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FINAL REPORT

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OPTIMAL SEEDING RATE WITH PLANT GROWTH REGULATORS AND FUNGICIDES FOR SPRING WHEAT

Funded by: The Saskatchewan Ministry of Agriculture under the Canada-Saskatchewan Growing Forward bi-lateral agreement

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Project Identification

1. **Project Title:** Optimal Seeding Rate with Plant Growth Regulators (PGRs) and Fungicides for Spring Wheat
2. **Project Number:** 20140412
3. **Producer Group Sponsoring the Project:** Northeast Agriculture Research Foundation
4. **Project Location(s):** SE 30-44-18 W2 RM of Star City; Scott; Swift Current; Scott
5. **Project Start and End Dates (Month & Year):** April 2015 to January 2016
6. **Project Contact Person & Contact Details:**

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Objectives and Rationale

7. **Project Objectives:** The objective of this project is to provide producers with the information on the yield benefits associated with increasing the seeding rate of spring wheat accompanied by plant growth regulator (PGR) applications to reduce the risk of lodging and fungicides applications to control disease.
8. **Project Rationale:** Producers have noted benefits associated with increasing the seeding rate of spring wheat, higher than recommended, in order to target higher wheat yields. Generally, a more dense plant stand allows the crop to compete better with weeds. It can also reduce tillering, which results in a crop stand that is more developmentally similar. In addition, fungicide applications, like those to control Fusarium Head Blight (FHB), are easier to stage for optimal application timing with a more even crop stand. Proper staging of fungicides for FHB control is complicated with low plant densities because there is more tillering and each successive tiller on a plant is later than those that develop earlier. Proper application timing of fungicides can enhance and protect grain yield and quality. However, a more dense plant stand often induces or increases the risk of lodging. One way to

overcome lodging, with higher seeding rates, is to use a plant growth regulator. Plant growth regulators (PGRs) has proven effective at both IHARF and NARF since demonstrations began in 2013. They have effectively reduced crop height, lodging, and increased wheat yields. Overall, we expect to identifty the optimal seeding rate to use with PGRs and fungicides in order to enhance spring wheat yield and quality across Saskatchewan.

Methodology and Results

9. Methodology: This demonstration was conducted at three Agri-ARM sites in 2015. At each site, the trial was set up in a Randomized Complete Block Design with four replicates. Each site selected the most appropriate wheat variety for their region and seeded at the various treatment rates (Table 1).

Table 1: Description of Treatment Used at Each Site for ADOPT Optimal Seeding Rate with Plant Growth Regulators and Fungicides in Spring Wheat.

Treatment #	Seeding Rate (Seeds/m^2)	PGR Applied	Fungicide Applied
1	100	No	No
2	200	No	No
3	300	No	No
4	400	No	No
5	100	Yes	No
6	200	Yes	No
7	300	Yes	No
8	400	Yes	No
9	100	No	Yes
10	200	No	Yes
11	300	No	Yes
12	400	No	Yes
13	100	Yes	Yes
14	200	Yes	Yes
15	300	Yes	Yes
16	400	Yes	Yes

Soil samples were taken at each site in order to fertilize appropriately for a targeted 70 bu/ac wheat crop. Soil residual nutrient levels for each site can be found in Appendix 1. Fertilizer application product, rates, and placements are as indicated in Table 2. Herbicides and insecticides were applied and selected based on the best product to control the specific pests at each site. The plant growth regulator (PGR) used was Manipulator applied at 1.78 L/ha at Zadoks 31 as recommended. Caramba was the fungicide used and applied at

280 mL/ac at head emergence. Each site was harvested using a plot combine when the wheat crop reached maturity. The specific agronomic info for each site is included in Appendix 1.

Table 2: Fertilizer Applied at each site based on soil test recommendations to target a 70 bu/ac crop.

Site	Fertilizer	Kg/ha	Placement
Melfort	46-0-0	227.3	Side-banded
	11-52-0	59.82	Seed-placed
Scott	46-0-0	210.9	Mid-row
	11-52-0	54.0	Side-banded
	21-0-0-24	46.9	Side-banded
Swift Current	30-15-0-6	337.1	Side-banded

Crop emergence, crop height, lodging ratings, days to maturity as well as grain yield and quality were recorded. For crop emergence, the number of wheat seedlings in 2 one meter paired rows in the front and back of each plot (4 meters total) were counted. After the crop had reached physiological maturity, 25 plants from each plot were measured for total height from the ground to top of the head (excluding awns). Lodging and maturity ratings were taken at the same time. For lodging, the Belgian Scale was used to measure the extent and severity of lodging, where the area of each plot that is lodged is estimated (1 = no lodging and 10 = the entire plot is lodged). Intensity of lodging is rated on a 1-5 scale where 1 indicates stems are upright while 5 is stems that are totally flat. The lodging score is calculated as follows: area (1-10) * intensity (1-5) * 0.2. Grain yield was determined by cleaning the whole sample harvested from each plot and weighed. A subsample from each plot was then used to determine thousand kernel weight (g/ 1000 seeds), grade (CCC Standards), % fusarium damaged kernels, test weight (g/0.5L), and % protein.

Weather

In Melfort, the average temperature throughout the growing season was similar to the long-term average (Table 4). May was the only month to be lower than average, with the rest all being warmer. Overall, moisture received was greater than the long term average. May was the only month to receive substantially less precipitation than average. June and August were relatively normal. July was exceptionally wet with over 100 mm falling within six hours, late in the month. September was also very wet and received 42.3 mm more than average for the month.

In Scott, mean monthly temperature during the growing season was similar to the long-term average (Table 4). May was slightly cooler, while June and July were slightly warmer, and August and September were average. May, June, and July were very dry in comparison to the long term average. These months received 88%, 69%, and 36% of their respective totals. Conversely, August and September received 63% and 38% more than their monthly averages, respectfully.

At Swift Current, conditions were exceptionally dry during May with the month only receiving 2.9 mm of rain. June was dry as well receiving only a third of the average precipitation. July was exceptionally wet, receiving double the amount of normal precipitation in that month. Lastly, August and September received slightly more precipitation than normal. Overall, precipitation was less than average, but conditions substantially improved from the beginning of the growing season.

Overall, Melfort tended to be the wettest location followed by Scott and then Swift Current during 2015, in line with long term averages. Swift Current was also warmer than either Scott or Melfort on average per month. However, the overall average temperature at each site is similar.

Table 4: Mean monthly temperature and precipitation, and Long-Term Averages from 1981 to 2010 for Melfort, Scott, and Swift Current SK., 2015.

Location	Year	May	June	July	Aug	Sept	Average/Total
				Temperature (^{0}C)			
Melfort	2015	9.9	16.4	17.9	17.0	11.9	14.6
	Long term	*10.7*	*15.9*	*17.5*	*16.8*	*10.8*	*14.3*
Scott	2015	9.3	16.1	18.1	16.8	10.9	14.2
	Long term	*10.9*	*15.3*	*17.1*	*16.5*	*10.4*	*14.0*
Swift	2015	10.3	17.1	18.7	18.3	12.6	15.4
Current	*Long term*	10.8	15.4	18.4	18.1	12.3	15.0
				Precipitation (mm)			
Melfort	2015	7.1	54.8	149.8	57.4	70.0	339.1
	Long term	*42.9*	*54.3*	*76.7*	*52.5*	*38.7*	*265.0*
Scott	2015	4.1	19.4	46.4	74.5	49.6	194.0
	Long term	*36.3*	*61.8*	*72.1*	*45.7*	*36.0*	*215.9*
Swift	2015	2.9	20.7	101.6	51.5	42.5	219.2
Current	*Long term*	50.4	77.7	54.1	45.6	35.7	263.5

10. Results:

Crop Emergence

Overall, at all three sites, precipitation received throughout May was significantly lower than the long-term average. These dry early season conditions resulted in often sporadic and/or difficult germination situations. At Melfort, 4 plots of wheat at the 300 seeds/m^2 seed rate were inadvertently sown shallower than intended. These plots had much lower than expected crop emergence, and this data was excluded from the results. As expected, there was a statistically significant increase in plant density as seed rate increased (Table 5). However, there was a general trend for the percentage of seeds planted that emerged

(% emerged) to decline as seed rates increased. This trend was most evident at Melfort where overall emergence was highest, and least at Swift Current where overall emergence was lowest. Declining percent emergence as seed rates increase is a typical response. It reflects intra-plant competition for moisture, which is vital for germination and emergence. Intra-plant competition increases as the number of seeds within the immediate area increases. However, this does not explain why this effect was less evident at Swift Current. Site differences in soil conditions may have influenced results, but further investigation would be needed to evaluate whether this was the case. Regardless, plant densities at all locations tended to be lower than expected. Due to lower than typical emergence rates, producers should be reminded of the adverse associated with the effects of decreased seeding rates, especially under dry conditions.

Table 5: Effect of seed rate on plant density (plants/m^2) at Melfort, Scott, and Swift Current, SK in 2015.

Seed Rate	**Melfort**		**Scott**		**Swift Current**	
(seeds/m2)	plants/m^2	% emerged	plants/m^2	% emerged	plants/m^2	% emerged
100	88	88	63	63	49	49
200	122	61	114	57	90	45
300	174	58	164	55	140	47
400	207	52	209	52	188	45
P-Value	<0.001		<0.001		<0.001	

Height, Lodging, and Maturity

At Melfort and Scott, crop height was significantly affected by PGR application and seed rate (Table 6). Height was not significantly affected by interactions. At Swift Current there were no significant effects of any factors or their interactions on crop height. At Swift Current they seeded a Durum wheat variety, while Melfort and Scott both used Shaw VB, a HRSW. Thus differences between sites may have been related to wheat type. Moreover, field scale trials with Manipulator have shown that Durum responds variably to Manipulator, so there is no surprise there was no height effect by the PGR. In addition, height response differences may also be due to climatic condition differences between each site. Due to the very dry growing season, the plants may have been stressed and unable to achieve full height potential, therefore were unable to be shortened as much as it could have.

At both Melfort and Scott, where PGR was effective, crop height was the shortest at the 400 seeds/m^2 seed rate (Table 6). At Melfort, height was similar for the 100, 200, and 300 seeds/m^2 rates, averaging 85 cm. At Scott, the tallest plants belonged to the 100 seeds/m^2 treatment, while the 200 and 300 seeds/m^2 treatments were the same at 72 cm.

Interestingly, overall crop height was much shorter at Swift Current than at Scott or Melfort, and this may have played a role in the lack of any significant response of crop height to seed rate or PGR.

Table 6: Influence of seed rate, PGR, and Fungicide application on crop height, lodging and days to maturity for wheat grown at Mlefort, Scott and Swift Current SK in 2015.

Treatment	Melfort	Scott	Swift Current	Melfort	Melfort	Scott	Swift Current
Seed Rate		*Height (cm)*		*Lodging*		*Days to Maturity*	
100	85	74	59	0.3	99	99	102
200	86	72	59	0.8	97	94	99
300	87	72	59	0.5	97	91	98
400	80	69	59	0.5	96	91	99
P value	<0.001	0.015	0.881	0.057	0.127	<0.001	<0.001
PGR							
Yes	75	67	59	0.3	98	94	99
No	94	77	59	0.8	97	93	100
P value	<0.001	<0.001	0.456	<0.001	0.516	0.059	0.327
Fungicide							
Yes	84	71	59	0.6	97	94	100
No	85	72	59	0.5	98	93	99
P value	0.271	0.165	0.532	0.423	0.055	0.025	0.523

Melfort was the only site to have lodging occur and overall levels were very low. Here, PGR application and the interaction between seed rate, PGR, and fungicide were factors having a slight effect on lodging (Table 6). With PGR application, the average rating for lodging was 0.3, a very minimal amount. Having no PGR applied resulted in a higher rating of 0.8 (Table 7). Although there was no significant effect of seeding rates, lodging was highest at the 200 seeding rate and intermediate at 300 and 400 seeds/m^2. Any of the combined treatments that received PGR were statistically similar to each other (Figure 1). The control and fungicide only treatments had more lodging recorded. The control group did not have significantly different lodging. However, in the fungicide only group, the 200 seed rate had the highest lodging rating. It was significantly different from the other results in its group, with the other three seed rates not being different from each other.

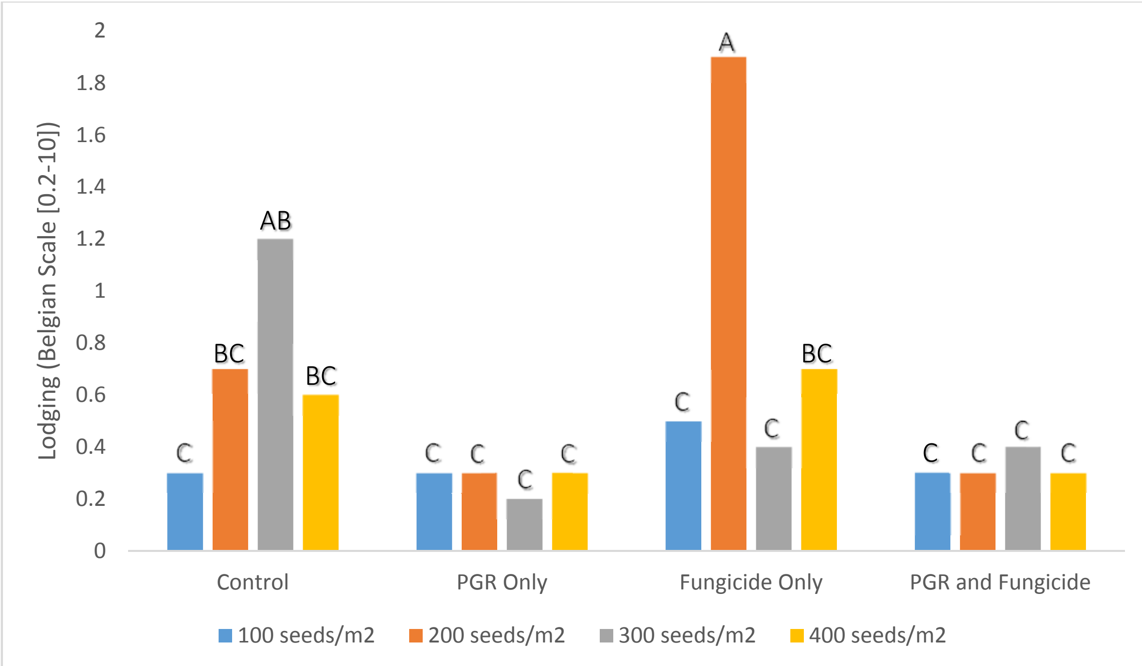

Figure 1: Treatment mean differences between the rates of lodging at Melfort, SK in 2015. Letters with the same letter are statistically similar to each other

At Scott and Swift Current, days to maturity were significantly reduced by increased seeding rates (Table 6). In addition, the days to maturity at Scott were slightly affected by PGR, Fungicide, and the interaction between seed rate and PGR. At Melfort, days to maturity were unaffected by any factor and averaged 97 days (Table 7). At Scott, addition of PGR and fungicide delayed maturity by about 1 day, but the P value for the PGR effect was only 0.059 (Table 6).

Yield and Grain Quality

One of the objectives of this demonstration was to illustrate and identify the best combination of factors to increase yield in wheat. Unfortunately, there was no single treatment or combination of treatments that significantly impacted yield. Fungicide application was the only factor to slightly affect yield in Scott, while seed rate and fungicide application were the factors slightly affecting yield in Melfort (Table 8). At Swift Current, yield was not affected statistically by any factor. Yield was greatest at Melfort and the least at Swift Current. At Melfort, the highest yields were from the 200 and 300 seed rate treatments, which were similar to each other averaging 3700 kg/ha (Table 8). The lowest yields were found at the 100 and 400 seed rates, which were also similar to each other, at 2950 kg/ha. The fungicide application also resulted in yield increase of about 100 kg/ha (Table 8). At Scott, the fungicide application also increased yield but was more dramatic with a 400 kg/ha increase (Table 8).

Table 8: Influence of seed rate, PGR, and Fungicide application and their interactions on grain yield and fusarium damaged kernels at Melfort, Scott and Swift Current SK in 2015.

Treatment	Melfort	Scott	Swift Current	Melfort	Scott	Swift Current
Seed Rate		*Yield (kg/ha)*			*Fusarium damaged kernels (%)*	
100	3008^{b}	2536^{b}	2211^{a}	1.5^{a}	0.009^{a}	N/A
200	3792^{a}	2799^{ab}	2218^{a}	1.0^{ab}	0.005^{a}	N/A
300	3630^{a}	2916^{a}	2202^{a}	1.5^{a}	0.004^{a}	N/A
400	2899^{b}	2675^{ab}	2108^{a}	0.9^{b}	0.004^{a}	N/A
P value	0.0002	0.1482	0.6025	0.0461	0.1754	N/A
PGR						
Yes	3275^{a}	2744^{a}	2154^{a}	1.5^{a}	0.007^{a}	N/A
No	3389^{a}	2719^{a}	2215^{a}	1.0^{b}	0.004^{a}	N/A
P value	0.4713	0.8334	0.3582	0.0132	0.1723	N/A
Fungicide						
Yes	3548^{a}	2950^{a}	2167^{a}	1.3^{a}	0.008^{a}	N/A
No	3117^{b}	2513^{b}	2202^{a}	1.1^{a}	0.003^{b}	N/A
P value	0.0086	0.0006	0.5915	0.2335	0.0191	N/A

Another objective of this demonstration was to illustrate the best combination of agronomic inputs to protect and improve wheat yield. One would expect that the application of fungicide would have a significant impact on maintaining grain quality. However, fungicide application only had a significant effect on protecting kernels from fusarium head blight damage at Scott (Table 8). Contrary to what one might expect, seed rate and PGR application were the factors to affect the percentage of FHB damaged kernels at Melfort. In 2015, Swift Current was unaffected by Fusarium Head Blight. Another factor that determined grain quality is percentage protein. At Melfort, protein was statistically affected by seed rate (Table 9). Generally, protein tended to be lowest at the lowest and highest seeding rates, and highest at the mid rates. At Scott, seed rates slightly affected wheat protein, however, the resulting levels are insignificant in general terms, with levels only differing between 0.1 to 0.3% (Table 9). PGR and fungicide significantly affected protein at Scott with PGR increasing and fungicide decreasing protein content. The interaction between seed rate and fungicide also affected protein at Scott. Without PGR and fungicide application protein was higher. Swift Current did not report a protein percentage for their demonstration.

Table 9: Influence of seed rate, PGR, and Fungicide application and their interactions on grain protein and bushel weight at Melfort, Scott and Swift Current SK in 2015.

Treatment	Melfort	Scott	Swift Current	Melfort	Scott	Swift Current
	Protein (%)			*Bushel Weight (kg/Hl)*		
Seed Rate						
100	12.8	14.4	N/A	74.4	80	78
200	13.2	14.2	N/A	75.2	80	79
300	13.1	14.1	N/A	75.4	80	79
400	11.9	14.2	N/A	74.2	81	79
P value	<0.001	0.012	N/A	0.010	0.310	0.015
PGR						
Yes	12.7	14.0	N/A	74.2	80	79
No	12.8	14.4	N/A	75.4	81	79
P value	0.528	<0.001	N/A	<0.001	<0.001	0.540
Fungicide						
Yes	12.8	14.0	N/A	75.2	81	78
No	12.7	14.4	N/A	74.4	80	79
P value	0.752	<0.001	N/A	0.184	<0.001	0.134

Thousand kernel weight and bushel weights are also factors that affect grain quality. Thousand kernel weight was slightly affected by PGR application in Melfort and Scott (data not shown). In addition, thousand kernel weight was affected at Scott by the interaction between seed rate and fungicide. Swift Current was the only site to have the thousand kernel weight affected by seed rate.

Overall, a number of factors affected bushel weight. At Melfort and Swift Current, seed rate affected bushel weight (Table 9), with the lowest seed rate having lower bushel weight than either of the mid rates. At Melfort, the highest seed rate also resulted in low bushel weight. Bushel weight was significantly decreased by PGR at both Melfort and Scott, while fungicide increased bushel weight at these two sites. Overall, although these effects on bushel weight tended to be rather small, and because they were not very consistent, were of limited practical significance.

Percentage of fusarium damaged kernels, percentage protein, thousand kernel weight, and bushel weight are all factors that help determine the grade of wheat. This ultimately determines the price a producer will receive for their crop and can be used as an economic indicator. Differences between the grades of each treatment were only recorded at Melfort. All treatments at Scott were rated as Grade 1 CWRS, while Swift Current was Grade 2 CWAD. At Melfort, grade was affected significantly by seed rate and PGR application (Figure 2). However, due to inconsistency between effects, it is difficult to predict the practical significance of any of these effects.

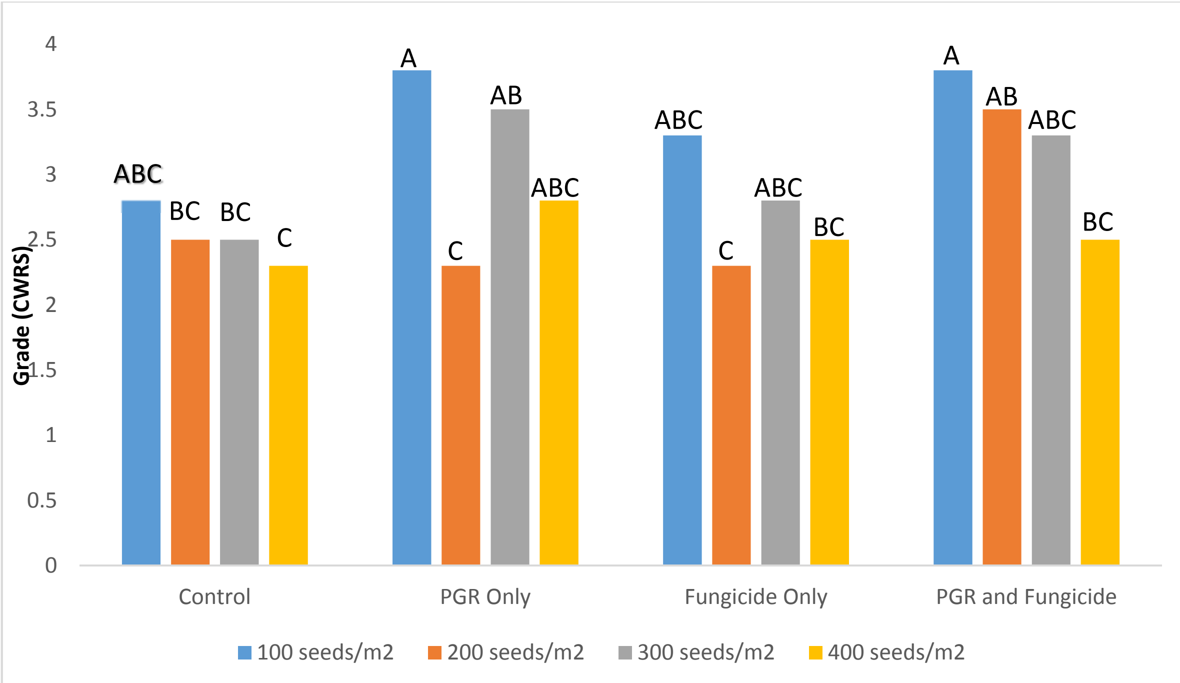

Figure 2: Mean differences between the grades of each treatment for Melfort, SK, 2015.

11. **Conclusion and Recommendation:** Overall, there was no single combination of factors that consistently increase yield or grain quality at all three sites, as we had hoped. As expected, plant densities were highly affected by seeding rate. Melfort had the greatest response to plant density in comparison to Scott or Swift Current, which had the least response. This response to seeding rate is most likely a reflection of the dry conditions at seeding. Each site would have had different soil moisture reserves at the time of seeding. Melfort and Scott then received a small amount of moisture in the following weeks likely generating the response. Height was significantly affected by PGR application at Melfort and Scott. As expected, height was substantially shorter with PGR application at these sites. In addition, seed rate affected height at Melfort as well. The lowest seeding rate had taller plants and decreased with seed rate, resulting in the 400 seeds/m^2 treatment being the shortest. Swift Current did not see a response to PGR application, which is likely a result of a combination of factors. One, is that the plants may have been severely stressed from the dry conditions and did not achieve their full height potential, therefore were unable to shorten as much. The other is that Durum wheat varieties have been known to have a variable response to Manipulator, as shown in field scale trials. Lodging and maturity rate treatment differences reflected expected trends. Yield was unaffected by any factor in Swift Current. At Melfort and Scott, yield was increased with fungicide application. In addition, at Melfort, yields were higher at the 200 and 300 seeds/m^2 rate treatments. As for grain quality, % FHB damaged kernels was reduced with PGR and fungicide applications separately at Melfort and Scott (Swift Current did not have FHB). The treatment that had higher yields at Melfort and Scott, were also associated with a higher percentage protein. PGR application also

increased bushel weights at Scott and Melfort as well. Overall, there was only a difference in resulting grade of each treatment at Melfort. The results was highly inconsistent and no trends were confirmed. Overall, the optimal seeding rate, in combination with PGR and fungicide application, to increase yield and quality in wheat was unidentified at each site. This may be due to the overall climatic conditions at each site, as they were very variable throughout the growing season. However, this demonstration does show that the current recommended seeding rate for spring wheat, and the application of PGR and/or fungicides, each provide their own benefit for increasing yield and protecting/improving grain quality.

Supporting Information:

12. Acknowledgements: 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. This project was featured as part of our Annual Field Day hosted by both AAFC and NARF on July 22nd, 2015. We would also like to thank Engage Agro for their in-kind contribution of Manipulator for each site. Lastly, Stephanie Ginter, Gaylene Dagenais, Rikki Schick, and Jillian Anderson for their technical assistance in conducting this demonstration.

13. Abstract and Summary:

There are many benefits associated with increasing the seeding rate of spring wheat, such as improved weed competition, more uniform development, and increased yields. However, many producers tend to stay with the recommended rate due to increased lodging and possibly of disease, both which outweigh the benefits in most years. Therefore, the objective of this project was to provide producers with information on the yield benefits associated with increasing the seeding rate of spring wheat when accompanied by plant growth regulators (PGRs) and fungicides. Thus we hope to identify the optimal seeding rate to be used with these agronomic practices. This demonstration was put into place at three Agri-ARM sites (Melfort, Scott, and Swift Current) in Saskatchewan. At each site, 100, 200, 300, and 400 seeds/m^2 were seeded during May 2015. These seeding rates were then randomly treated as a control or had a PGR and/or fungicide applied. Plant density, height, lodging, maturity, yield, and grain quality factors were all recorded, as a measure of treatment effects. All sites had plant densities that were significantly impacted by seed rate, as expected, but varied in emergence rates due to dry conditions during seeding. Heights were only significantly reduced by PGR application at Melfort and Scott. Surprisingly, fungicide application resulted in a significant increase on the amount of FHB damage at Scott. Overall, yield and quality were affected by a variety of independent factors at each site. Fungicide was associated with higher yields at both Melfort and Scott, while PGR was associated in increasing thousand kernels weights and bushel weights.

Lastly, Melfort was the only site to experience grade differences between treatments, however, they were inconsistent. Overall, we were unable to identify the optimal seeding rate to be used with PGR and fungicide application, as all factors provide their own benefits.

Appendix 1: Agronomic Information Collected From Each Site.

Table 1: Soil test residual levels from composite samples submitted from each site reported as lb/ac.

Site	NO3-N	P	K	SO4-S	NO3-N	P	K	SO4-S
	0-6"				**6-12"**			
Melfort	15	24	>510	8	21	N/A	N/A	9
Scott	21	42	508	16	9	N/A	N/A	9
	0-12"							
Swift Current	31	17	N/A	N/A				

Table 3: Specific agronomic information for each site.

Site	Variety	Seed Date	Herb. App. Date	Herb. Prod. & Rate	PGR Appl. Date	Fungicide Appl. Date	Desiccation Prod. & Rate	Desiccation Date	Harvest Date
Melfort	Shaw VB	May 20th			June 26th	July 13th			Sept. 30th
Scott	Shaw VB	May 12th	Pre-plant: May 15th	Roundup @ 0.75L/ac & Pardner 0.4 L/ac			Glyphosate @ 1L/ac – August 20th		Sept. 1st
			In-crop: June 10th	Buctril M @ 0.4 L/ac & Axial 0.48 L/ac					
Swift Current	Strongfield (Durum)	May 28th	In-crop: June 15th	Liquid Achieve @ 0.2 L/ac, Buctril M @ 0.4L/ac & Turbocharge @0.5 L/0.1L	July 9th	July 27th		N/A	Sept. 11th