate 540 at 1L/ac and AIM at 35mL/ac on May 9
Variety	CDC Arborg	CDC Arborg
Seeding rate	143 kg/ha	143kg/ha
Seeding Date	May 23	May 16
Row Spacing (cm)	0.3048m	0.2540m
Plot size	16.5m^2	16.8m^2
Kg/ha K_2O-SO_4	11-0	11-8
Post-emergent herbicide	Prestige XC (A at 166ml/ac and B at 809mL/ac) June 28	Buctril M at 0.4L/ac June 16
Emergence Counts	June 16	June 7
Foliar fungicide	None	Caramba at 0.4L/ac July 14
Maturity	August 25-September 1	Augut 10-14
Harvest Date	September 6	August 23

Table 3. Soil sample results for 4R Management: Right Rate and Placement for Fertilizer in Oats at Melfort and Scott, SK in 2022.

Depth	NO3-N (kg/ha)	Olsen-P (ppm)	K (ppm)	S (kg/ha)	pH	Organic Matter (%)	Salts (mmho/cm)
Melfort							
0-15cm	44	13	453	36	5.8	9.5	0.35
15-30cm	34			49	6.1		0.38
Scott							
0-15cm	18	6	289	6	5.4	4.4	0.14

15-60cm	18			2	7.6		0.24

Data collection consisted of plant density, maturity, grain yield, test weights, and thousand kernel weights. Plant density was measured by counting the seedlings along two 1-meter sections of crop row per plot. The average between the two counted rows was then divided by the row spacing at each respective site to determine the plants/m^2 (PPMS). Days to maturity (DTM) was noted by recording the day the majority of plants in a plot reached the hard dough stage (Zadoks 87). This was then converted to the days that it took each plot to reach maturity since the day of seeding. Grain yield was determined at each site by weighing each harvested plot sample and converting the grams per plot to a kg/ha equivalent, while correcting for consistent moisture. Test weights (TW) were determined by weighing the grams of seed in a 0.5-litre to the nearest hundredth of a gram. Thousand kernel weight (TKW) was determined by counting and weighing a minimum of 500 seeds per plot, and converting the weight into grams per 1000 seeds. Lastly, statistical analysis was completed for each site separately using randomized complete block for treatments 1-3, factorial analysis for treatments 8-12, and split-plot analysis for treatments 4-9. All statistical analysis was completed using Statistix 10.

10. **Results:**

Environmental Conditions:

The 2022 growing season brought about above average temperatures at both sites, with below average precipitation at Scott and above average precipitation at Melfort (Table 4). At Scott average growing season temperature was 15.6 °C, which was a 0.8°C increase from the long-term average. Growing season precipitation at Scott was 186.7mm, which was 82% of the long-term average, or a deficit of 40.0mm. At Melfort, average growing season temperature was 15.2°C, which was a 0.2°C increase from the long-term average. Growing season precipitation at Melfort was 240.3mm, which was 106% of the long-term average, or a surplus of 14.0mm.

Table 4. Mean temperatures and precipitation collected from the Environment Canada Weather Station for 4R Management: Right Rate and Placement for Fertilizer in Oats at Melfort and Scott, SK from May to August 2022.

	May	June	July	August	Average/Total
		--Temperature(°C)--			
Scott 2022	10.0	15.0	18.3	18.9	15.6
Long-term^x	10.8	14.8	17.3	16.3	14.8
Melfort 2022	9.9	15.2	18.2	18.7	15.5
Long-term^x	10.7	15.9	17.5	16.8	15.2
		--Precipitation(mm)--			
Scott 2022	11.0	57.1	86.5	32.1	186.7 (82%)
Long-term^x	38.9	69.7	69.4	48.7	226.7
Melfort 2022	90.8	78.1	34.9	36.5	240.3 (106%)
Long-term^x	42.9	54.3	76.7	52.4	226.3

^{x} Long-Term Climate Normal from local Environment Canada Weather Station (1981-2010)

Plant Density (PPMS)

Plant density (PPMS) was only significant at Scott for nitrogen placement (p=0.0036), nitrogen rate (p=0.0159) and the interaction between the two factors (p=0.0401). The significant effect of nitrogen placement was that PPMS was reduced when nitrogen was side-banded as compared to when nitrogen was midrow-banded. The average difference between the placements was 29 PPMS. Melfort demonstrated a similar trend, although the result was not significant. The significant effect of nitrogen rate was that PPMS was significantly reduced at the 125kg/ha nitrogen rate as compared to the 75 kg/ha rate. PPMS was also reduced at the 100 kg/ha rate, however the difference was not significant. When the difference was significant PPMS was reduced by an average of 33 PPMS from the 75kg/ha rate to the 125 kg/ha rate. Melfort again demonstrated a similar average reduction in PPMS at the higher nitrogen rates as compared to 75 kg/ha, although the difference was not significant. The significant effect of the two-way interaction between nitrogen placement and rate at Scott was that PPMS was significantly reduced from the 75 kg/ha to the 125 kg/ha nitrogen rate when nitrogen was side-banded; however, there was no significant difference in PPMS between rates when nitrogen was midrow-banded (Figure 1).

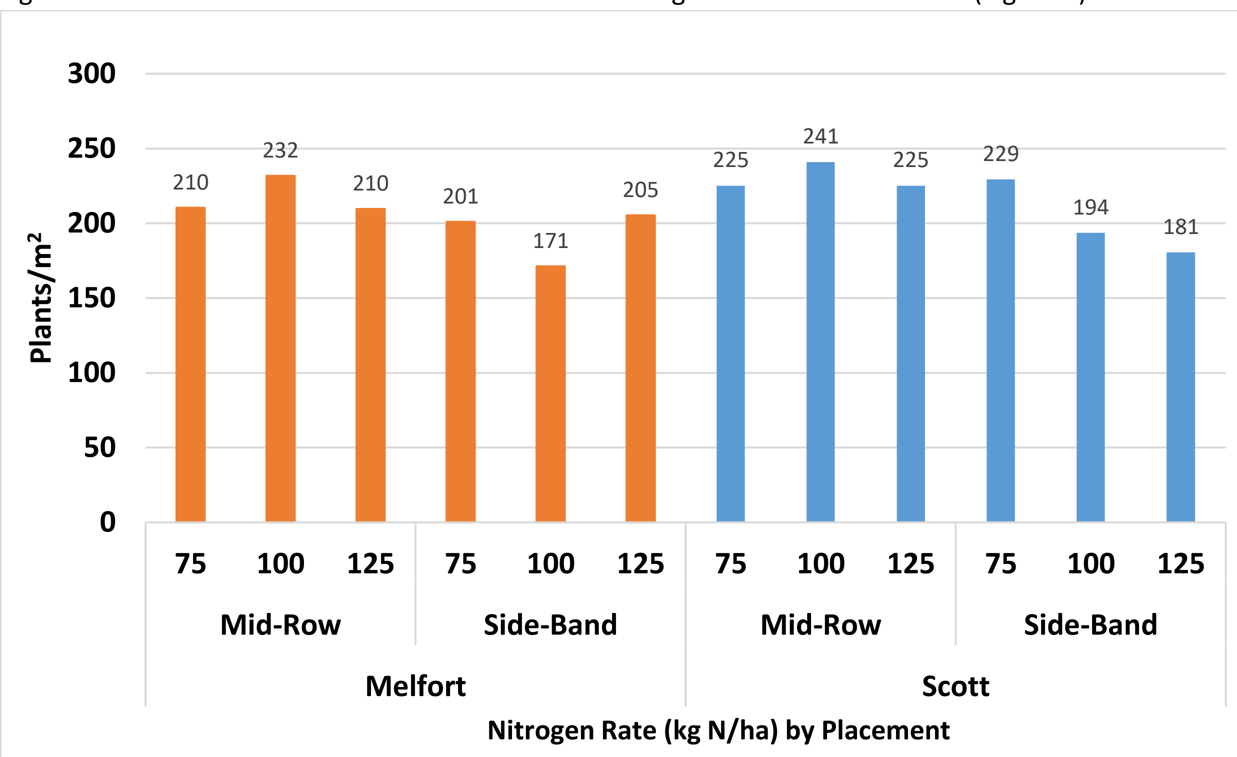

Figure 1. Treatment means for the effect of nitrogen placement and nitrogen rates on plant density (plants/m^2) for 4R Management: Right Rate and Placement for Fertilizer in Oats at Scott and Melfort, SK in 2022.

Days to Maturity (DTM)

Days to maturity (DTM) was significant at Scott for nitrogen rate ($p<0.0001$; $p=0.0121$) and nitrogen placement ($p=0.0305$). The significant effect of nitrogen rate was significant when analyzed as a factorial arrangement with phosphorus placement ($p<0.0001$) and when analyzed as a split-plot with nitrogen placement ($p=0.0121$). The effect was similar under both analyses where DTM was significantly increased at 125 kg/ha as compared to 75 kg/ha of nitrogen. The difference between the analyses was that DTM was also significantly increased at 100 kg/ha as compared to 75 kg/ha only as a result of the factorial analysis. Overall, the significant difference in DTM were very small at +0.5 days (100 kg/ha factorial), +0.9 days (125 kg/ha split-plot), and +1.3 days (125 kg/ha factorial) as compared to 75 kg/ha of applied nitrogen. The significant effect of nitrogen placement at Scott was that DTM was prolonged by 0.8 days for the side-banded nitrogen treatments as compared to the midrow-banded. At Melfort the only significant effect to DTM was an interaction between nitrogen rate and phosphorus placement ($p=0.0214$). The significant effect was that DTM was significantly increased by 1.5-1.7 days when phosphorus was placed in the seed row at 125 kg/ha of nitrogen as compared to all other treatments, aside from phosphorus in the side-band with 75 kg/ha of nitrogen. Overall, average DTM was longer at Melfort averaging 95.6-96.5 days depending on analyses as compared to Scott where average DTM ranged from 86.8-88.6 days.

Grain Yield

The only significant effect to grain yield was phosphorus at Scott ($p=0.0024$) and nitrogen placement at Melfort ($p=0.0210$). The effect of phosphorus placement at Scott was that grain yield was significantly increased when phosphorus was applied as compared to when no phosphorus was applied; however, there was no significant difference due to phosphorus placement (Figure 2; Figure 3). Average yield increases as compared to when no phosphorus was applied were 381kg/ha for seed-placed and 299 kg/ha for side-banded. At Melfort a similar trend occurred; however, the difference was not significant. At Melfort average yields were increased by 506 kg/ha when phosphorus was seed-placed as compared to when no phosphorus was applied. Grain yield between the control and side-banded phosphorus treatment were much less at Melfort with an average increase of 20kg/ha when phosphorus was side-banded as compared to the control. The significant effect of nitrogen placement at Melfort was that yield was significantly increased when nitrogen was side-banded as compared to midrow-banded (Figure 3). The average increase in yield was 328 kg/ha. Scott demonstrated a similar trend with no statistical significance; however, the difference was much smaller at an average yield increase of 45 kg/ha when nitrogen was side-banded as compared to midrow-banded. Overall, oat yields were much greater at Melfort averaging 6377-7644 kg/ha (170-200 bu/ac) as compared to Scott where average yield ranged from 2820-3227 kg/ha (74-85 bu/ac), depending on the treatments used within the analyses.

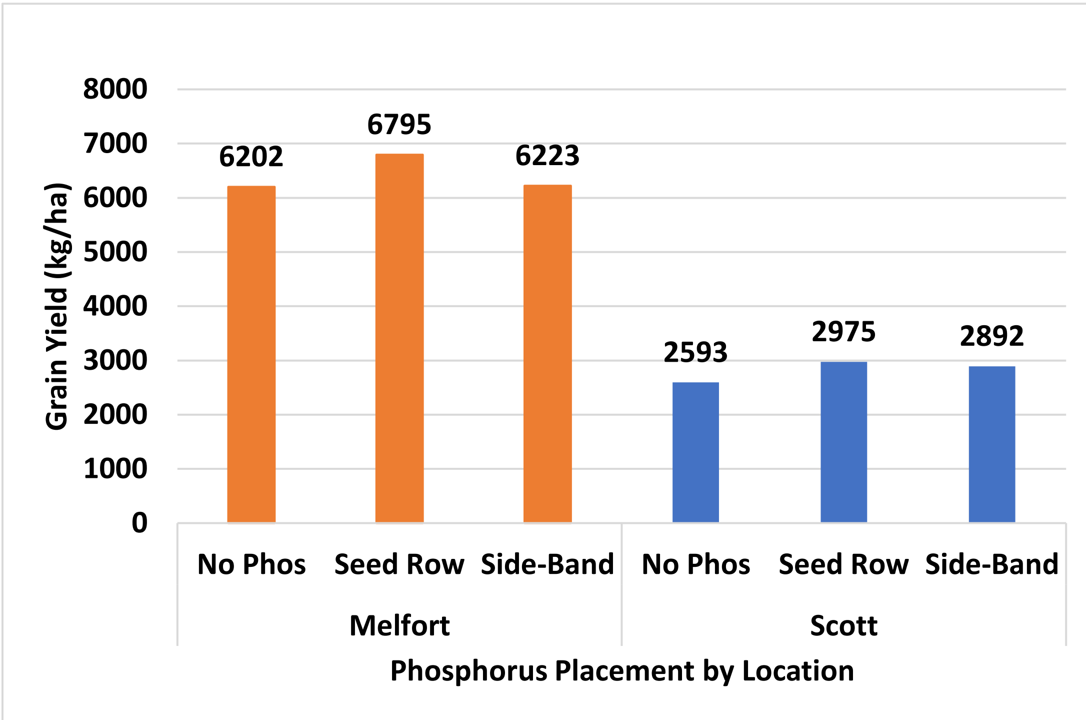

Figure 2. The effect of phosphorus placement on oat seed yield for 4R Management: Right Rate and Placement for Fertilizer in Oats at Scott and Melfort, SK in 2022

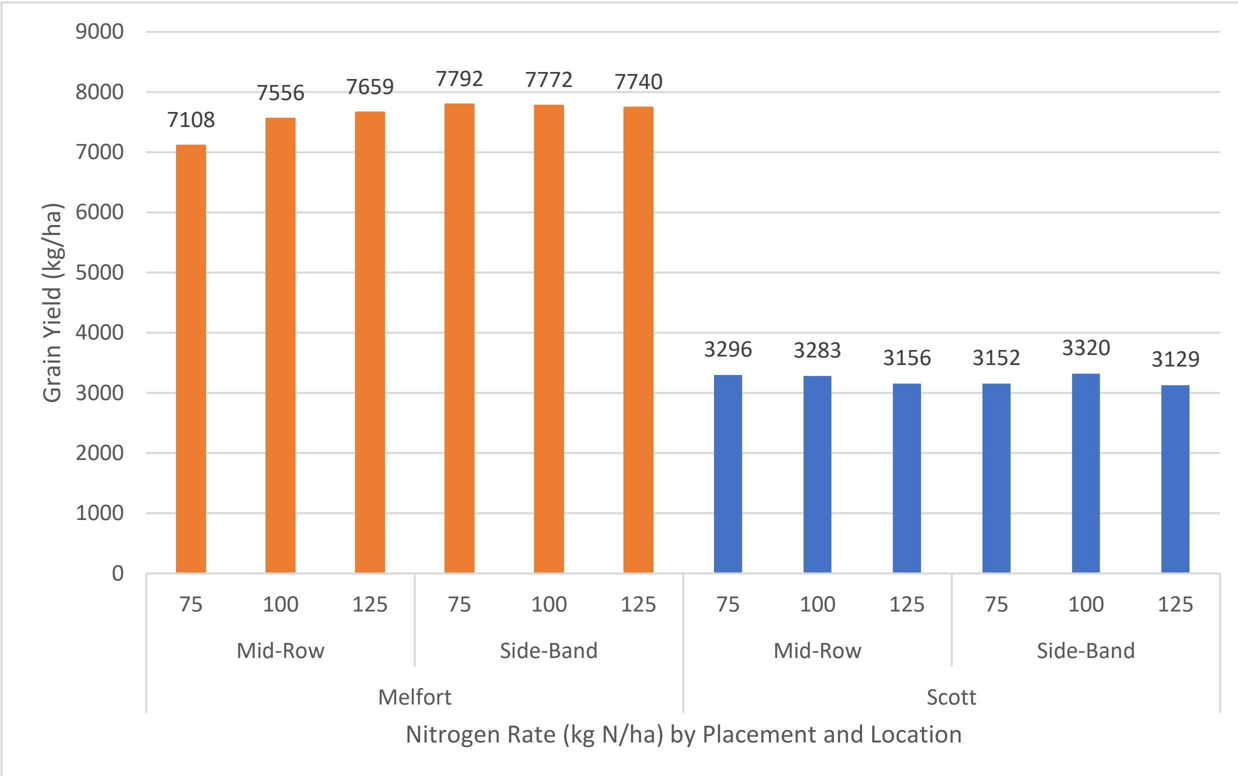

Figure 3. Treatment means for the effect of nitrogen placement and nitrogen rates on grain yield for 4R Management: Right Rate and Placement for Fertilizer in Oats at Scott and Melfort, SK in 2022

Grain Quality

Test weight (TW) and thousand kernel weights (TKW) were not significantly affected by any treatment factors at either site in this demonstration. Overall, Melfort had very high TW averaging at around 260g/0.5L and Scott had much lower TW averaging at 225-235 g/0.5L depending on the statistical analysis used (Figure 4). Average TKW was more comparable between the sites with Melfort averaging at 38.2-38.5 g/1000 seeds, and Scott averaging at 33.8-36.5 g/1000 seeds, depending on the analyses used.

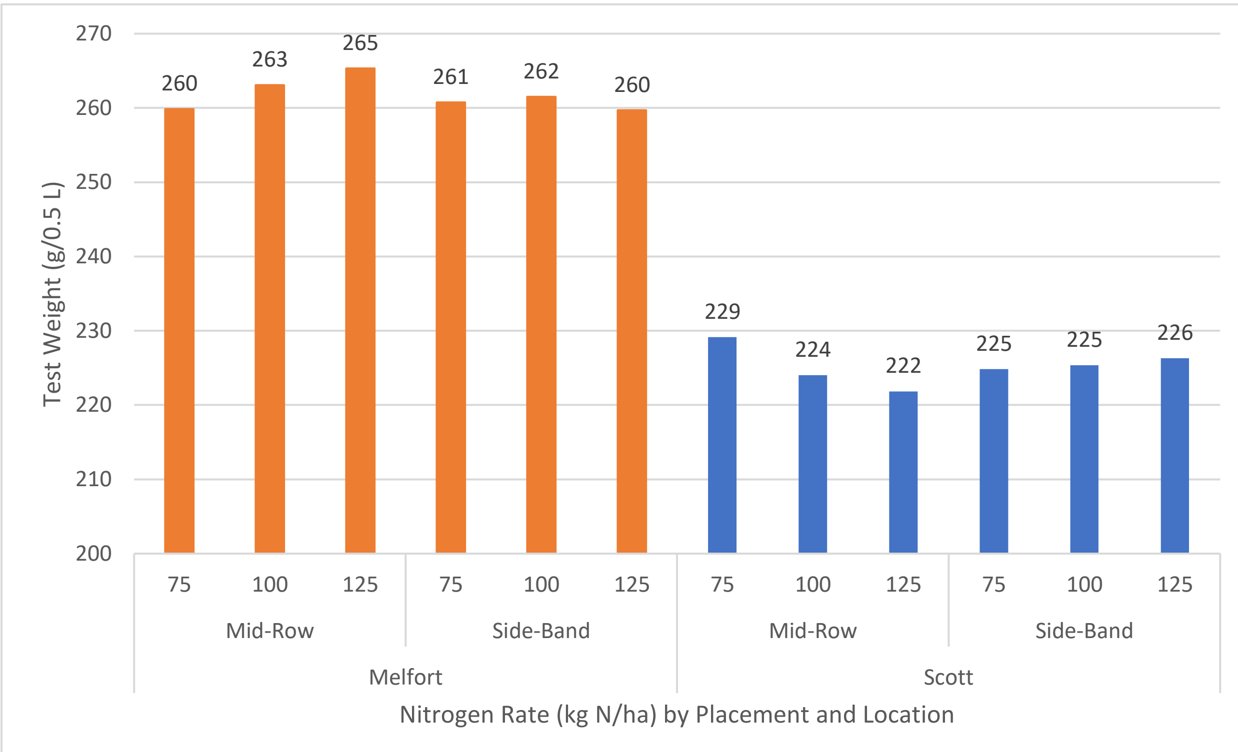

Figure 4. Treatment means for the effect of nitrogen placement and nitrogen rates on oat test weight (g/0.5L) for 4R Management: Right Rate and Placement for Fertilizer in Oats at Scott and Melfort, SK in 2022

11. Conclusion and Recommendation:

There were many significant treatment effects of nitrogen placement, nitrogen rate, and phosphorus placement on oat plant density, days to maturity, and grain yield at both locations in this demonstration; however, there were no significant treatment effects to oat test weights and thousand kernel weights. When nitrogen placement was significant side-banded nitrogen decreased plant density, increased days to maturity, and increased grain yield as compared to midrow-banded nitrogen. When nitrogen rate was significant, increasing rates from 75 to 125 kg/ha decreased plant density and increased the days to maturity. Additionally, when nitrogen rate was increased in the side-band plant densities were reduced as compared to the midrow. When treatment effects of phosphorus were significant, days to maturity was increased when phosphorus was seed-placed in combination with high rates (125 kg/ha) of applied nitrogen as compared to when phosphorus was side-banded. Additionally, phosphorus application significantly increased oat yield, but there was no significant effect of phosphorus placement. Due to dry and hot conditions at Scott and high residual soil nitrogen at Melfort throughout this demonstration results may vary from that of higher moisture and cooler temperature conditions as well as lower residual soil nitrogen at each of the participating locations. Another year of this demonstration would be beneficial to further demonstrate the response of oats to nitrogen placement, nitrogen rate, and phosphorus placement under different soil and climatic conditions in Saskatchewan.

Supporting Information:

12. Acknowledgements: This project was funded under the Agricultural Demonstration of Practices and Technologies (ADOPT) initiative under the Canadian Agricultural Partnership bi-lateral agreement between the federal government and the Saskatchewan Ministry of Agriculture. The Saskatchewan Oat Development Commission and the Northeast Agriculture Research Foundation would like to express our gratitude to the Saskatchewan Ministry of Agriculture's ADOPT program for funding this demonstration and for providing signage as well as Fertilizer Canada for providing additional funding for the project. Thank you to all participating sites including the Western Applied Research Corporation and the Northeast Agriculture Research Foundation staff for their hard work in completing this demonstration.

13. Extension: The Northeast Agriculture Research Foundation presented the results of this demonstration to Saskatchewan oat growers at the Saskatchewan Oat Development Commission Annual General Meeting on January 11th, 2023 at Prairieland Park in Saskatoon, SK. The presentation has also been made available as of January 20th, 2023 by the Northeast Agriculture Research Foundation on YouTube. The final report with be made available on both the Northeast Agriculture Research Foundation's (neag.ca) and the Western Applied Research Corporation's (warc.ca) websites.

14. Abstract and Summary:

Oats are commonly grown within the black soil zone of Saskatchewan and are known to be very responsive to nitrogen and sometimes phosphorus supplementation. Although oats are known to be responsive to fertilization of these nutrients, very little is known of the response of oats to the placement of nitrogen and phosphorus fertilizers. As in many other grain crops, it can be hypothesized that as higher amounts of fertilizer are placed closer to the seed in oats seedling mortality will increase. To demonstrate the response of oats to nitrogen placements, nitrogen rates, and phosphorus placements a small-plot demonstration was conducted at Scott and Melfort, SK in 2022. The treatment arrangement used was an unbalanced split-plot with the control treatments and midrow-banded nitrogen within one half of the split-plot and side-banded nitrogen within the second half of the split-plot. The sub-plot for nitrogen placement was nitrogen rates of 75, 100, and 125 kg/ha. The secondary sub-plot factor for nitrogen placement was phosphorus placement in the seed-row or in the side-band. Data collection consisted of plant density, days to maturity, grain yield, test weights (TW) and thousand kernel weights (TKW). There were many significant treatment effects of nitrogen placement, nitrogen rate, and phosphorus placement on oat plant density, days to maturity, and grain yield at both locations in this demonstration; however, there were no significant treatment effects to oat test weights and thousand kernel weights. When nitrogen placement was significant side-banded nitrogen decreased plant density, increased days to maturity, and increased grain yield as compared to midrow-banded nitrogen. When nitrogen rate was significant, increasing rates decreased plant density and increased the days to maturity. Additionally, when nitrogen rate was increased in the side-band plant densities were reduced as compared to the midrow. When treatment effects of phosphorus were significant, days to maturity was increased when phosphorus was seed-placed in combination with high rates (125 kg/ha) of applied nitrogen as compared to when phosphorus was side-banded. Furthermore, phosphorus application significantly increased oat yield, but there was no significant effect of phosphorus placement. Overall, oats were quite responsive to nitrogen placement, nitrogen rates, and phosphorus fertilization in this one-year demonstration.

15. Appendices:

Table 5. Statistical Analyses and treatment means for phosphorus placement (P place) in 4R Management: Right Rate and Placement for Fertilizer in Oats at Scott and Melfort, SK in 2022. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, P ≤ 0.05).

	Scott[y,z]					Melfort[y,z]				
	PPMS	DTM	Yield	TW	TKW	PPMS	DTM	Yield	TW	TKW
P place (p-value)	0.1904	0.4219	0.0024**	0.2600	0.0754	0.1541	0.9461	0.4302	0.1784	0.8579
Grand Mean	237.0	86.8	2820.2	235.7	36.5	228.4	96.5	6377.8	264.9	38.2
CV	8.35	0.6	3.2	1.5	3.1	14.5	2.2	7.8	1.0	2.8
P-place										
No fertilizer	252.5a	86.8a	2593.4b	238.3a	37.8a	241.6a	96.5a	6202.1a	266.1a	38.3a
Seed-placed P	235.2a	86.5a	2974.6a	235.0a	35.7a	197.7a	96.3a	6708.6a	262.5a	38.4a
Side-banded P	223.2a	87.0a	2892.5a	233.8a	36.0a	246.1a	96.8a	6222.8a	266.0a	38.0a

[y]The analyses only includes the control treatments (1-3) within the split-plot, with phosphorus placement analyzed as a randomized complete block

[z]Significance level of the p-value: *p<0.05, ** p<0.01, *** p<0.001

Table 6. Statistical Analyses and treatment means for nitrogen rate (N rate) and phosphorus placement (P place) in 4R Management: Right Rate and Placement for Fertilizer in Oats at Scott and Melfort, SK in 2022. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, P ≤ 0.05).

	Scott [y,z]					Melfort [y,z]				
	PPMS	**DTM**	**Yield**	**TW**	**TKW**	**PPMS**	**DTM**	**Yield**	**TW**	**TKW**
N rate (p-value)	0.0159*	<0.0001***	0.9117	0.8460	0.2766	0.02972	0.1913	0.8650	0.8805	0.6783
P place (p-value)	0.8770	0.2997	0.4513	0.3209	0.0826	0.1797	0.2182	0.0744	0.6809	0.5754
N rate X P Place (p-value)	0.2933	0.3419	0.1506	0.4594	0.9968	0.3025	0.0214*	0.9709	0.8156	0.1455
Grand Mean	201.9	88.6	3226.8	226.4	34.2	201.5	95.7	7644.3	261.0	38.4
CV	10.1	0.4	5.2	1.58	3.7	15.6	0.8	4.1	1.4	2.0
N rate										
75 kg/ha	220.5a	88.0c	3212.5a	227.0a	33.7a	214.9a	95.6a	7690.6a	261.3a	38.2a
100 kg/ha	197.8ab	88.5b	3247.1a	226.3a	34.7a	189.6a	95.4a	7636.1a	261.2a	38.6a
125 kg/ha	187.3b	89.3a	3220.6a	226.0a	34.4a	199.9a	96.1a	7606.1a	260.4a	38.4a
P Place										
Side-band (SB)	202.5a	88.7a	3253.3a	227.2a	34.7a	210.5a	95.5a	7520.3a	261.3a	38.3a
Seed-place (SP)	201.2a	88.5a	3200.3a	226.7a	33.8a	192.5a	95.9a	7768.2a	260.7a	38.5a
N rate X P Place										
75 kg/ha SB	211.6ab	88.0c	3273.1a	229.0a	34.1a	228.8a	96.0ab	7588.9a	261.8a	38.0a
100 kg/ha SB	202.0ab	88.5bc	3174.7a	226.5a	35.2a	208.0a	95.3b	7500.1a	260.8a	38.2a
125 kg/ha SB	193.9ab	89.5a	3312.0a	226.0a	34.9a	194.7a	95.3b	7472.0a	261.2a	38.8a
75 kg/ha SP	229.3a	88.0c	3152.0a	225.0a	33.2a	200.9a	95.3b	7792.4a	260.8a	38.5a
100 kg/ha SP	193.7ab	88.5bc	3319.6a	225.5a	34.2a	171.2a	95.5b	7772.1a	261.5a	39.0a
125 kg/ha SP	180.6b	89.0ab	3129.3a	226.5a	33.9a	205.3a	97.0a	7740.2a	259.7a	38.0a

[y]The analyses only includes the side-banded nitrogen treatments within the split-plot, with nitrogen rate and phosphorus rate analyzed as a two-way factorial
[z]Significance level of the p-value: *p<0.05, ** p<0.01, *** p<0.001

Table 7. Statistical Analyses and treatment means for nitrogen placement (N place) and nitrogen rate (N rate) in 4R Management: Right Rate and Placement for Fertilizer in Oats at Scott and Melfort, SK in 2022. Means within a column followed by the same letter do not significantly differ (Tukey-Kramer, P ≤ 0.05).

	Scott [y,z]					Melfort [y,z]				
	PPMS	DTM	Yield	TW	TKW	PPMS	DTM	Yield	TW	TKW
N place (p-value)	0.0036**	0.0305*	0.3315	0.7399	0.9638	0.4150	0.5181	0.0210*	0.2654	1.000
N rate (p-value)	0.0851	0.0121*	0.0839	0.2605	0.8423	0.8795	0.6286	0.5074	0.4392	0.4943
N place X N rate (p-value)	0.0401*	0.8404	0.3881	0.0808	0.1158	0.0712	0.3632	0.4004	0.2395	0.7147
Grand Mean	215.8	88.1	3222.6	225.3	33.8	204.9	95.6	7604.5	261.7	38.5
CV	9.2	0.6	4.0	1.6	3.4	11.8	2.3	2.4	1.4	2.5
N place										
Midrow-band (MB)	230.4a	87.7b	3245.0a	225.0a	33.8a	217.2a	95.3a	7440.9b	262.8a	38.5a
Side-band (SB)	201.2b	88.5a	3200.3a	225.7a	33.8a	192.5a	95.9a	7768.2a	260.7a	38.5a
N rate										
75 kg/ha	227.3a	87.6b	3223.9a	227.1a	34.0a	205.6a	95.3a	7450.2a	260.3a	38.5a
100 kg/ha	217.3a	88.1ab	3301.2a	224.8a	33.7a	201.5a	95.5a	7664.0a	262.3a	38.7a
125 kg/ha	202.9a	88.5a	3142.8a	224.1a	33.6a	207.4a	96.0a	7699.4a	262.5a	38.2a
N place X N rate										
MB 75 kg/ha	225.2ab	87.3b	3295.8a	229.3a	34.7a	210.4a	95.3a	7108.1a	259.9a	38.6a
MB 100 kg/ha	240.9a	87.8ab	3282.8a	224.0a	33.2a	231.7a	95.5a	7555.9a	263.1a	38.5a
MB 125 kg/ha	225.2ab	88.0ab	3156.3a	221.8a	33.4a	209.6a	95.0a	7658.6a	265.3a	38.3a
SB 75 kg/ha	229.3ab	88.0ab	3152.0a	225.0a	33.2a	200.9a	95.3a	7792.4a	260.8a	38.5a
SB 100 kg/ha	193.7bc	88.5ab	3319.6a	225.5a	34.2a	171.2a	95.5a	7772.1a	261.5a	39.0a
SB 125 kg/ha	180.6c	89.0a	3129.3a	226.5a	33.9a	205.3a	97.0a	7740.2a	259.7a	38.0a

[y]The analyses only includes the side-banded and midrow-banded nitrogen treatments with seed-placed phosphorus. The two-way interaction of N place and N rate was analyzed as a split-plot with placement as the main plot and nitrogen rate as the sub-plot.

[z]Significance level of the p-value: *p<0.05, ** p<0.01, *** p<0.001