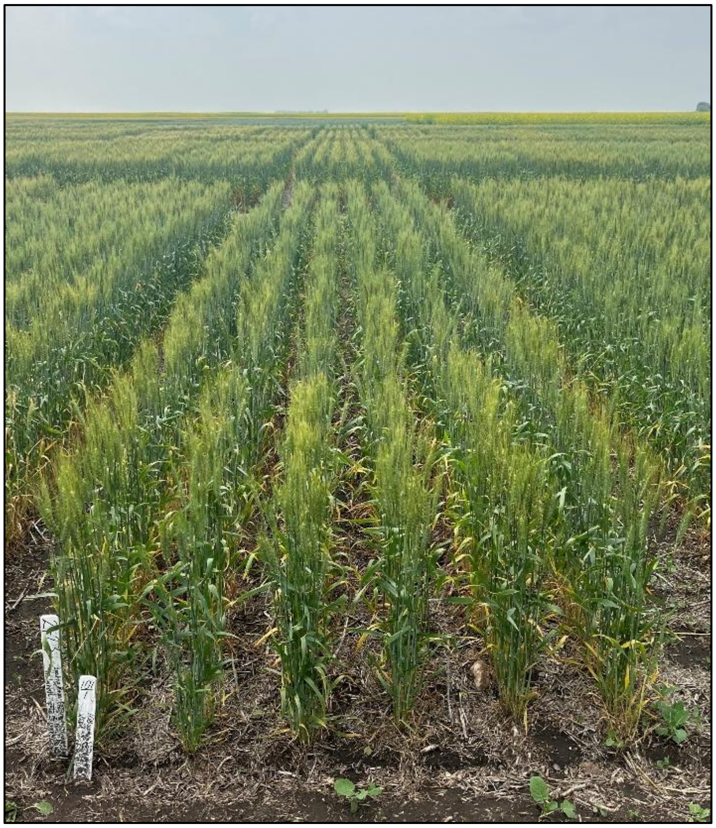
2023 Final Report

for the

Saskatchewan Wheat Development Commission (SWDC)

Evaluation of Seeding Rates of Wheat Under Various Environmental Conditions

(SWDC Ref #279-221123)



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Project Identification

1. **Project Title:** Evaluation of Seeding Rates of Wheat Under Various Environmental Conditions
2. **Project Code (as is in contract):** SWDC Ref #279-221123
3. **Producer Group Sponsoring the Project:**
4. **Project Locations:** Melfort (RM #428), Yorkton (RM #244), Swift Current (RM #137), Indian Head (RM #458), Prince Albert (RM #461), Scott (RM #380)
5. **Project start and end dates:**
6. **Project Contact Person & Contact Details:**

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Objectives and Rationale

Project Objectives:

The objective of this study was to evaluate the ideal seeding rate for spring wheat under various environmental conditions.

Project Rationale:

The current seeding rate recommendations for wheat target between 215-275 plants/m^2 (Saskatchewan Seed Guide, 2021). Selecting a target plant population is important for establishing good plant stands for achieving optimum yield and improving weed and disease management. Research has shown that opting for increased seeding rates can improve weed control, disease suppression and under good moisture conditions can increase yields. Higher seeding rates create a more competitive plant stand for managing weed competition. As well, higher plant populations typically result in fewer tillers, which can result in more uniform flowering and make FHB fungicide applications more precise. On the contrary, lower seeding rates may be a more practical and economical practice in dry years. Dryer years typically result in fewer weeds and lower disease risk, therefore, the management benefits realized with higher seeding rates may not be as valuable. As well, a lowered plant stand means less competition for resources, especially limited resources such as moisture. Studies have shown, under drought conditions, lower seeding rates tended to yield higher than high seeding rates. Therefore, it would be more beneficial to compare seeding rates under various environmental conditions as producers have no control on environmental factors such as temperature and precipitation.

When producers are determining their seeding rates, they take into account many factors such as seed source and quantity, seed weight, soil moisture and temperature, fertilizer capabilities, etc. Therefore, when producers are choosing a seeding rate and weather predictions are not guaranteed, this research could benefit producers in deciding what seeding rate is successful in various weather conditions. This was achieved by replicating this trial in multiple sites in Saskatchewan, where a wide range of environmental conditions might be expected.

Methodology and Results

Methodology:

Seven seeding rate treatments were arranged in a randomized complete block design with four replications at six sites throughout Saskatchewan. The sites in this trial included Scott, Indian Head, Melfort, Prince Albert, Swift Current and Yorkton. Seeding rate treatments ranged from 108 seeds/m^2 to 432 seeds/m^2, with increments of approximately 55 seeds/m^2 (Table 1). At each location a common, high yielding hard red spring wheat (HRSW) variety was chosen (Appendix A2). The trial was seeded with a Fabro drill and row spacings of 8-inch at Swift Current, 12-inch at Melfort, and 10-inch at Scott and Prince Albert. Indian Head and Yorkton used a Seed Master drill with 12-inch row spacing. Seed depths ranged from ¾" to 2", depending on soil conditions at time of seeding. Scott, Indian Head, Melfort, and Prince Albert seeded this trial into canola stubble. The Swift Current and Yorkton site seeded into durum and wheat stubble. Fertility was applied as to not be limiting, based on soil test recommendations. Seeding rates were based on the protocol. Pesticides (herbicides, insecticides, herbicides) were conducted at the site managers discretion, with all pests kept non-limiting using registered pesticides. Plots were combined with small plot combines (Wintersteiger or Zurn) at physiological maturity.

Table 1. Treatment list for "Evaluation of Seeding Rates of Wheat Under Various Environmental Conditions" in Scott, Indian Head, Melfort, Prince Albert, Swift Current and Yorkton, SK. 2023.

TRT #	Seeding Rates	
	seeds/m^2	plants/ft^2
1	108	10
2	163	15
3	217	20
4	272	25
5	326	30
6	378	35
7	432	40

Data Analysis

The data was statistically analyzed using R Studio (ver.2021.9.2.382) (RStudio Team, 2022) and JMP software (JMP, 2024) to determine the effects of seeding rate on plant density, head density, tillering, head length, head size, lodging, yield, and seed quality of wheat in various locations throughout Saskatchewan. For individual sites, a random intercept mixed effects model was used to investigate differences in response variables with seeding rate as a fixed effect and replication as a random effect. Sites were combined based on their respective yield responses to seeding rate and from there we were able to determine two subgroups which coincided with trends in growing season precipitation. Therefore, for the combined analysis, data was subset into moisture groups based on the percent of long-term average precipitation for each site. Data from a similar study at Scott and Swift Current in 2022 was included in the combined analysis because the data strongly supported trends observed in the 2023 study. The high moisture group included sites with greater than 70% of their respective long-term averages, which consisted of Swift Current-22, Prince Albert-23, Yorkton-23, and Swift Current-23. The low moisture group included sites with less than 70% of their respective long-term averages and included Scott-22, Scott-23, Indian Head-23, and Melfort-23. The Swift Current-23 site was excluded from the combined analysis for head density, tillering, head length, head size, lodging, yield, and seed quality due to a hail storm on July 22nd that significantly impacted the quality of those plots. Pearson's correlation coefficient was used to determine the impact of certain variables on yield and protein. Linear and quadratic regression models were used to indicate type of relationship between response variables and seeding rates under the different environmental conditions. When analysis of variance (ANOVA) indicated significant differences ($p < 0.05$).

Data Collection

Composite soil samples were collected at each site in the fall of 2022 and/or the spring of 2023 at two soil depths and submitted to Agvise laboratories for analysis of organic matter, pH, cation exchange capacity, and macronutrient concentrations (Appendix A3). Plant emergence counts were conducted approximately 2 weeks after emergence by counting 4 x 1 meter row lengths per plot. Head density was conducted by counting 4 x 1-meter sections of crop row when head emergence was complete. Tillering was calculated by dividing the plant density by the head density to provide the number of tillers per plant. Lodging was evaluated at physiological maturity, on a scale of 1-10, where 1 is upright and 10 is flat. Head length was determined by measuring 20 head lengths in cm per plot. Yields were determined from cleaned harvested grain samples and corrected to 14.5% moisture content. Protein was collected as an indicator of seed quality. Thousand kernel weight (TKW) was collected at Scott, Indian Head, Melfort, Swift Current and Yorkton as an additional parameter, but it was not required as per the contract. Head size (seeds/head) was calculated based on yield (g/ft2), head density (heads/ft2), and seed weight (g/seed) (Figure 1). The 2023 and long-term weather data was collected by on-site weather stations and/or Environment Canada, depending on the location.

Head Size:

Step 1: Calculate grams/head = $\frac{\text{Yield (grams per ft}^2\text{)}}{\text{Head Density (heads per ft}^2\text{)}}$

Step 2: Head Size (seeds/ head) = $\frac{\text{Grams per head}}{\text{Grams per one seed}}$

Figure 1. Calculation to determine head size (seeds/head) of wheat.

Growing Conditions

The mean monthly temperature and cumulative precipitation were recorded at all six sites for the months of May to August. The percentage of long-term average (LTA) was calculated to provide insight into whether or not these growing season conditions were above or below the climate normal for each respective site. Overall, the above average growing season temperatures and below average precipitation indicated relatively drought-like conditions for all six sites. Despite this, there were differences in growing season conditions between sites that influenced the results of this study. Mean temperatures for each month and the entire growing season were fairly similar across all sites; however, the comparison to respective long-term averages varied. Long-term temperature averages followed the order of Prince Albert<Indian Head<Swift Current<Melfort<Yorkton<Scott; where the closer the LTA was to 100%, the closer that sites temperature was to their climate normal. The cumulative precipitation varied considerably across months and sites. In May, all sites received below average precipitation, except the Swift Current site. In June, Scott and Yorkton received above average precipitation, while all other sites were below average. July was a particularly dry month for all sites, receiving considerably less precipitation than average, except for Swift Current which received above average precipitation for this month. Unfortunately, this site also experienced a hail storm on July 22nd, which resulted in approximately 50% yield loss. For the month of August, three sites (Scott, Indian Head, Melfort) received below average precipitation while the other three sites (Prince Albert, Swift Current, Yorkton) received above average precipitation. While the cumulative growing season precipitation was below average at all six sites, the variation in precipitation across months differentiated these sites.

Table 2. Mean monthly temperature (°C) along with the long term (1981-2010) averages for the 2023 growing season at Scott, Indian Head, Melfort, Prince Albert, Swift Current and Yorkton, SK.

Location	**Year**	**May**	**June**	**July**	**August**	**Average**
		----------------------------Mean Temperature (°C) ----------------------------				
Scott	2023	14.9	17.2	17.1	17.4	16.7 *(113%)*
	Long-term	10.8	14.8	17.3	16.3	14.8
Indian Head	2023	14.0	19.4	16.7	17.7	16.9 *(108%)*
	Long-term	10.8	15.8	18.2	17.4	15.6

Melfort	2023	14.1	19.2	16.9	17.3	16.9 *(111%)*
	Long-term	10.7	15.9	17.5	16.8	15.2
Prince Albert	2023	14.4	18.8	16.6	17.1	16.7 *(106%)*
	Long-term	11.1	16.3	18.6	16.9	15.7
Swift Current	2023	14.8	17.8	18.5	17.8	17.2 *(110%)*
	Long-term	11.0	15.7	18.4	17.9	15.8
Yorton	2023	14.1	19.4	16.8	17.8	17.0 *(112%)*
	Long-term	10.4	15.5	17.9	17.1	15.2

Table 3. Total monthly precipitation (mm) along with the long term (1981-2010) averages for the 2023 growing season at Scott, Indian Head, Melfort, Prince Albert, Swift Current and Yorkton, SK.

Location	**Year**	**May**	**June**	**July**	**August**	**Sum**
		------------------------Cumulative Precipitation (mm)------------------------				
Scott	2023	16.6	81.1	29.7	31.7	159.1 *(70%)*
	Long-term	38.9	69.7	69.4	48.7	226.7
Indian Head	2023	12.9	49.6	15.9	40.8	119.2 *(49%)*
	Long-term	51.7	77.4	63.8	51.2	244.1
Melfort	2023	31.5	26.4	16.4	50.0	124.3 *(56%)*
	Long-term	39.8	54.3	76.7	52.4	223.2
Prince Albert	2023	22.8	52.8	40.8	51.2	167.6 *(81%)*
	Long-term	34.1	62.0	67.6	42.9	206.6
Swift Current	2023	48.8	33.8	76.7	47.5	206.8 *(91%)*
	Long-term	42.1	66.1	44.0	35.4	188
Yorton	2023	20.0	83.4	17.4	72.6	193.4 *(72%)*
	Long-term	48.3	79.9	78.2	62.2	268.6

Results & Discussion:

Plant Densities

There were significant linear responses for all six sites ($p<0.001$). A linear response to seeding rate indicates that wheat plant densities increased for every increase in seeding rate. This rate of increase was similar across sites, indicating that increasing seeding rates consistently increases plant densities. Additionally, the mean plant density ranged considerably at each location from 15 plants/ft^2 at Swift Current to 22 plants/ft^2 at Indian Head ($p=0.020$). The mean plant densities for sites followed the order of Swift Current < Yorkton < Melfort < Prince Albert < Scott < Indian Head. The effect of seeding rate on plant densities varied slightly when sites were grouped by low and high moisture conditions. At the low moisture sites, there was a significant linear response to seeding rates ($p<0.001$), whereby the plant densities increased at a rate of 0.69 plants/ft^2 for each increase in seeding rate (Figure 2a). At the high moisture sites, a significant quadratic response ($p<0.001$) found that plant densities increased as seeding rates increased, but began to plateau at higher seeding rates (Figure 2b). Altogether, all sites followed similar trends, but the impact of seeding rate on plant densities varied slightly based on moisture conditions.

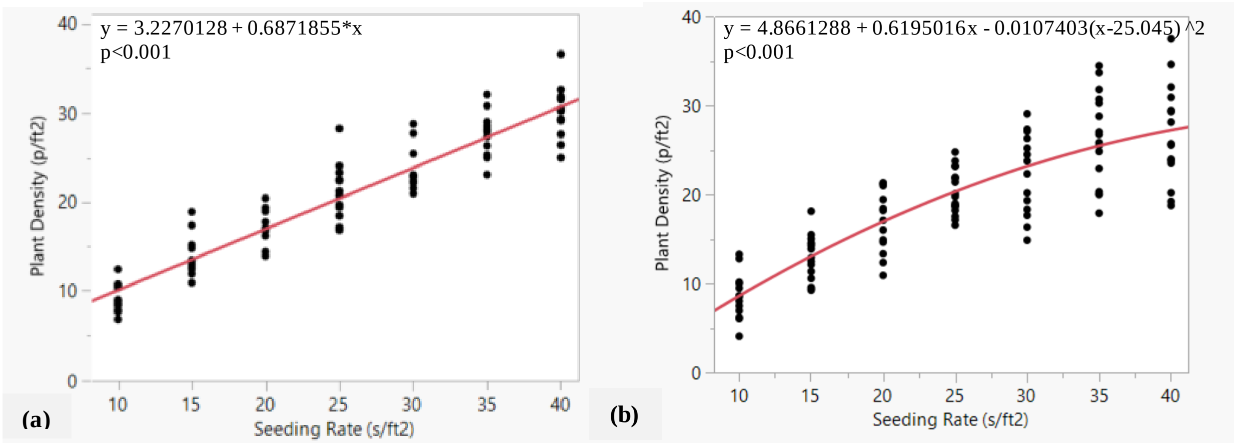

Figure 2. Effect of seeding rate (seeds/ft^2) on plant density (plants/ft^2) in low (a) and high (b) moisture conditions.

Head Densities

The head densities at all six sites indicated significant linear responses to seeding rates, where head densities increased as seeding rates increased. Furthermore, head density at each site followed a similar linear trend to plant density; whereby increased seeding rates resulted in increased plant densities and head densities. Additionally, head densities significantly differed between sites ($p<0.001$). The greatest head densities were recorded at Indian Head (54 heads/ft^2), followed by Prince Albert (38 heads/ft^2), Scott (37 heads/ft^2), Yorkton (35 heads/ft^2), and Melfort (25 heads/ft^2). Analysis of moisture groups detected subtle differences in the effect of head density on yield in different environmental conditions. At the low moisture sites, there was a strong positive correlation of head density to yield ($r=0.81$; $p<0.001$), indicating that head density has a strong influence on yields (Figure 3a). According to the histogram borders, the highest yields (80-85 bu/ac) most frequently occurred at head densities between 52.5-57.5 heads/ft^2 (Figure 3a). The response to seeding rate was not significant ($p=0.182$), and the head densities (52.5-57.5 heads/ft^2) correlated to high yields were found consistently through seeding rates of 15-40 seeds/ft^2 (Figure 4a). Thus, in low moisture conditions, head density strongly influences yields, but different seeding rates do not necessarily influence head densities. At the high moisture sites, head density was also strongly correlated to yield ($r=0.81$; $p<0.001$) (Figure 3b). The linear response showed that the highest yields (90-100 bu/ac) most frequently occurred at the highest head densities (47.5-50 heads/ft^2) (Figure 3b). Additionally, the highest head densities (47.5-50 heads/ft^2) most consistently occurred at seeding rates of 30-35 seeds/ft^2 (Figure 4b). Therefore, seeding wheat at rates between 30-35 seeds/ft^2 will result in head densities that are correlated to high yields. Ultimately, head densities were strongly correlated to yield regardless of moisture conditions; however, the head densities that were correlated to high yields were achieved at different seeding rates.

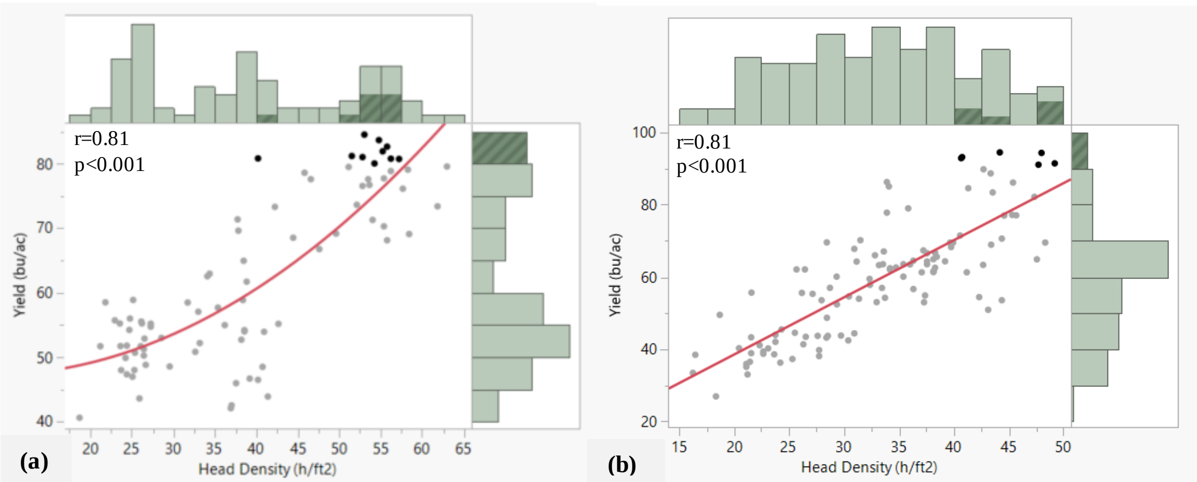

Figure 3. Correlations between head density (heads/ft^2) and yield (bu/ac) in low (a) and high (b) moisture conditions.

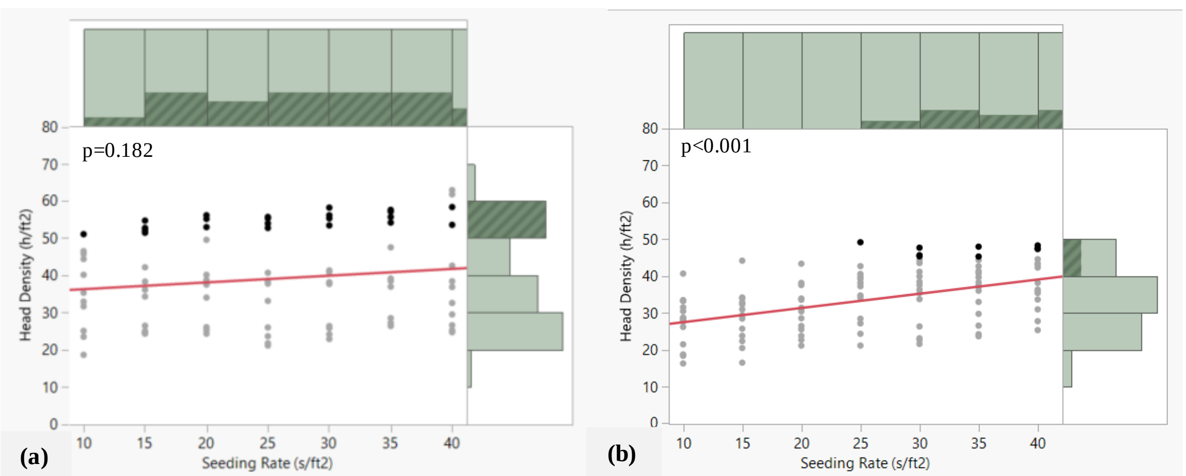

Figure 4. Effect of seeding rate on head density (heads/ft^2) in low (a) and high (b) moisture conditions.

Tiller Density

The amount of tillering per plant was determined by dividing the head densities by the plant densities to get the number of heads per plant, which indicates the number of tillers per plant. There was a significant linear trend at all six sites ($p<0.001$), where the number of tillers per plant decreased as the seeding rates increased. This is a common phenomenon, as many producers will use higher seeding rates to reduce the number of tillers for better fungicide spray timing. Analysis of the moisture groups found that tillering was significantly correlated to yield at low ($r=0.49$; $p<0.001$) and high ($r=0.20$; $p=0.036$) moisture sites (Figure 5). At low moisture sites, the highest yields (80-85 bu/ac) frequently occurred at tiller densities of 1.5-2.0 and 2.5-3.5 tillers/plant (Figure 5a). There was a significant response of tiller density to seeding rates ($p<0.001$), and tillers ranging from 1.5-3.5 tillers/plant most commonly occurred at seeding rates of 15-20 seeds/ft^2 (Figure 6a). This indicates that seeding rates between 15-20 seeds/ft^2 will result in tiller densities that are correlated to high yields. At high moisture sites, the correlation to yield was weaker, but still significant (r=0.20; p=0.036) (Figure 5b). Additionally, the highest yields (90-100 bu/ac) occurred at tiller densities of 1.0-2.5 and 3.0-4.0 tillers/plant (Figure 5b). These tiller densities were most commonly found at seeding rates of 25-30 seeds/ft^2 (Figure 6b). Overall, tiller density had a strong influence on yields in low and high moisture conditions, but the seeding rates to achieve these high yields were 15-20 seeds/ft^2 at low moisture sites and 25-30 seeds/ft^2 at high moisture sites.

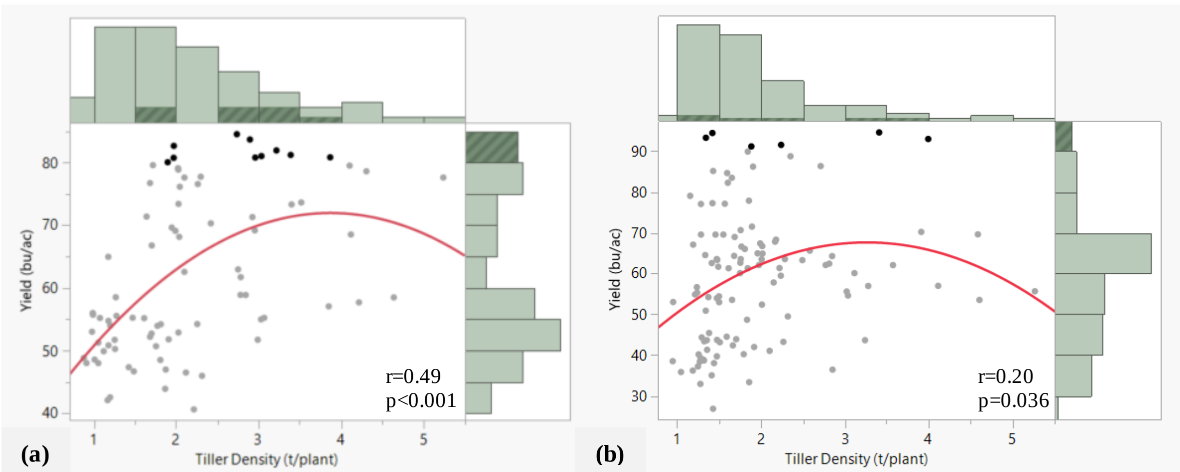

Figure 5. Correlations between tiller density (tillers/plant) and yield (bu/ac) in low (a) and high (b) moisture conditions.

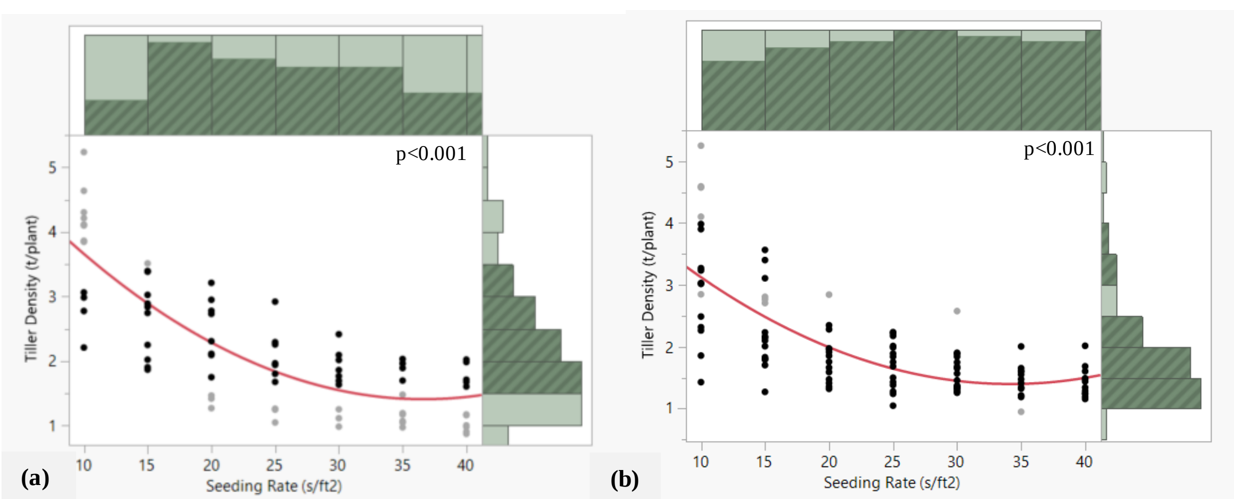

Figure 6. Effect of seeding rate on tiller density (tillers/plant) in low (a) and high (b) moisture conditions.

Head Length

The head length was measured at all sites to determine whether seeding rates influenced the head length of wheat. There were significant linear responses at four sites; Prince Albert, Indian Head, Melfort, and Swift Current. At these sites, head length decreased as seeding rate increased. Competition among plants for moisture and nutrients at high seeding rates could result in less resources for head development. Alternately, the Scott (p=0.005) and Yorkton (p=0.012) sites had a significant quadratic response. At these sites, head length decreased as seeding rates increased from 10 to 30 seeds/ft^2. As seeding rates increased above 30 seeds/ft^2 the head length either plateaued (Yorkton) or increased slightly (Scott). This indicates that at these sites, seeding rates above 30 seeds/ft^2 do not have negative impacts on head length. Furthermore, mean head lengths were significantly different between sites (p<0.001). The greatest mean head length was observed at Prince Albert (8.12 cm), followed by Yorkton (7.71 cm), Scott (7.51 cm), Indian Head (6.67 cm), Swift Current (6.56 cm), and Melfort (6.36 cm). Analysis of moisture groups found that head length was not significantly correlated to yield at both low (r=0.18; p=0.111) and high (r=0.16; p=0.094) moisture sites. Thus, indicating that head length does not influence yield, even in different moisture conditions. Both moisture groups resulted in significant responses to seeding rates (p<0.001) with similar trends (Figure 7). At low moistures sites, the head length decreased by 0.03 cm for each increase in seeding rate, while the high moisture sites decreased by 0.02 cm by each increase in seeding rate. Overall, head length consistently decreased as seeding rates increased regardless of moisture conditions.

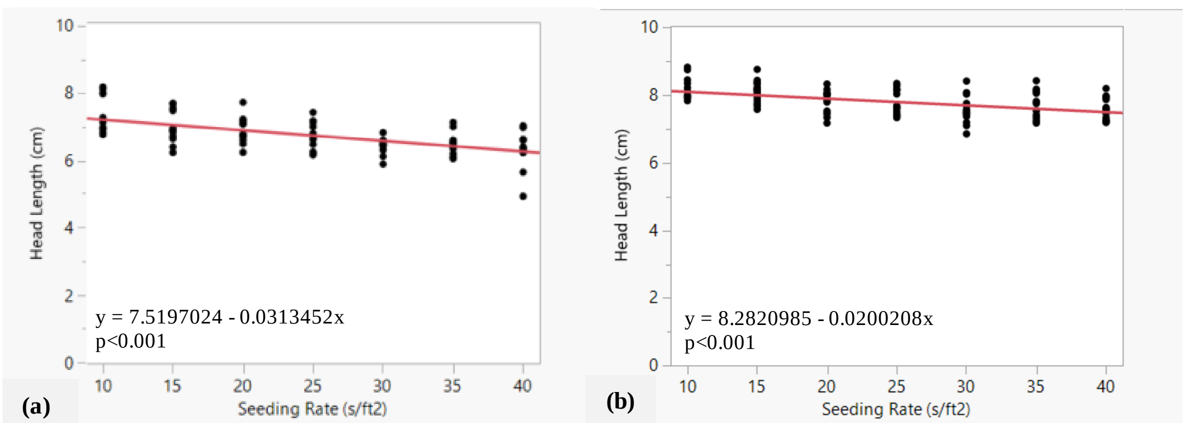

Figure 7. Effect of seeding rate on head length (cm) in low (a) and high (b) moisture conditions.

Head Size

Head size was calculated to determine whether different seeding rates influence the number of seeds produced per head. There was a significant linear response to seeding rate at all sites, whereby the head size decreased as seeding rates increased. Generally, as seeding rates increase the competition for resources also increases so that less resources are available for seed development at high seeding rates, resulting in lower number of seeds per head. The strongest response occurred at Scott, Yorkton, Indian Head, and Swift Current (p<0.001), where the head size decreased at larger increments as seeding rates increased. At these sites, head sizes ranged from 24-31 seeds/head at Scott, 24-34 seeds/head at Yorkton, 23-29 seeds/head at Indian Head, and 45-66 seeds/head at Swift Current. The effect of seeding rate on head size was lesser at Melfort (p=0.042), although still significant. The head sizes at Melfort ranged from 31-36 seeds/head. Analysis of moisture groups found differences in the effect of head size on yield. At low moisture sites, the head size was not significantly correlated to yield (r=0.01; p=0.935); however, the highest yields were most consistently found at head sizes between 25 to 27.5 seeds/head (Figure 8a). These head sizes most frequently occurred at seeding rates of 15-20 and 35-40 seeds/ft^2 (Figure 9a). Alternately, there was a significant negative correlation to yield at the high moisture sites (r=-0.23; p=0.032). At these sites, yields decreased linearly at a rate of 0.68 bu/ac for each unit increase in head size (Figure 8b). The highest yields occurred most frequently at head sizes between 27.5 to 30 seeds/head (Figure 8b), and these head sizes occurred most frequently at 30-35 seeds/ft^2 (Figure 9b). The response of head size was significant for both moisture groups and tended to decrease as seeding rate increased (p<0.001) (Figure 9). Ultimately, the head size of wheat influenced yields in high moisture conditions and resulted in the highest yields at seeding rates of 30-35 seeds/ft^2.

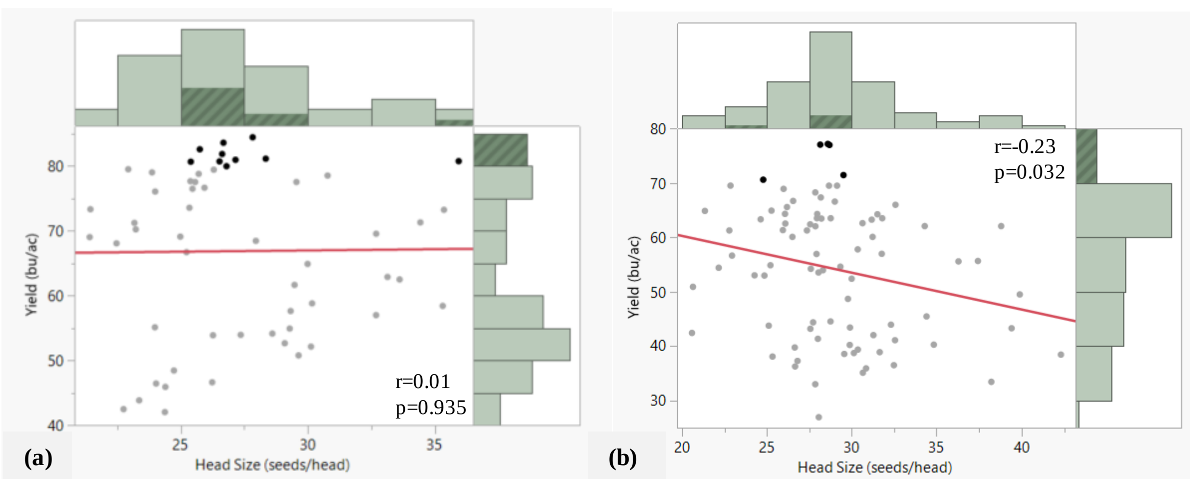

Figure 8. Correlations between head size (seeds/head) and yield (bu/ac) in low (a) and high (b) moisture conditions.

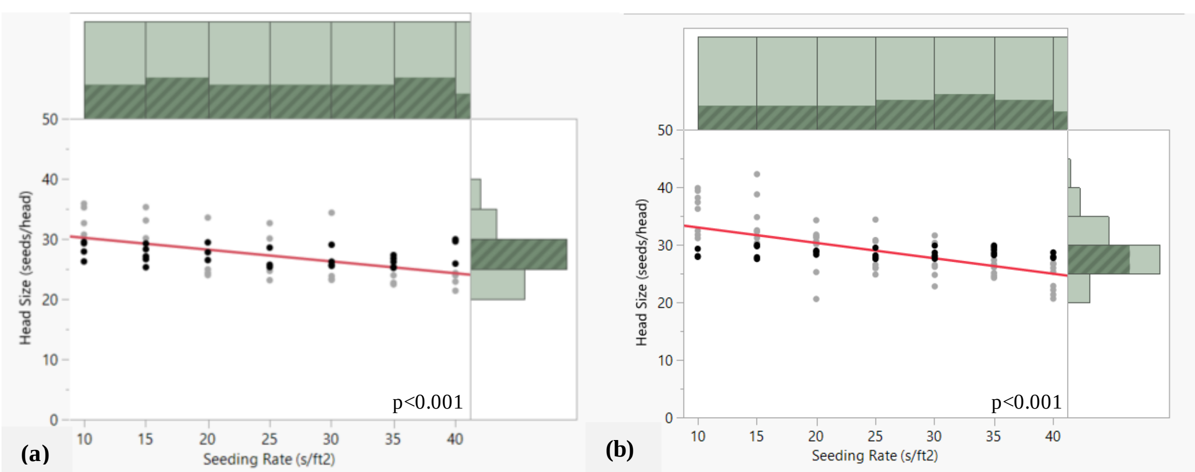

Figure 9. Effect of seeding rate on head size (seeds/head) in low (a) and high (b) moisture conditions.

Lodging

There was minimal lodging recorded at all six sites in this study. It was expected that with high seeding rates the risk of lodging would be increased; however, that was not necessarily the case. At Scott, Yorkton, Indian Head, Melfort, and Swift Current, there was no response to seeding rates, as all seeding rates resulted in lodging values of 1.0. At the Prince Albert site there was a slight linear response (p=0.041), where lodging increased from 1.3 to 3.5 as seed rates increased. Mean lodging for sites did not vary significantly (p=0.790) with all sites ranging between 1.0 and 1.5, except Prince Albert with the highest mean lodging rating of 2.4. The Prince Albert site had relatively high precipitation throughout the growing season, which could explain the slight response to seeding rate as opposed to no response at the other sites. Analysis of low and high moisture sites also found different responses. There was no significant response to seeding rates at low moisture sites (p=0.135), as mentioned above these sites mostly experienced no lodging and received ratings of 1.0. However, at high moisture sites there was a slightly significant response (p=0.056) where lodging increased by 0.03 for each increase in seeding rate. Therefore, the risk of lodging might be greater in high moisture conditions when using high seeding rates.

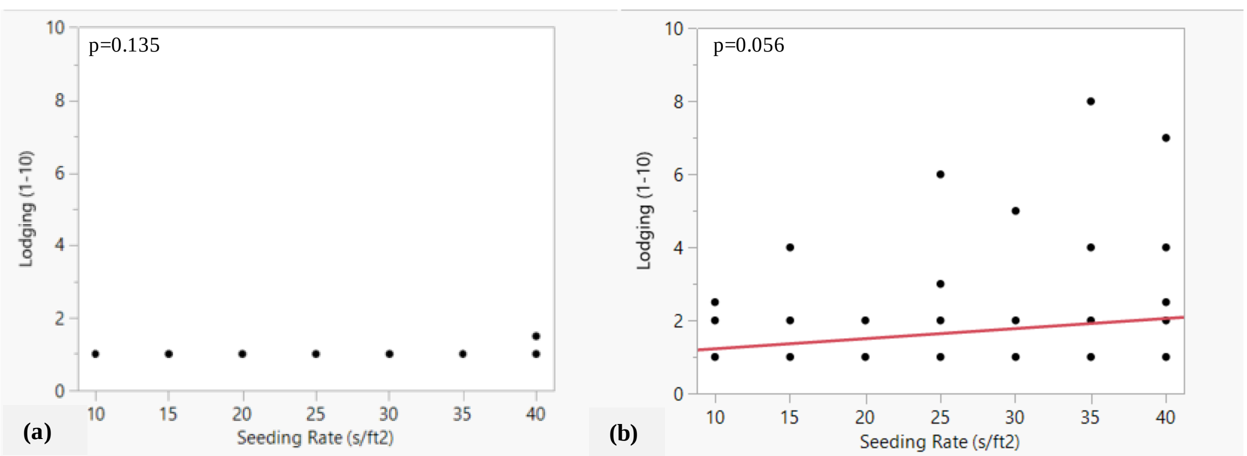

Figure 10. Effect of seeding rate on lodging (1-10) in low (a) and high (b) moisture conditions.

Yield

The yield response to seeding rates varied depending on location. At Scott and Yorkton there was a significant linear response so that as seeding rates increased, the yield continually increased. This effect was marginally significant at Scott (p=0.067) with a difference between the lowest and highest yield of 5 bu/ac. Whereas at Yorkton, the yield response was significant (p=0.037) with a 10 bu/ac difference between the highest and lowest yielding treatments. Similarly, the Prince Albert site showed a quadratic response to seeding rates, where the yields increased as seeding rates increased and peaked at 35 seeds/ft^2 (p=0.523).

Alternately, yields showed a significant linear decrease as seeding rates increased at the Indian Head site ($p=0.286$) from 76.1 bu/ac at 10 seeds/ft^2 to 74.7 bu/ac at 40 seeds/ft^2. For the Swift Current and Melfort sites, the yields were unaffected by seeding rate treatments and resulted in minimal yield differences of 3.2 bu/ac ($p=0.164$) and 3.6 bu/ac ($p=0.865$), respectively. Due to the inconsistency in yield trends across locations, a combined analysis between low and high moisture groups was used to discern consistent treads based on precipitation. This analysis determined that in low moisture conditions, the yield decreased linearly as seeding rates increased ($p=0.271$), whereas in high moisture conditions the yield increased linearly as seeding rates increased ($p=0.047$) (Figure 13). Correlations between yield determining factors revealed that head density and tillering were significantly correlated to yield at low (Figure 11) and high (Figure 12) moisture sites. Indicating that these factors have a large influence on yield, regardless of moisture conditions. Additionally, head size was significantly correlated to yield at high moisture sites only (Figure 12). Evaluating the influence of these factors on yield and their responses to seeding rates at low moisture sites determined that the head densities and tillers that consistently resulted in high yields most commonly occurred at seeding rates of 15-20 seeds/ft^2. As a result, the highest yields in low moisture conditions were achieved at seeding rates of 15-25 seeds/ft^2 (Figure 13a). As for the high moisture sites, the head density and tillers that resulted in the highest yields consistently occurred at seeding rates of 30 seeds/ft^2. Expectedly, the highest yields were most commonly found at seeding rates of 35-40 seeds/ft^2 (Figure 13b). These results tell us that the seeding rates to optimize yield vary slightly depending on moisture conditions. Based on the results of this study, seeding rates at 20 seeds/ft^2 in low moisture conditions and 30 seeds/ft^2 in high moisture conditions can consistently optimize wheat yields.

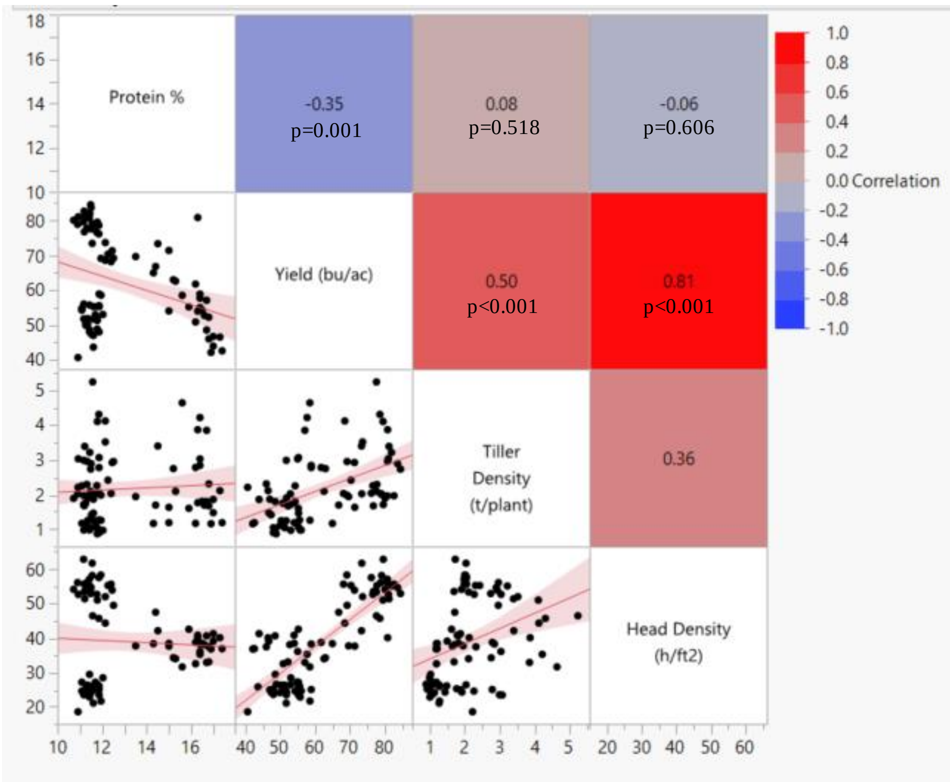

Figure 11. Correlations between protein (%), yield (bu/ac), tiller density (tillers/plant), and head density (heads/ft^2) in low moisture conditions.

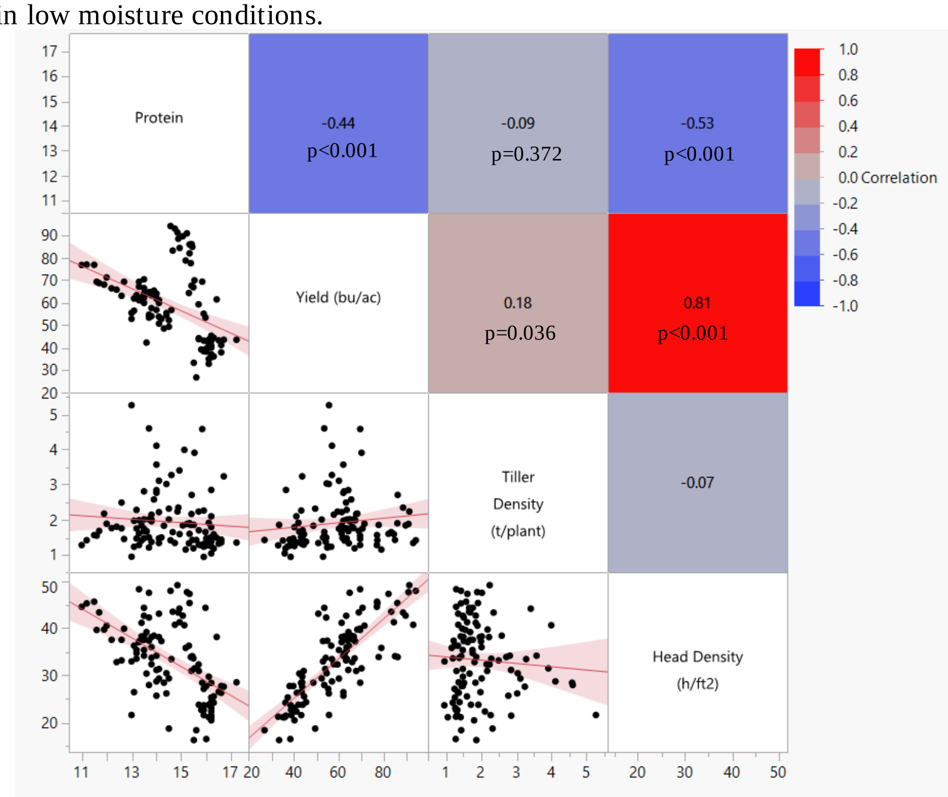

Figure 12. Correlations between protein (%), yield (bu/ac), tiller density (tillers/plant), and head density (heads/ft^2) in high moisture conditions.

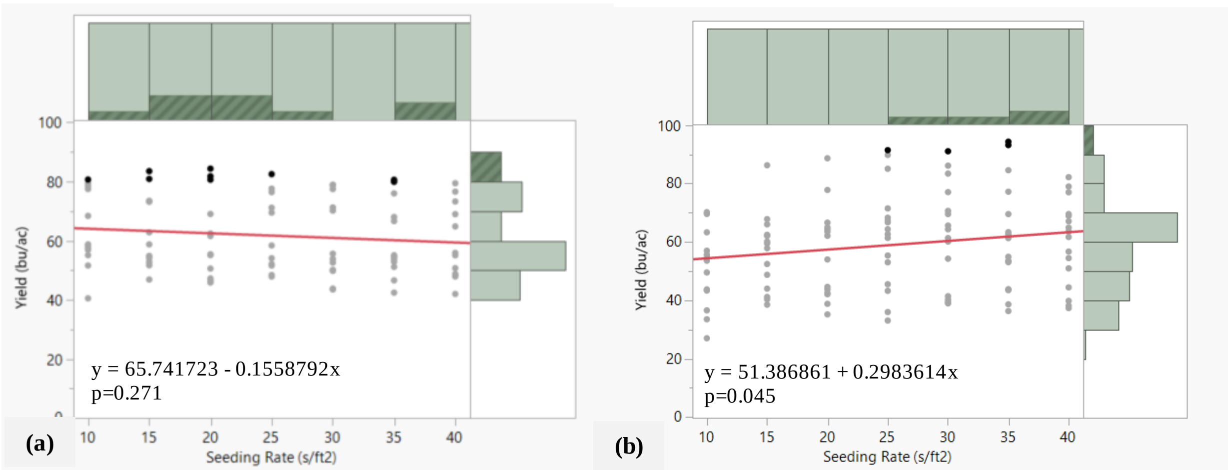

Figure 13. Effect of seeding rate on head size (seeds/head) in low (a) and high (b) moisture conditions.

Protein

Protein is an important factor for marketing wheat and can vary substantially based on environmental conditions; therefore, evaluating seeding rates at different locations can provide insight into the best seeding rates for optimum protein in different moisture conditions. The results of this study found similar trends across all sites, but the degree to which seeding rate affected protein varied. There were no significant responses at Prince Albert, Indian Head, and Melfort. At these sites, protein levels tended to decrease as seeding rates increased, but differences between seeding rate treatments were minimal. Alternately, there were significant linear responses at Scott (p=0.019), Yorkton (p=0.011), and Swift Current (p=0.004). At these sites, highest protein levels occurred with seed rates of 10 and 15 seeds/ft^2 and the lowest protein levels occurred with seed rates of 35 and 40 seeds/ft^2. Furthermore, protein levels significantly varied between sites (p<0.001). The highest mean protein was recorded at Swift Current (16.6%), followed by Prince Albert (15.4%), Yorkton (13.6%), Scott (13.1%), Indian Head (11.6%), and Melfort (11.5%). Protein levels were significantly correlated to yield at low (r=-0.35; p=0.001) and high (r=-0.44; p<0.001) moisture sites, whereby protein tended to decrease as yields increased (Figure 11, 12). This inverse relationship between protein and yield was consistent across individual sites. At low moisture sites, protein was not significantly correlated to head densities (p=0.606) or tillering (p=0.518) (Figure 11). However, at the high moisture sites, protein was negatively correlated to head densities (r=-0.53; p<0.001) and followed a similar trend to yield (Figure 12). The effect of seeding rates on protein was not significant at low (p=0.910) or high (p=0.204) moistures sites (Figure 14). Overall, the seeding rates and moisture conditions had minimal effects on protein levels in wheat and yield was the most influential factor.

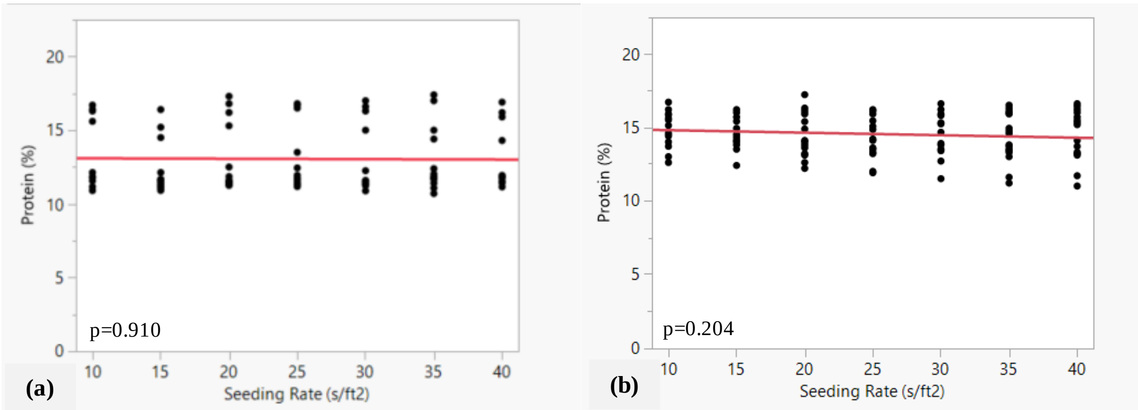

Figure 14. Effect of seeding rate on protein (%) in low (a) and high (b) moisture conditions.

Seed Weight

The seed weight response to seeding rates was similar across locations. The general trend across all sites suggested that seed weight decreased as seeding rates increased, so that the lowest seed weights commonly occurred at the highest seeding rates. At Scott (p=0.332) and Melfort (p=0.537) this response was not significant. However, there was a significant linear response at Yorkton (p=0.048), Indian Head (p=0.023), and Swift Current (p=0.001). Seed weights were significantly different between sites (p<0.001). The highest mean seed weight was recorded at Yorkton (41.2 g), followed by Melfort (39.7 g), Scott (37.3 g), Indian Head (35.4 g), and Swift Current (29.6 g). Seed weights were not measured for the Prince Albert site. When sites were analyzed in moisture groups, there was no response to seeding rate at low (p=0.532) or high (p=0.671) moisture sites (Figure 15). Thus, suggesting that seeding rate does not significantly impact the seed weight irrespective of moisture conditions.

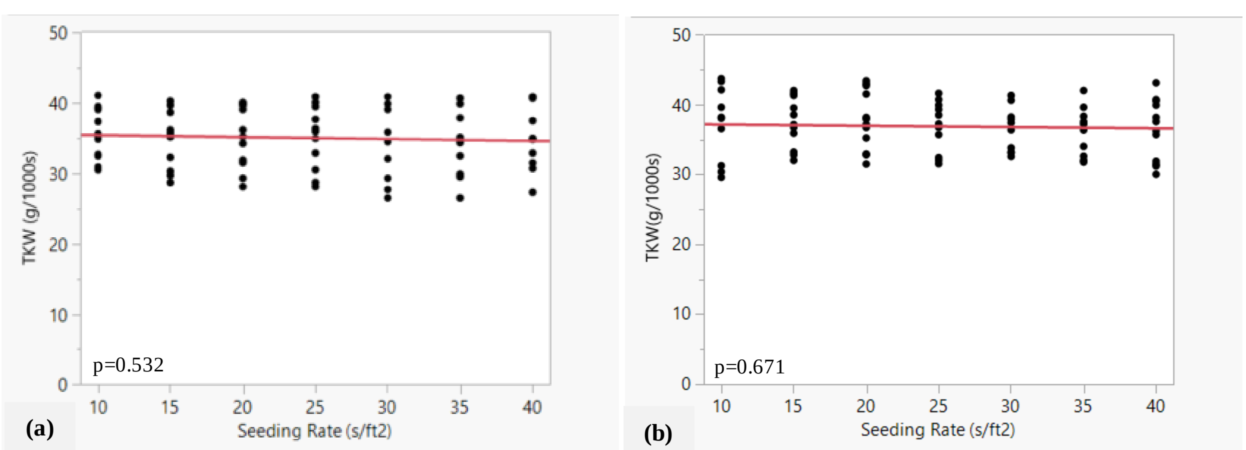

Figure 15. Effect of seeding rate on seed weight (g/1000 seeds) in low (a) and high (b) moisture conditions.

Conclusion and Recommendations:

This study demonstrated the effects of seeding rates under various environmental conditions throughout Saskatchewan. Consistent trends emerged across all locations for all factors evaluated in this study except yield. The plant and head densities tended to increase as seeding rates increased at all locations; however, the effect was stronger at high moisture sites than low moisture sites. Furthermore, lodging also tended to increase with increasing seeding rates, but only at high moisture sites. Tiller density, head length, and head size tended to decrease as seeding rates increased for all locations, but to a greater degree at high moisture sites than low moisture sites. The effect of seeding rate on protein and seed weight was minimal for all locations regardless of moisture conditions. Protein was influenced to a greater degree by the yield trends observed at each location than moisture conditions. The effect of seeding rate on yield varied greatly depending on location. Therefore, low and high moisture groups were analyzed to confirm consistent trends. At low moisture sites the yields tended to decrease as seeding rates increased; whereas at high moisture sites the yields tended to increase as seeding rates increased. Head density and tillering were the most significant factors influencing yields compared to other factors evaluated in the study. However, the impact of these factors varied based on moisture conditions. The highest yields for both head density and tillering occurred consistently at seeding rates of 20 seeds/ft^2 in low moisture conditions and 30 seeds/ft^2 in high moisture conditions. Consequently, the highest yields also occurred most frequently at these seeding rates. Therefore, it is recommended that 20 seeds/ft^2 in low moisture conditions and 30 seeds/ft^2 in high moisture conditions can be used to optimize yields. Ultimately, this study confirms that seeding rates to optimize yield vary based on environmental conditions. Further research to understand these impacts on topography throughout a field would be beneficial to determine whether varying seeding rates based on topography could be used to optimize yields throughout entire fields.

Extension Activities

A fact sheet will be created and distributed on the websites for all six locations as well as participating location events to ensure the information will be transferred to producers. The trial was showcased during the growing season at the annual "Scott Field Day" on July 12th, 2023 (WARC), the "Indian Head Crop Management Field Day" on July 18th (IHARF), the "NARF & AAFC Joint annual field day" at Melfort on July 26th, and "Walk the Plots" Radio Show on August 13th (WCA). Results from the study will be presented at "IHARF Soil & Crop Management Seminar" on February 7th (IHARF), "Independent Consulting Agronomist Network" on February 8th (IHARF), "Crop Opportunity" on March 7th (WARC), and the "Agri ARM Winter Webinar" on March 26th, 2024.

Supporting Information

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Appendices:

Appendix A1. p values for seeding rates in wheat and their interactions on plant density, plant establishment, head density, head length, lodging, yield, protein and seed weight at six sites across Saskatchewan in 2023.

Effect	Plant Density	Plant Establishment	Head Density	Head Length	Lodging	Yield	Protein	Seed Weight
		---------------------------------------p value---						
Seed Rate (SR)	**<0.001***	**<0.001**	**<0.001**	**<0.001**	**0.021**	0.139	**<0.001**	**<0.001**
Site (S)	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.790	**<0.001**	**<0.001**	**<0.001**
S x SR	0.304	**0.041**	**<0.001**	**0.030**	**0.001**	0.286	**0.034**	**0.065**
SR - linear	**<0.001**	0.146	**0.011**	**<0.001**	0.060	0.590	0.438	0.266
SR - quadratic	**0.012**	**0.021**	0.538	0.430	0.817	0.473	0.685	0.751

*Bold numbers indicate significance at p<0.05 using estimated marginal means comparison.

Appendix A2. Agronomic information for the study of "Evaluation of Seeding Rates of Wheat Under Various Environmental Conditions" study at a) Scott, b) Indian Head, c) Melfort, d) Prince Albert, e) Swift Current and f) Yorkton, Saskatchewan, 2023.

a) Scott, SK			
Agronomic Information	Product	Rate	Date
Fertilizer	73-17-7-3	150 lb/ac (sideband)	May 12, 2023
Seed	AAC Wheatland VB	As per protocol	May 12, 2023
Herbicide: Pre-plant In-Crop 2nd In-Crop	 Glyphosate 540 & AIM Axial & Infinity Buctril M	 1 L/ac & 0.35 L/ac 0.5 L/ac & 0.33 L/ac 0.4 L/ac	 May 11, 2023 June 2, 2023 June 13, 2023
Fungicide	Caramba	400 mL/ac	July 5, 2023
Insecticide	Decis	60 mL/ac	July 7, 2023
Desiccation	Glyphosate 540, Heat LQ & Merge	1 L/ac, 59mL/ac & 200 mL/ac	August 15, 2023
Harvest	-	-	August 28, 2023

b) Indian Head			
Agronomic Information	Product	Rate	Date

Fertilizer	Urea (46-0-0), monoammonium phosphate (11-52), potash (0-0-60) and ammonium sulfate (21-0-0-24)	135-40-20-20 kg N-P_2O_5-K_2O-S/ha (sideband)	May 10, 2023
Seed	AAC Wheatland VB	As per protocol	May 10, 2023
Herbicide: Pre-plant In-Crop 2nd In-Crop	- Octain XL & Simplicity GoDRI -	- 0.45 L/ac & 28 g/ac -	- June 8, 2023 -
Fungicide	Prosaro Pro & Agrol 90	0.304 L/ac & 0.125%	June 30, 2023
Insecticide	Coragen Max	33.3 mL/ac	June 22, 2023
Desiccation	Roundup Weathermax	0.67 L/ac	August 12, 2023
Harvest	-	-	August 18, 2023

c) Melfort			
Agronomic Information	Product	Rate	Date
Fertilizer	Urea (46-0-0), monoammonium phosphate (11-52), potash (0-0-60) and ammonium sulfate (21-0-0-24)	132 lb/ac, 50 lb/ac, 15 lb/ac and 10 lb/ac	May 17, 2023
Seed	AAC Starbuck	As per protocol	May 17, 2023
Herbicide: Pre-plant In-Crop 2nd In-Crop	StartUp Prestige XL Axial	1 L/ac 0.947 L/ac 0.5 L/ac	May 19, 2023 June 7, 2023 June 20, 2023
Fungicide	Caramba	0.4 L/ac	July 17, 2023
Insecticide	Decis 5EC	60 mL/ac	June 23, 2023
Desiccation	-	-	-
Harvest	-	-	August 29, 2023

d) Prince Albert			
Agronomic Information	Product	Rate	Date
Fertilizer	Urea (46-0-0) and monoammonium phosphate (11-52)	110 lb/ac and 23 lb/ac	June 5, 2023
Seed	AAC Brandon	As per protocol	June 5, 2023
Herbicide: Pre-plant In-Crop 2nd In-Crop	Prepass XC A&B - -	100 mL/ac & 940 mL/ac - -	May 26, 2023 - -
Fungicide	-	-	-
Insecticide	-	-	-

Desiccation	-	-	-
Harvest	-	-	September 7, 2023

e) Swift Current			
Agronomic Information	Product	Rate	Date
Fertilizer	30-15-0-6	266 lb/ac	May 9, 2023
Seed	CDC Adamant VB	As per protocol	May 9, 2023
Herbicide: Pre-plant In-Crop 2nd In-Crop	NA Liquid Achieve, Buctril M & Carrier -	NA 200 mL/ac, 400 mL/ac & 0.5L/100L -	April 28, 2023 June 8, 2023 -
Fungicide	-	-	-
Insecticide	-	-	-
Desiccation	-	-	-
Harvest	-	-	August 19, 2023

f) Yorkton			
Agronomic Information	Product	Rate	Date
Fertilizer	Urea (46-0-0) and monoammonium phosphate (11-52)	240 lb/ac & 58 lb/ac	NA
Seed	AAC Alida VB	As per protocol	NA
Herbicide: Pre-plant In-Crop 2nd In-Crop	- Simplicity & Agral 90 Axial	- NA NA	- June 7, 2023 June 12, 2023
Fungicide	Prosaro XTR	NA	July 5, 2023
Insecticide	-	-	-
Desiccation	NA	NA	NA
Harvest	-	-	NA

Appendix A3. Soil test information for the study of "Evaluation of Seeding Rates of Wheat Under Various Environmental Conditions" study at Scott, Indian Head, Melfort, Prince Albert, Swift Current and Yorkton, Saskatchewan, 2023.

Location	**Depth (cm)**	**N (lb/ac)**	**P (ppm)**	**K (ppm)**	**S (lb/ac)**	**Organic Matter (%)**	**Soil pH**	**CEC (meq)**
Scott	0-15 15-30	6 4	19 -	314 -	30 26	4.0 -	6.4 7.6	18.0 -
Indian Head	0-15 15-60	9.01 11.9	6 -	596 -	31.9 251.8	6.2 -	7.6 8.1	46.6 -
Melfort	0-15 15-30	16 24	9 -	401 -	32 54	7.6 -	6.4 7.3	- -

Prince Albert	0-15 15-30	49 58	15 -	139 -	22 16	3.6 -	5.5 6.1	19.1 -
Swift Current	0-15 15-30	5 6	5 -	231 -	8 10	3.1 -	6.2 6.8	17.5 -
Yorkton	0-15 15-30	16 17	16 -	353 -	26 20	7.8 -	6.8 7.7	27.4 -

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