Field Pea Input Study

2014 Final Report

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Funded by:

Saskatchewan Pulse Growers
SPG Project AGR1123

EXECUTIVE SUMMARY

Yield responses to individual inputs are often measured in research or on-farm trials, however, it is less well understood how the combination of multiple inputs can interact and affect yields. Farmers need to determine not only which inputs will have the largest impact on harvestable yield but also provide the best economic return. Treatments used in this study started with an "empty" input package (seeding rate of 60 seeds m^{-2} with liquid inoculant) and the effects of additional inputs such as high seeding rate (120 seeds m-2), foliar fungicide, seed treatment, granular inoculant (instead of liquid inoculant) or 30 lbs N ac^{-1} starter fertilizer both alone and in various combinations were measured. The "full" input package received all five of the additional inputs. The objective of the experiment was to determine 1) which individual agronomic inputs contribute most to field pea seed yield 2) which combination produces the highest seed yield and economic return and 3) how plant population, leaf and stem disease, crop maturity, grain yield and quality are affected by input interactions. Field trials were conducted in 2012-2014 at the Agri-ARM sites located at Scott, Swift Current, Melfort and Indian Head SK and a fifth site, Minto MB, was added in 2014. Due to excess moisture in 2013, the trial at Melfort was terminated; therefore data was collected from only twelve site years. Plant density was increased from an average of 56 to 102 and 52 to 89 plants m-2 with low to high seeding rates at high and low yielding sites, respectively. This range of densities is outside the traditionally recommended plant density, so it is difficult to assess if our current recommendations provide the crop with plant density high enough to maximize yield potential. Granular inoculant and ST also increased plant density, but to a much lower extent than SR. Starter N fertilizer resulted in significant, but relatively small reductions in plant density. Disease levels were generally higher with SR early and later in the growing season and lower with Fn later in the season, regardless of environment. Granular inoculant also decreased disease levels when averaged across high yielding site years. Maturity was affected by SR and Fz only; generally, SR decreased maturity and Fz increased maturity. Under relatively good growing conditions, such as those encountered at Scott, Melfort and Minto, input combinations of two or three inputs interacted in an additive fashion on average at high yielding sites. Generally, averaged across high yielding sites, seed yield increased and yield variability decreased with each additional input added to the input package. Higher seeding rates, Fn and GI were the three inputs which consistently increased seed yields and economic return at these sites, especially when applied all in combination. In contrast, the addition of ST or Fz did not consistently improve yields or economic returns. Under poor growing conditions, such as those encountered at Indian Head and Swift Current, seed yields were more variable and input interactions were generally not additive. The overall response to SR and Fn was significant; however, the high cost of the Fn resulted in those treatments having the lowest economic return. Either SR or Fz applied alone maximized yield and economic return averaged across low yielding sites. We recommend all farmers use seeding rates to target the recommended plant population to maximize yield potential. Under situations where the farmer targets relatively high yields, we recommend also using a granular inoculant to ensure nodulation and nitrogen fixation can provide sufficient levels of nitrogen to the crop. If the crop develops a thick canopy and/or disease develops, adding a foliar fungicide will protect and maintain the yield potential of the crop. We do not expect to see a yield response using starter nitrogen fertilizer, except when there are other limitations which restrict yield potential and nitrogen fixation. Seed treatments did not result in consistent yield improvements in field peas and therefore the reasons for this should be further investigated.

INTRODUCTION

Yield responses to individual inputs are often easily measured in research or on-farm trials, however, it is less well understood how the combination of multiple inputs can interact and affect yields. Farmers need to determine not only which inputs will have the largest impact on harvestable yield but also provide the best economic return. A previous input combination study with canola showed that the combined effect of the recommended agronomic practices increased the canola yield in synergistic fashion; the full input package had higher yield than the sum of the different agronomic practices alone (Blackshaw et al. 2010). The inputs farmers most commonly consider for field peas in western Canada are seeding rate, seed treatment, inoculant type, foliar fungicide and starter nitrogen (N) fertilizer. This study was conducted to determine which of these inputs contributes most to field pea seed yields when applied alone or in combination. In addition, the results will help farmers determine which combination of inputs results in the highest seed yields and economic returns.

Appropriate inoculation and hence nodulation in field peas is important in maximizing yield potential and yield stability. Clayton et al. (2003) found that granular inoculants increased field pea biomass, seed yield and seed protein concentration compared to liquid or peat based inoculants. Generally, nitrogen (N) fertilizer application is not required in field pea production since properly inoculated pulse crop form symbiotic associations with Rhizobium which provide sufficient levels of fixed N to satisfy the crop's demand. Starter N fertilizer may be beneficial when soil residual N is low, providing an alternative available N source when nodulation is restricted or delayed early in the growing season; however, excess fertilizer N can reduce nodule formation and N fixation in pulse crops. Clayton et al. (2004) found no benefit of starter N and higher rates of N reduced pea nodulation. A study by McKenzie et al. (2001) showed benefits of starter N only when spring soil test N at the 0-30 cm depth was less than 20 kg ha^{-1}.

Several studies have investigated the optimum seeding rate and plant density of field pea. Gan et al. (2002) reported that optimum dryland pea plant density is 65-70 plants m^{-2} when grown in southwestern Saskatchewan on wheat stubble. Johnston et al. (2002) found that field pea yield was optimized at 80 plants m^{-2} (108 seeds m^{-2}) and yields dropped significantly at populations below 50 plants m^{-2}. Lower seeding rates were not able to produce maximum yield at locations with higher yield potential. Similar results were found in a study by Townley-Smith and Wright (1994), where field pea yield increased with increasing seeding rate between 50-100 seeds m^{-2}. Increasing stand density was also found to reduce weed populations (Townley-Smith and Wright 1994), since higher plant populations produce a more competitive crop that is less affected by the presence of weeds. Currently, the Saskatchewan Pea Production Manual (Saskatchewan Pulse Growers) recommends a plant density of 75-85 plants m^{-2} and calculate seeding rates based on target plant population, thousand kernel weight (TKW), and expected emergence rate.

Fungicide seed treatments have produced variable responses in field pea. Fungicide seed treatments may be recommended when spring conditions favour disease development or when soil disease inoculum levels are high. In North Dakota, fungicide seed treatment did not improve plant stand, yield or decrease root diseases (Henson et al. 2004). Kutcher et al. (2002) saw few benefits from seed-applied fungicide on field pea in Saskatchewan, where seed treatment had an effect on seed yield in only one of thirteen site-years. Foliar fungicides are also recommended when conditions favour disease development. Bailey et al. (2000) saw decreased foliar disease, increased yield and seed weight when azoxystrobin was used to control foliar disease in field pea. Disease levels are dependent on environmental conditions and fungicides are found to be more beneficial in years with higher levels of disease.

This field pea input study has drawn on the literature to establish the treatments used in this study: starting with an "empty" input package (seeding rate of 60 seeds m^{-2} with liquid inoculant), the effects of additional inputs such as high seeding rate (120 seeds m-2), foliar fungicide, seed treatment, granular inoculant (instead of liquid inoculant) or 30 lbs N ac^{-1} starter fertilizer both alone and in various combinations were measured. The "full" input package received all five of the additional inputs.

OBJECTIVES

Within the different soil/climatic zones of western Canada, determine 1) which individual agronomic inputs contribute most to field pea seed yield 2) which combination produces the highest seed yield and economic return and 3) how plant population, leaf and stem disease, crop maturity, grain yield and quality are affected by input interactions.

MATERIALS AND METHODS

Field trials were conducted in 2012-2014 at the Agri-ARM sites located at Scott, Swift Current, Melfort and Indian Head SK and a fifth site, Minto MB, was added in 2014. Due to excess moisture in 2013, the trial at Melfort was terminated after assessing plant populations; therefore data was collected from only twelve site years.

Twenty two treatments were arranged as a randomized complete block design with four replicates. The check treatment received only the "empty" input package (seeding rate of 60 seeds m^{-2} with a liquid inoculant) (Table 3). All other treatments received the "empty" input package with the addition of one, two, three or four of the additional inputs: higher seeding rate (SR), a seed treatment (ST), granular inoculant (GI) (instead of liquid inoculant), starter N fertilizer (Fz) or two applications of foliar fungicide (Fn) (Table 1). The "full" input package received all five of the additional inputs. Only Fz was not applied in combinations of three or four inputs to reduce the number of treatments in the study.

A semi-leafless yellow pea variety (CDC Meadow) was direct seeded into spring wheat, barley or canola stubble between mid-May to early June (Table A.1). Liquid inoculant and ST were applied to the seed prior to seeding. Granular inoculant was applied in the seed-row at recommended rates based on row spacing unique to the seeder used at each location (Table A.1). Starter N fertilizer was applied away from the seed, in the side- or mid-row band. Foliar fungicide treatments received Headline EC when peas reached the 10% flower stage. An application of Priaxor DS was applied 10-14 days after the first Fn application (Table A.1). Phosphorus fertilizer was applied according to soil test recommendations (Table A.1), either in the seed row (if rates were <15lbs P_2O_5 ac^{-1}) or in the side or mid-row (if rates were >15lbs P_2O_5 ac^{-1}). Herbicides and desiccants were used as required at all sites (Table A.1).

Plant density was assessed approximately three weeks after seeding (Table A.1) by counting all seedlings in a 1 m section of crop row at two locations in each plot. Average area of *Mycosphaerella* infected leaves and stems was rated in each plot using the Xue scale (Xue et al. 1997) near timing of first fungicide application and again after the second application of fungicide (Table A.1). Maturity was assessed by determining the days to flower initiation (10% of plant initiated flowering) (DTF) and days to reach physiological maturity (DTM) in each plot. Plots were straight-combined using Wintersteiger plot combines in late-August to early-September (Table A.1). Seed yield data is reported at clean grain weight. Seed protein content was measured using a near-infrared reflectance grain analyzer (Foss NIR Systems, Inc., Laurel, MD, USA). Thousand kernel weight and test weight are reported as g 1000 seeds^{-1} and kg hL^{-1}. A summary of the weather data estimated from the nearest weather station at each site is provided in Appendix A.

Table 1. Details of inputs applied in the Empty input package and as additional inputs

Input	Empty Package	Additional Inputs
Seeding rate (SR)	60 viable seeds m^{-2}	60 viable seeds m^{-2}
Seed treatment (ST)	None	Apron Maxx RTA at 235mL 100kg^{-1} seed *(Fludioxonil + Metalaxyl-M & S-isomer*)
Inoculant (GI)	Liquid Boost N^{z} Liquid Cell-Tech^{y}	Granular Optimize^{z} Granular Cell-Tech^{y}
Starternitrogen fertilizer (Fz)	None	Granular Urea at 30 lb N ac^{-1} (*46-0-0*)
Foliar Fungicide (Fn)	None	Headline EC at 160mL ac^{-1} (*pyraclostrobin*) Priaxor DS at 160mL ac^{-1} (*pyraclostrobin + fluxapyroxad*)

^{z}Used in 2012 and 2013 site years

^{y}Used in 2014 site years

Site years were grouped in terms of high yielding (mean yield >3000 kg ha^{-1}) and low-yielding (mean yield <3000 kg ha^{-1}) site years and analyzed separately. There were six site years in each group: Indian Head and Swift Current site years were considered low yielding and Melfort, Scott and Minto were considered high yielding site years. All variables were analyzed using the MIXED Procedure in SAS 9.3. Treatments were considered fixed effects and site years and replicates were considered random effects. Treatment means were separated using Fisher's Protected LSD test and letter groupings were assigned using the SAS macro "pdmix800". Single degree of freedom contrasts were used to determine the response to inputs among treatments using the "estimate" command in Proc Mixed. To determine the type of interaction between various inputs (i.e. additive, synergistic, antagonistic), sequential additivity was first calculated by multiplying relative yields of individual inputs; the ratio between relative yield increase and sequential additivity determined the type of interaction (Wallace 1990). A ratio below 0.95 was antagonistic, 0.95-1.05 was sequentially additive and above 1.05 was synergistic. An economic analysis was conducted using prices from the 2014 Saskatchewan Ministry of Agriculture Crop Planning Guide and from verbal communication with local ag-retails to determine the economic return of each treatment.

RESULTS AND DISCUSSION

Plant Density

The treatment effect was highly significant for plant density under both low and high yielding environments (*P<0.001*), as expected, likely due to the differences in seeding rates among treatments (Table C.1 and C.2). Single degree of freedom contrasts revealed that SR resulted in 46 and 37 plants m^{-2} more than the low seeding rate when averaged across high and low yielding sites, respectively (Table C. 3 and C. 4). The mean plant population using the low seeding rate was, on average, 56 and 52 plants m^{-2}, averaged across high and low yielding sites, respectively, which is well below the recommended target population (75-85 plants m^{-2}). Treatments receiving the SR were close to the recommended plant population at low yielding sites (average 89 plants m^{-2}) and higher at high yielding sites (average 102 plants m^{-2}).

Seed treatment and GI also increase plant population under both environments, but to a lesser extent compared to SR (Table C. 3 and C. 4). Improved seedling vigour and disease resistance using a ST and/or GI may have increased the survival of the seedlings. In contrast, Fz significantly decreased plant population by 7-8 plants m^{-2} on average (Table C. 3 and C. 4). Nitrogen fertilizer was placed in the side-band at all sites, therefore the risk of seedling damage caused by fertilizer toxicity should be negligible. There was a significant increase in plant population with Fn treatments when averaged across low yielding site years (Table C.4), but there is no logical explanation for this, as plant counts were done before fungicide treatments were applied. Although statistically significant differences in plant population were detected with ST, GI and Fz, these differences were small and may not have been agronomically significant.

Disease Ratings

Overall disease ratings prior to foliar fungicide application were similar (2.2) between the average of high and low yielding site years, however, disease levels were only affected by treatment when averaged across high-yielding site years (*P=0.021*) (Table C.2). Averaged across all treatments, SR significantly increase disease ratings by 0.20 and 0.29 at low and high yielding sites, respectively (Table C.3 and C.4). The higher amount of canopy associated with higher seeding rates early in the growing season likely caused the greater disease levels and provided a more conducive environment for disease development. Interestingly, disease levels decreased with GI application at high yielding sites (Table C.3). Perhaps the improved nodulation and in turn, nitrogen nutrition, provided by the granular inoculant increased the plant’s overall health and resistance to disease. Averaged across low yielding site years, Fz also decrease disease levels (Table C.4) which may have also been due to improve nitrogen nutrition or a slightly lower plant population.

Although overall disease ratings conducted after foliar fungicide application were higher when averaged across high yielding sites compared to low yielding sites (4.5 compared to 3.4), the response to treatments was similar at both sites. The treatment effect was highly significantly at both environments (*P<0.001*) (Table C.1 and C.2) and as expected, treatments receiving Fn had on average, significantly lower disease levels compared to those that did not (Table C.3 and C.4). Similar to earlier disease ratings, treatments with SR had significantly higher levels of disease (Table C.3 and C.4). Granular inoculant was the only input which resulted in inconsistent effects on disease ratings later in the growing season: averaged across high yielding sites it reduced disease (Table C.3) while at low yielding sites it increased disease (Table C.4).

Maturity Assessment

Averaged across both high and low yielding site years, the treatment effect was significant for DTF (P = *0.010*, *0.002*, respectively) but not DTM (P = *0.972*, *0.150*, respectively) (Table C.1 and C.2) and the response was similar at both sites. Single degree of freedom contrasts revealed that the only inputs to affect maturity were SR and Fz: SR decreased DTF and DTM when averaged across low yielding sites and only DTF averaged across high yielding sites, while Fz had the opposite effect on these variables at these sites (Table C.3 and C.4).

Seed Yield

Seed yield was significantly affected by treatment when averaged across both high and low yielding sites (P = <*0.001*, *0.003*, respectively). Results of single degree of freedom contrasts show that overall, SR and Fn significantly increased seed yields under both environments (Table C.2 and C.3); however, average yield increases were higher when averaged across high yielding sites compared to low yielding sites. In addition, GI significantly increased yields at high yielding sites (Table C.2), but not low yielding site years (Table C.3). Overall, ST and Fz did not affect seed yield under either environment (Table C.2 and C.3).

When applied alone, SR significantly increased seed yields compared to the empty input package under both environments and resulted in yields that were not significantly different than the full input package when averaged across the low yielding site years (Table C.1 and C.2); therefore, yield was maximized using SR only at these sites. In addition, Fn also significantly increased seed yield when applied alone, but only when averaged across high yielding site years (Table C.1). Although Fz applied alone did not significantly increase seed yields above the empty package, it was also not significantly different than the full input package when averaged across low yielding site years (Table C.2). Neither GI nor ST significantly increased seed yields under either environment when applied alone (Table C.1 and C.2)

Adding additional inputs generally increased seed yield and decreased yield variability (Figure D.1 and D.2). Averaged over all high yielding sites, adding any one of GI, SR or Fn alone increased grain yield and decreased yield variability compared to the empty input package (Figure D.1). Adding any two of those three inputs further decrease yield variability and increased grain yield (Figure D.1). Adding all three inputs in combination resulted in the highest seed yields and lowest yield variability (Figure D.1). Interestingly, adding ST or ST and Fz did not further increase grain yields or decrease yield variability at these sites (Figure D.1). Using the ratio of observed versus expected relative mean yield to determine how inputs interacted we see that input combinations at the high-yielding sites were near the 1:1 ratio, with some exceptions, revealing that most input combinations are behaving in an additive fashion (Table D.1). The exceptions were the full input package and the combination of four inputs (SR, Fn, ST, GI) which had ratios of 0.68 and 0.74, respectively, while the average of all treatments with more two or more inputs was 0.91 at high yielding sites (Table D.1). Therefore, if applying two or three inputs in combination, each input will contribute the same relative yield increase as compare to if it was the only input applied. Using four or five of the inputs, i.e. adding the seed treatment and/or starter N fertilizer, there is no additional yield increase from the additional input, likely because yield potential has already been maximized.

At the low-yielding sites the average ratio of all input combination treatments was lower than at high yielding sites (0.76); therefore the input combinations are generally, with some exceptions, not behaving in an additive fashion (Table D.1). The interaction should not be described as antagonistic; instead there is likely something else at these sites which is limiting yield potential (i.e. disease at Indian Head or moisture limitations at Swift Current). In addition, using SR alone resulted in relatively large yield increase (Table C.2), which we suspect likely maximized yield potential. Consequently, any additional inputs would not have improved yield much beyond that, resulting in less additive interactions when SR was in the input combination. Yield variability at low yielding sites was, on average, much higher than at high yielding sites (Figure D.2).

The input combination with the highest observed versus expected relative mean yield ratio at both high and low-yielding sites was the combination of granular inoculant and seed treatment (Table D.1). This may be due to the antagonistic effects between the liquid inoculant applied with the seed treatment resulting in relatively low seed yields, perhaps due to negative effects on nodulation even though the seed treatment and liquid inoculant are registered as compatible. The seed treatment may have resulted in better yields when paired with a granular inoculant, as the pair are more compatible or robust under a range of environments. In addition, combinations of granular inoculant and fungicide and ST, SR, GI and Fn were also behaving in an additive fashion at low yielding sites (Table D.1).

Seed Quality

The overall effect of treatment on TKW was significant ($P = <0.001$) when averaged across high or low yielding site years (Table C.1 and C.2). Under both situations, Fn applied alone resulted in the highest TKW while the combination of ST, SR and GI resulted in the lowest TKW (Table C.1 and C.2). Single degree of freedom contrasts revealed that overall, SR decreased TKW by 3.4 and 3.0g and Fn increased TKW by 10.4 to 10.8g when averaged over high or low yielding site years respectively (Table C.3 and C.4). The treatment effect was only significant for TW averaged across high yielding site years ($P= 0.007$) (Table C.1); the trends were similar to the differences found in TKW (Table C.3).

Protein was not affected by treatment at either the high or low yielding site years (Table C.1 and C.2). However, averaged across high yielding sites, single degree of freedom contrasts revealed significantly higher protein when using GI compared to liquid and lower protein when adding ST compared to treatments without (Table C.3). The protein increase from GI can likely be explained by improved nodulation and nitrogen fixation achieved with the granular inoculant but the response from seed treatment is puzzling. Averaged across low-yielding sites, protein was increased by the addition of Fz and was reduced by addition of a Fn (Table C.4). These results are expected as the Fz likely provided sufficient N to satisfy the crop requirements under these low-yielding situations. In contrast, Fn did increase yields overall, which likely diluted the protein in the seed.

Net Return

The ranking of highest to lowest economic return among treatments varied from low to high yielding site years. Generally, the treatments with that resulted in the highest economic return at the high yielding sites contained some combination of GI, SR and Fn, with the combination with all three of these inputs resulting in the highest economic return. Although Fn and SR resulted in similar increases in seed yield when applied alone, the higher cost of the fungicide application resulted in much lower economic return. In contrast, the treatments with the highest economic return at the low yielding sites contained fewer inputs and those containing Fn were ranked among the lowest. At low yielding sites, using only SR resulted in the highest net return followed by Fz only.

CONCLUSIONS

Plant density was increased from an average of 56 to 102 and 52 to 89 plants m^{-2} with low to high seeding rates at high and low yielding sites, respectively. This range of densities is outside the traditionally recommended plant density, so it is difficult to assess if our current recommendations provide the crop with plant density high enough to maximize yield potential. Granular inoculant and ST also increased plant density, but to a much lower extent than SR. Starter N fertilizer resulted in significant, but relatively small reductions in plant density.

Disease levels were generally higher with SR early and later in the growing season and lower with Fn later in the season, regardless of environment. Granular inoculant also decreased disease levels when averaged across high yielding site years. Maturity was affected by SR and Fz only; generally, SR decreased days to maturity and Fz increased days to maturity.

Under relatively good growing conditions, such as those encountered at Scott, Melfort and Minto, input combinations of two or three inputs interacted in an additive fashion when averaged across at high yielding sites. Generally, averaged across high yielding sites, seed yield increased and yield variability decreased with each additional input added to the input package. Higher seeding rates, Fn and GI were the three inputs which consistently increased seed yields and economic return at these sites, especially when all three were applied in combination. In contrast, the addition of ST or Fz did not consistently improve yields or economic returns. Under poor growing conditions, such as those encountered at Indian Head and Swift Current, seed yields were more variable and input interactions were generally not additive, suggesting that some other factor (i.e. root disease, drought) was limiting yield at these sites. The overall response to SR and Fn was significant; however, the high cost of the Fn resulted in those treatments having the lowest economic return. Either SR or Fz applied alone maximized yield and economic return averaged across low yielding sites.

We recommend all farmers use adequate seeding rates to target the recommended plant population to maximize field pea yield potential. Under situations where the farmer expects relatively high yields, we also recommend using a granular inoculant to ensure nodulation and nitrogen fixation can provide sufficient levels of nitrogen to the crop. If the crop develops a thick canopy and/or disease develops, adding a foliar fungicide will protect and maintain the yield potential of the crop. We do not expect to see a yield response using starter nitrogen fertilizer, except potentially when residual N is extremely low or when there are extreme cases of late season root rot or moisture limitations which limit yield potential and nitrogen fixation. Seed treatments did not result in consistent yield improvements in field peas and therefore the reasons for this should be further investigated.

ACKNOWLDGEMENTS

Financial support for this project is provided by the Saskatchewan Pulse Growers for the Saskatchewan sites and the Manitoba Pulse Growers for the Minto site. We would like to thank Monsanto BioAg for donating inoculants used in this study. We would also like to acknowledge the excellent technical assistance provided by Tristan Coelho, Don Sluth, Colleen Kirkham, Don Luthi and Christiane Catellier.

This research has been presented at several extension events and conferences including the Scott Field Day (July 2012, 2014, Scott SK), the IHARF Crop Management Field Day (July 2013, 2014, Indian Head SK), the Agri-ARM Research Update (January 2013, Saskatoon SK), the Regional Pulse Workshop (February 2013, 2014, North Battleford SK) and the ASA, CSSA and SSSA International Annual Meetings (November 2014, Long Beach CA).

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Appendix A

Historical Climate Data and Site Characteristics

Table A.1. Summary of field operations and site characteristics from all site years

	Indian Head			Swift Current			Melfort		Scott			Minto
Field Operation	2012	2013	2014	2012	2013	2014	2012	2014	2012	2013	2014	2014
Seeding Date	May 19	May 12	May 15	Jun 5	May 11	May 30	May 16	May 16	May 10	May 22	May 14	Jun 3
Plant Density Assessment Date	Jun 18	Jun 3	Jun 6	Jun 27	Jun 4	Jun 24	Jun 8	June 6	Jun 1	Jun 12	Jun 4	Jun 27
Fungicide 1 Application Date	Jul 6	Jul 4	Jul 8	Jul 6	Jul 3	Jul 16	-[z]	July 9	Jul 9	Jul 4	Jul 9	Jul 24
Fungicide 2 Application Date	Jul 20	Jul 11	Jul 16	Jul 18	Jul 11	Jul 25	-	July 22	Jul 20	Jul 15	Jul 22	Jul 6
Disease Rating 1 Date	Jul 6	Jul 3	Jul 8	Jul 6	Jul 3	Jul 16	-	N/A[y]	Jul 10	Jul 3	Jul 11	Jul 21
Disease Rating 2 Date	Aug 8	Aug 1	Aug 5	Jul 30	Jul 25	Aug 5	-	July 31	Aug 10	Jul 25	Jul 25	Aug 14
Desiccation Date	Aug 15	Aug 17	Aug 14	N/A	N/A	N/A	Aug 17	Aug	Aug 13	Sep 3	Aug 18	N/A
Harvest Date	Aug 21	Aug 28	Sep 1	Aug 12	Aug 19	Aug 27	Aug 28	Aug. 29 - Sep. 12	Aug 20	Sep 9	Aug 27	Sep 12
Site Characteristics												
Previous Crop	Spring Wheat	Spring Wheat	Barley	Durum Wheat	Durum Wheat	Spring Wheat	Canola	Canola	Barley	Spring Wheat	Canola	Oats
Row Spacing (inches)	12	12	12	9	9	9	8	-	10	10	10	8
Residual Soil N (lbs N ac^{-1} 0-60cm)	16	31	23	12[z]	5[z]	6[z]	44	-	16	20	13	40
Residual Soil P (lbs P_2O_5 ac^{-1} 0-15cm)	16	18	17	15	14	29	29	-	30	43	32	20
Residual Soil K (lbs K_2O ac^{-1} 0-15cm)	>540	>600	>540	452	558	503	>540	-	247	>540	528	508
Residual Soil S (lbs S ac^{-1} 0-60cm)	45	36	27	12[z]	10[z]	3[z]	46	-	15	50	25	408
Soil pH (0-15cm)	7.7	7.8	8.1	6.1	6.3	6.3	-	-	5.6	6.3	5.8	8.1
P fertilizer applied (lbs P_2O_5 ac^{-1})	16.1	16.1	16.1	15	15	15	-	15	14	17	25	15.6

[z]Missing records
[y]Not applicable because operation was not conducted
[x]0-15cm depth

Table A.2. Mean monthly temperature and long-term normals (1981-2010) for the 2012-2014 growing seasons at Indian Head, Swift Current, Melfort and Scott SK and Minto MB**.**

Location	Year	May	June	July	August	Average
			Mean Temperature (°C)			
Indian Head	2012	9.9	16.5	19.2	17.1	15.7
	2013	11.9	15.3	16.3	17.1	15.2
	2014	14.4	14.4	17.3	17.4	15.9
	Long-term	10.8	15.8	18.2	17.4	15.6
Swift Current	2012	9.4	15.5	20.0	19.0	16.0
	2013	12.6	15.5	16.8	19.2	16.0
	2014	10.9	13.4	18.1	18.1	15.1
	Long-term	10.9	15.4	18.5	18.2	15.8
Melfort	2012	9.6	15.2	18.9	17.1	15.2
	2014	10.0	14.0	17.5	17.6	14.8
	Long-term	10.7	15.9	17.5	16.8	15.2
Scott	2012	9.7	15.1	18.6	17.0	15.1
	2013	12.6	14.8	16.5	17.4	15.3
	2014	9.3	13.9	17.4	16.8	14.4
	Long-term	10.8	15.3	17.1	16.5	14.9
Minto	2014	10.8	15.5	17.8	17.8	15.5
	Long-term	12.6	17.1	19.5	18.5	16.9

Table A.3. Total monthly precipitation and long-term normals (1981-2010) for the 2012-2014 growing seasons at Indian Head, Swift Current, Melfort and Scott SK and Minto MB.

Location	Year	May	June	July	August	Total
			Precipitation (mm)			
Indian Head	2012	79.4	51.0	124.6	30.4	285.4
	2013	17.1	103.8	50.4	6.1	177.4
	2014	36.0	199.2	7.8	142.2	385.2
	Long-term	49.0	77.4	63.8	51.2	241.4
Swift Current	2012	98.3	107.0	17.2	8.2	230.7
	2013	11.2	103.0	50.4	13.5	178.1
	2014	27.5	108.6	29.9	104.0	270.0
	Long-term	48.5	72.8	52.6	41.5	215.4
Melfort	2012	55.2	112.3	97.8	68.1	333.4
	2014	24.3	167.3	38.8	57.9	288.3
	Long-term	39.8	54.3	76.7	52.4	223.2
Scott	2012	50.6	164.6	56.4	51.4	323.0
	2013	38.9	113.5	26.1	63.3	241.8
	2014	23.1	60.4	128.0	30.1	241.6
	Long-term	4.8	61.8	72.1	45.7	184.4
Minto	2014	52.3	165.8	30.1	131.2	379.4
	Long-term	49.9	85.3	67.4	58.5	261.1

Appendix B

Pea Mycosphaerella Rating Scale

Table B.1. Mycorsphaerella rating scale foe field peas (Xue et al., 1997)

	Plant Position		
Disease severity	Upper	Middle	Lower
0	F[z]	F	F
1	F	F	L
2	F	F	M
3	F	L	M
4	L	L	M
5	L	M	M
6	L	M	S
7	M	M	S
8	M	S	S
9	S	S	S

[z]Free of disease on leaves/stems; L - light infection, 1-20% of leaves/stems showing symptoms; M - moderate infection 21-50%; S - severe infection, 51-100%.

Appendix C

Least Squared Means and Single Degree of Freedom Contrast Estimates

Table C.1. Treatment means of plant density, days to flower and maturity, seed yield, thousand kernel weight, test weight, seed protein and disease incidence averaged over all high yielding site years.

Treatment	Plant Density (plant m^{-2})	Days to Flower	Days to Maturity	Yield (kg ha^{-1})	TKW (g 1000 $seeds^{-1}$)	TW (kg hL^{-1})	Protein	Disease 1	Disease 2
Empty	52^{b}	51.8^{abcdef}	91.3	3375^{j}	183.3^{cdef}	84.6^{abcd}	23.4	2.3^{abcdef}	4.9^{abcde}
Full	102^{a}	52.1^{ab}	91.8	4615^{ab}	182.4^{defg}	84.6^{abcde}	23.4	2.1^{bcdefg}	4.3^{defgh}
ST^{z}	57^{b}	51.8^{abcde}	91.2	3512^{ij}	180.8^{efgh}	84.8^{abc}	23.2	2.2^{abcdefg}	5.1^{abc}
SR^{z}	106^{a}	51.6^{bcdef}	91.1	3958^{defghi}	177.1^{fgh}	84.5^{bcdef}	23.4	2.6^{ab}	5.6^{a}
GI^{z}	53^{b}	51.8^{abcde}	92.0	3800^{fghij}	180.6^{efgh}	84.6^{abcde}	23.7	1.9^{defg}	4.5^{cdef}
Fz^{z}	55^{b}	52.1^{ab}	92.2	3777^{ghij}	185.4^{bcde}	84.6^{abcde}	23.4	2.0^{cdefg}	4.9^{abcde}
Fn^{z}	53^{b}	51.4^{def}	91.6	3905^{efghi}	193.3^{a}	84.6^{abcde}	23.4	2.2^{abcdefg}	3.9^{fghi}
ST+SR	106^{a}	51.3^{f}	91.5	3729^{hij}	176.2^{gh}	84.1^{f}	23.3	2.7^{a}	5.6^{a}
ST+GI	57^{b}	52.0^{abc}	91.8	3864^{efghij}	182.1^{efg}	84.6^{abcde}	23.6	2.0^{cdefg}	4.4^{cdefgh}
Fz+GI	55^{b}	51.9^{abcd}	92.6	3826^{fghij}	180.7^{efgh}	84.7^{abcd}	23.7	1.7^{g}	4.3^{defgh}
Fz+SR	99^{a}	51.5^{cdef}	91.6	4027^{cdefgh}	180.4^{efgh}	84.3^{def}	23.4	2.5^{abcd}	5.4^{ab}
SR+Fn	101^{a}	51.5^{cdef}	91.5	4513^{abc}	191.2^{ab}	84.8^{abc}	23.5	2.6^{ab}	4.1^{fgh}
Fz+Fn	57^{b}	52.2^{a}	91.7	4168^{bcdefgh}	194.4^{a}	84.8^{abc}	23.2	2.2^{abcdefg}	3.8^{ghi}
GI+Fn	57^{b}	52.0^{abc}	92.1	4300^{abcdef}	190.8^{ab}	84.9^{ab}	23.6	1.8^{efg}	3.2^{i}
ST+Fn	58^{b}	52.0^{abcd}	91.8	3739^{ghij}	189.4^{abc}	84.8^{abc}	22.8	2.4^{abcde}	4.5^{cdefg}
ST+Fz	61^{b}	52.1^{ab}	91.4	3724^{hij}	181.6^{efg}	84.9^{ab}	23.2	2.5^{abcd}	5.0^{abcde}
SR+GI	100^{a}	51.7^{abcdef}	92.0	4145^{bcdefgh}	175.9^{gh}	84.2^{ef}	23.7	2.0^{bcdefg}	5.0^{abcd}
ST+SR+GI+Fn	101^{a}	51.5^{bcdef}	91.7	4658^{ab}	190.0^{abc}	84.5^{abcde}	23.2	2.4^{sbcde}	4.2^{efgh}
SR+GI+Fn	100^{a}	51.4^{def}	92.1	4757^{a}	190.5^{ab}	84.5^{abcde}	23.4	2.5^{abc}	4.1^{fgh}
ST+GI+Fn	56^{b}	51.9^{abcd}	91.8	4341^{abcde}	190.8^{ab}	84.9^{a}	23.3	1.8^{fg}	3.7^{hi}
ST+SR+GI	105^{a}	51.5^{cdef}	91.5	4435^{abcd}	174.0^{h}	84.4^{cdef}	23.7	2.0^{bcdefg}	4.9^{abcde}
ST+SR+Fn	101^{a}	51.3^{ef}	92.1	4246^{abcdefg}	189.4^{abcd}	84.5^{abcde}	23.2	2.2^{abcdefg}	4.6^{bcdef}
F Value	29.12	2.17	0.46	4.37	6.15	2.15	0.86	1.98	5.32
P>F	<.0001	0.0102	0.9722	<.0001	<.0001	0.0067	0.6431	0.0208	<.0001

^{z} ST – Seed Treatment; SR – Seeding Rate; GI – Granular Inoculant; Fz – Starter N Fertilizer; Fn – Foliar Fungicide.

$^{a\text{-}j}$ Means within a column followed by same letter grouping are not significantly different ($P > 0.05$) according to Fisher's Protected LSD.

Table C.2. Treatment means of plant density, days to flower and maturity, seed yield, thousand kernel weight, test weight, seed protein and disease incidence averaged over all low yielding site years.

Treatment	Plant Density (plant m^{-2})	Days to Flower	Days to Maturity	Yield (kg ha^{-1})	TKW (g 1000 $seeds^{-1}$)	TW (kg hL^{-1})	Protein	Disease 1	Disease 2
Empty	47[e]	50.1[abcdefg]	83.9	1710[g]	206.4[cdef]	82.3	21.5	2.2	3.4[cdefg]
Full	89[abc]	50.2[abcdef]	83.7	2415[a]	216.5[ab]	82.5	21.4	2.2	3.4[cdefg]
ST[z]	55[de]	50.3[abcd]	83.9	1845[fg]	210.2[bcde]	82.2	21.8	2.0	3.3[defgh]
SR[z]	86[c]	49.6[gh]	82.1	2360[abc]	201.7[f]	82.3	21.6	2.3	4.1[ab]
GI[z]	57[d]	50.0[bcdefgh]	83.4	1787[fg]	204.6[def]	82.1	21.3	2.2	3.8[abcd]
Fz[z]	49[de]	50.5[ab]	84.6	2072[abcdefg]	205.3[def]	82.5	22.0	2.0	3.7[abcde]
Fn[z]	51[de]	50.1[abcdefg]	80.4	1902[efg]	219.2[a]	82.4	21.5	2.1	3.0[gh]
ST+SR	85[c]	49.7[gh]	82.1	2107[abcdef]	202.2[ef]	82.5	21.6	2.4	3.8[abcd]
ST+GI	52[de]	50.0[bcdefgh]	83.8	2010[cdefg]	211.1[abcd]	82.5	21.6	2.3	3.5[cdefg]
Fz+GI	53[de]	50.2[abcde]	84.3	1794[fg]	207.3[cdef]	82.5	21.8	2.0	3.6[bcdef]
Fz+SR	85[c]	49.9[cdefgh]	82.5	2131[abcdef]	204.2[def]	82.6	22.0	2.3	3.7[abcde]
SR+Fn	87[abc]	49.8[efgh]	83.0	2051[abcdef]	211.5[abcd]	82.5	21.2	2.3	3.2[efgh]
Fz+Fn	53[de]	50.3[abc]	85.3	2016[abcdefg]	217.6[ab]	82.2	21.7	2.0	2.7[h]
GI+Fn	53[de]	50.3[abc]	84.5	1978[defg]	218.1[ab]	82.5	21.3	2.1	3.1[fgh]
ST+Fn	51[de]	50.1[abcdefgh]	84.7	2047[bcdefg]	214.6[abc]	82.5	21.5	2.2	3.0[gh]
ST+Fz	52[de]	50.5[a]	84.2	1884[efg]	206.5[cdef]	82.5	21.9	2.0	3.2[efgh]
SR+GI	96[a]	49.8[defgh]	82.2	2022[cdefg]	202.8[ef]	82.3	21.6	2.2	4.2[a]
ST+SR+GI+Fn	90[abc]	49.6[h]	82.9	2243[abcde]	214.6[abc]	82.5	21.1	2.4	3.7[abcde]
SR+GI+Fn	95[ab]	49.7[fgh]	83.5	2327[abcd]	214.2[abc]	82.5	21.3	2.4	3.5[cdefg]
ST+GI+Fn	55[de]	49.9[cdefgh]	84.1	2126[abcdef]	216.8[ab]	82.6	21.3	2.2	3.0[fgh]
ST+SR+GI	91[abc]	49.8[efgh]	82.0	2060[abcdefg]	200.2[f]	78.9	21.8	2.4	3.9[abc]
ST+SR+Fn	87[bc]	49.8[defgh]	83.2	2406[ab]	216.5[ab]	82.4	21.4	2.3	3.2[efgh]
F Value	39.41	2.44	1.37	2.30	4.36	1.14	0.94	1.28	3.38
P>F	<.0001	0.0016	0.1503	0.0030	<.0001	0.3144	0.5386	0.2084	<.0001

[z] ST – Seed Treatment; SR – Seeding Rate; GI – Granular Inoculant; Fz – Starter N Fertilizer; Fn – Foliar Fungicide.

[a-j] Means within a column followed by same letter grouping are not significantly different ($P > 0.05$) according to Fisher's Protected LSD.

Table C.3: Single degree of freedom contrasts comparing mean response to inputs at high yielding site years

	Contrast									
	Low SR[z] vs. High SR		No ST[z] vs. ST		Liquid vs. Granular Inoculant		No Fn[z] vs. Fn		No Fz[z] vs. Fz	
Variable	Estimate[y]	P > F	Estimate[y]	P > F	Estimate[y]	P > F	Estimate[y]	P > F	Estimate[y]	P > F
Plant density (plants m^{-2})	46	<.0001	6	0.0013	11	<.0001	3	0.1095	-7	0.0006
Seed yield (kg ha^{-1})	448	<.0001	40	0.6072	367	<.0001	476	<.0001	-57	0.5147
Days to flower	-0.39	<.0001	0.00	0.9719	-0.03	0.7167	-0.01	0.8632	0.33	0.0007
Days to maturity	-0.10	0.6507	-0.16	0.4712	0.40	0.0822	0.13	0.5779	0.18	0.4818
TKW (g 1000 $seeds^{-1}$)	-3.37	0.0020	-1.62	0.1325	-1.68	0.1173	10.39	<.0001	-0.55	0.6456
TW (kg hL^{-1})	-0.29	<.0001	0.02	0.7264	-0.09	0.1715	0.19	0.0041	0.06	0.422
Protein (%)	0.05	0.6403	-0.22	0.0449	0.22	0.0396	-0.19	0.0783	0.02	0.8858
Disease 1 (1-9)	0.29	0.0015	0.03	0.6902	-0.25	0.0061	0.03	0.7347	-0.08	0.3902
Disease 2 (1-9)	0.43	0.0003	0.17	0.1338	-0.33	0.0041	-0.90	<.0001	0.08	0.5506

[z]SR – Seeding Rate; ST – Seed Treatment; Fn – Foliar Fungicide; Fz – Starter N Fertilizer.
[y]Estimate is difference in second input minus first input

Table C.4: Single degree of freedom contrasts comparing mean response to inputs at low yielding site years

	Contrast									
	Low SR[z] vs. High SR		No ST[z] vs. ST		Liquid vs. Granular Inoculant		No Fn[z] vs. Fn		No Fz[z] vs. Fz	
Variable	Estimate[y]	P > F	Estimate[y]	P > F	Estimate[y]	P > F	Estimate[y]	P > F	Estimate[y]	P > F
Plant density (plants m^{-2})	36.7	<.0001	3.0	0.0245	13.3	<.0001	3.7	0.0048	-8	<.0001
Seed yield (kg ha^{-1})	281.3	<.0001	101.6	0.0749	83.5	0.1429	169.2	0.0034	-9.1	0.8856
Days to flower	-0.41	<.0001	-0.05	0.4749	-0.12	0.1049	-0.05	0.4941	0.36	<.0001
Days to maturity	-1.22	0.0043	0.16	0.6967	-0.07	0.8650	0.29	0.4911	0.99	0.0371
TKW (g 1000 $seeds^{-1}$)	-3.03	0.0185	1.51	0.2348	0.93	0.4646	10.77	<.0001	-0.75	0.6000
TW (kg hL^{-1})	-0.29	0.3546	-0.28	0.3627	-0.37	0.2324	0.37	0.2338	0.28	0.4178
Protein (%)	-0.11	0.3121	-0.03	0.7767	-0.19	0.0864	-0.31	0.0063	0.34	0.0073
Disease 1 (1-9)	0.20	0.0001	0.05	0.2786	0.07	0.1662	0.03	0.5774	-0.13	0.0211
Disease 2 (1-9)	0.38	<.0001	-0.11	0.2201	0.22	0.0138	-0.50	<.0001	-0.07	0.4599

[z]SR – Seeding Rate; ST – Seed Treatment; Fn – Foliar Fungicide; Fz – Starter N Fertilizer.

[y]Estimate is difference in second input minus first input

Appendix D

Yield Variability, Observed versus Expected Relative Yield Ratios and Relative Yield Increases

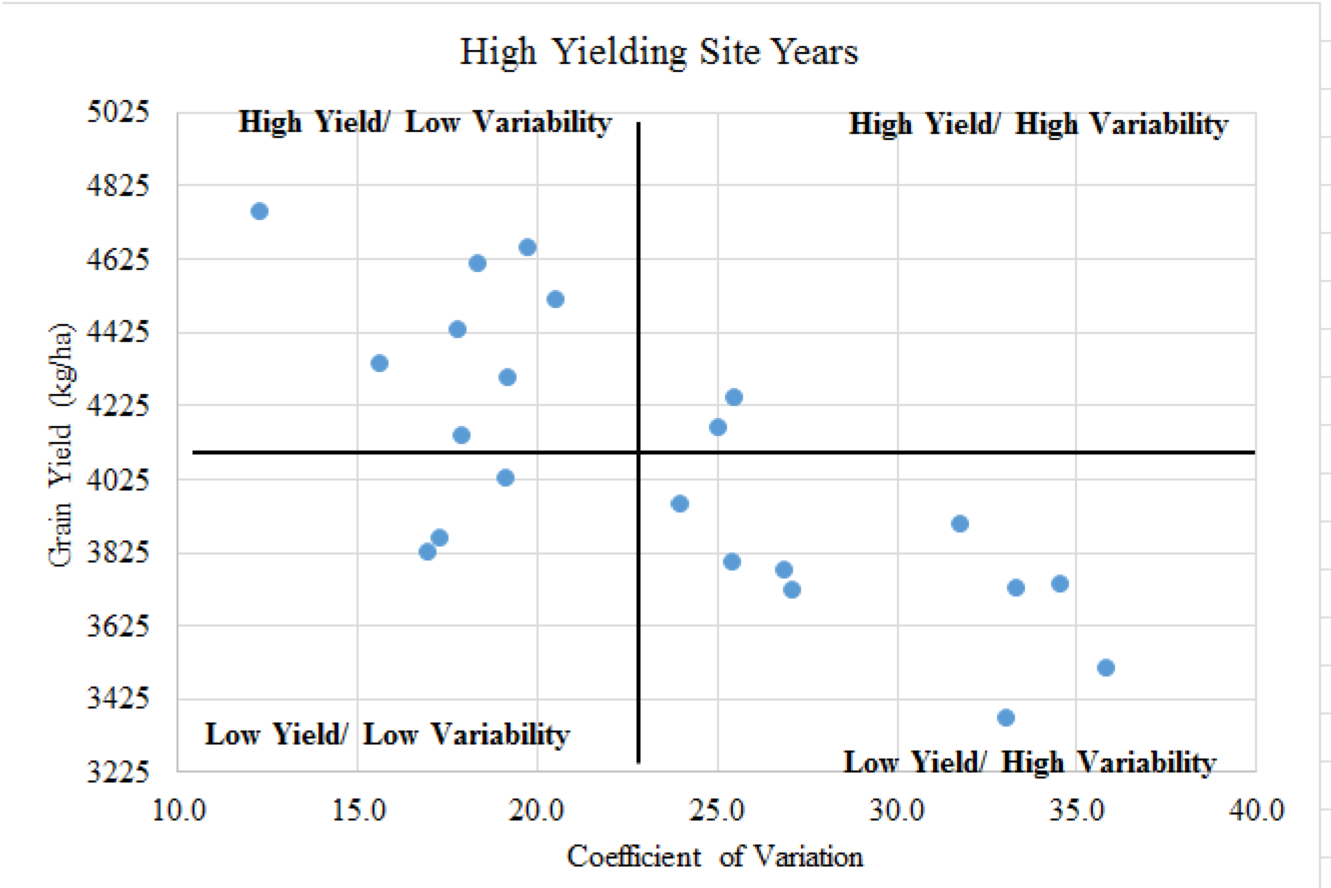

Figure D.1. Grain yield versus coefficient of variation of each treatment averaged over high yielding sites

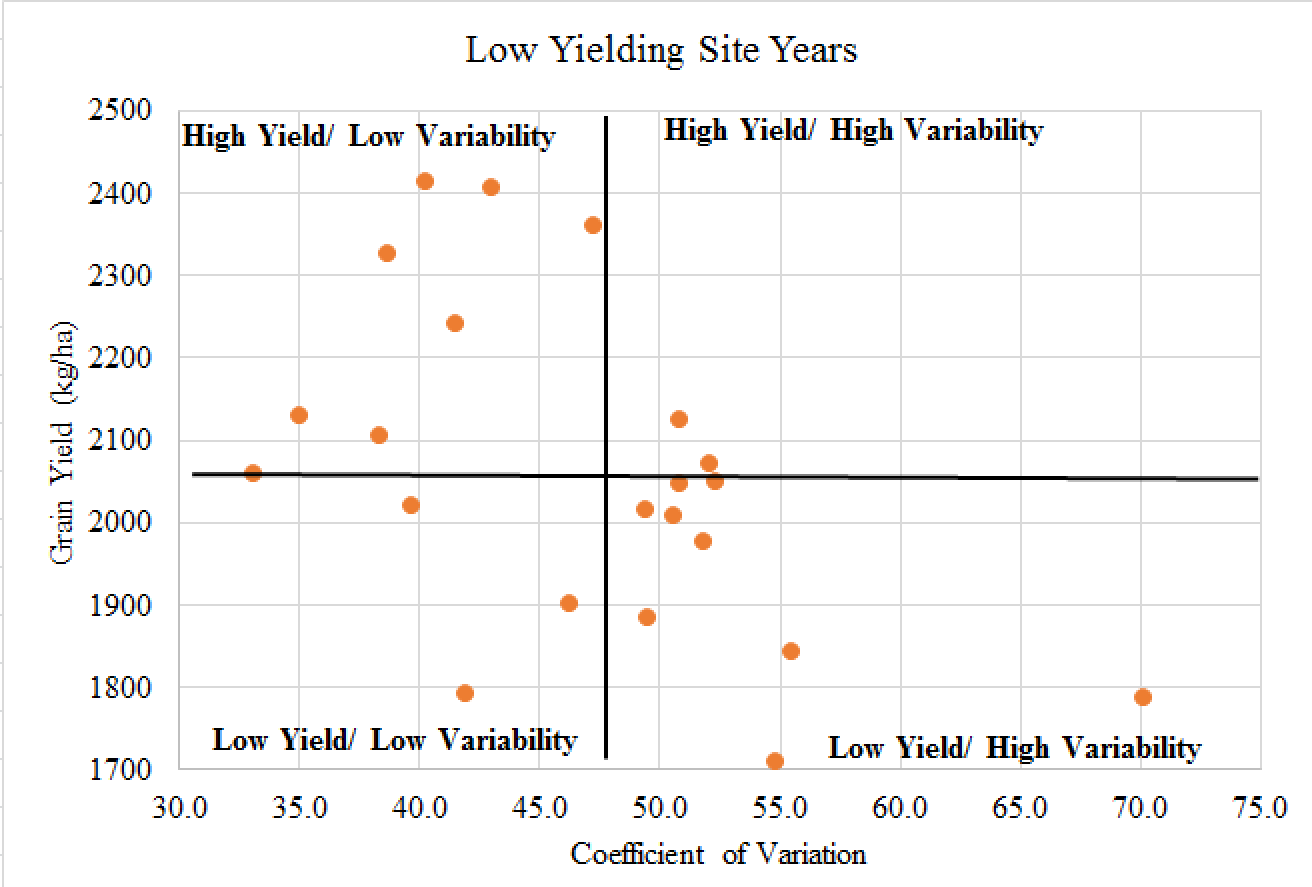

Figure D.2. Seed Yield versus coefficient of variation of each treatment averaged over low yielding sites

Table D.1. Analysis of variance for expected versus observed relative (as percentage of empty package) mean grain yield at high and low yielding site years

	High Yielding Site Years				Low Yielding Site Years			
Treatment	Expected	Observed	Ratio[z]	P Value	Expected	Observed	Ratio[z]	P Value
Full	1.96	1.34	0.68	0.2684	9.03	1.88	0.21	0.1580
ST+SR	1.23	1.14	0.93	0.1608	2.34	1.90	0.81	0.2055
ST+GI	1.22	1.22	1.00	0.9814	1.05	1.16	1.10	0.4614
Fz+GI	1.36	1.28	0.94	0.2545	1.56	1.17	0.75	0.3032
Fz+SR	1.39	1.31	0.94	0.2294	2.91	1.98	0.68	0.2969
SR+Fn	1.49	1.45	0.97	0.5375	1.67	1.24	0.74	0.1312
Fz+Fn	1.35	1.23	0.91	0.0245	1.34	1.19	0.89	0.4875
GI+Fn	1.42	1.36	0.96	0.4801	1.26	1.18	0.94	0.6099
ST+Fn	1.24	1.17	0.95	0.4601	2.55	1.41	0.55	0.3320
ST+Fz	1.17	1.14	0.98	0.8270	2.48	1.29	0.52	0.2543
SR+GI	1.41	1.34	0.95	0.5835	1.80	1.40	0.78	0.3686
ST+SR+GI+Fn	2.03	1.50	0.74	0.0857	1.50	1.52	1.01	0.8976
SR+GI+Fn	1.70	1.57	0.93	0.4724	1.67	1.39	0.83	0.3797
ST+GI+Fn	1.44	1.37	0.95	0.3515	1.82	1.52	0.83	0.3464
ST+SR+GI	1.51	1.37	0.91	0.2888	2.19	1.55	0.71	0.2620
ST+SR+Fn	1.48	1.29	0.87	0.0452	1.66	1.42	0.85	0.3449

[z]Oberseved mean divided by expected mean

Table D.2. Actual and relative yield increase of each input applied alone or in combination at high yielding site years.

Base Treatment	Base Yield (kg/ha)	Added Input	Treatment	Treatment Yield (kg/ha)	Actual Yield Increase (kg/ha)	% Yield Increase
Empty	3375	Fz	Fz	3777	402	11.9
GI	3800	Fz	Fz+GI	3826	26	0.7
SR	3958	Fz	Fz+SR	4027	69	1.7
Fn	3905	Fz	Fz+Fn	4168	263	6.7
ST	3512	Fz	ST+Fz	3724	213	6.1
ST+SR+GI+Fn	4658	Fz	Full	4615	-43	-0.9
Empty	3375	Fn	Fn	3905	530	15.7
ST	3512	Fn	ST+Fn	3739	227	6.5
SR	3958	Fn	SR+Fn	4513	555	14.0
GI	3800	Fn	GI+Fn	4300	500	13.2
Fz	3777	Fn	Fz+Fn	4168	391	10.4
SR+GI	4145	Fn	SR+GI+Fn	4757	611	14.7
ST+GI	3864	Fn	ST+GI+Fn	4341	477	12.3
ST+SR	3729	Fn	ST+SR+Fn	4246	518	13.9
ST+SR+GI	4435	Fn	ST+SR+GI+Fn	4658	223	5.0
Empty	3375	ST	ST	3512	137	4.1
SR	3958	ST	ST+SR	3729	-230	-5.8
GI	3800	ST	ST+GI	3864	64	1.7
Fz	3777	ST	ST+Fz	3724	-53	-1.4
Fn	3905	ST	ST+Fn	3739	-166	-4.2
GI+Fn	4300	ST	ST+GI+Fn	4341	40	0.9
SR+GI	4145	ST	ST+SR+GI	4435	290	7.0
SR+Fn	4513	ST	ST+SR+Fn	4246	-267	-5.9
SR+GI+Fn	4757	ST	ST+SR+GI+Fn	4658	-99	-2.1
Empty	3375	SR	SR	3958	583	17.3
ST	3512	SR	ST+SR	3729	217	6.2
GI	3800	SR	SR+GI	4145	345	9.1
Fz	3777	SR	Fz+SR	4027	251	6.6

Fn	3905	SR	SR+Fn	4513	608	15.6
GI+Fn	4300	SR	SR+GI+Fn	4757	456	10.6
ST+GI	3864	SR	ST+SR+GI	4435	572	14.8
ST+Fn	3739	SR	ST+SR+Fn	4246	507	13.6
ST+GI+Fn	4341	SR	ST+SR+GI+Fn	4658	317	7.3
Empty	3375	GI	GI	3800	425	12.6
ST	3512	GI	ST+GI	3864	352	10.0
SR	3958	GI	SR+GI	4145	187	4.7
Fz	3777	GI	Fz+GI	3826	49	1.3
Fn	3905	GI	GI+Fn	4300	396	10.1
SR+Fn	4513	GI	SR+GI+Fn	4757	243	5.4
ST+Fn	3739	GI	ST+GI+Fn	4341	601	16.1
ST+SR	3729	GI	ST+SR+GI	4435	706	18.9
ST+SR+Fn	4246	GI	ST+SR+GI+Fn	4658	411	9.7

Table D.3. Actual and relative yield increase of each input applied alone or in combination at low yielding site years.						
Base Treatment	Base Yield (kg/ha)	Added Input	Treatment	Treatment Yield (kg/ha)	Actual Yield Increase (kg/ha)	% Yield Increase
Empty	1710	Fz	Fz	2072	361	21.1
GI	1787	Fz	Fz+GI	1794	7	0.4
SR	2360	Fz	Fz+SR	2131	-229	-9.7
Fn	1902	Fz	Fz+Fn	2016	115	6.0
ST	1845	Fz	ST+Fz	1884	39	2.1
ST+SR+GI+Fn	2243	Fz	Full	2415	172	7.7
Empty	1710	Fn	Fn	1902	192	11.2
ST	1845	Fn	ST+Fn	2047	202	10.9
SR	2360	Fn	SR+Fn	2051	-310	-13.1
GI	1787	Fn	GI+Fn	1978	191	10.7
Fz	2072	Fn	Fz+Fn	2016	-55	-2.7
SR+GI	2022	Fn	SR+GI+Fn	2327	305	15.1
ST+GI	2010	Fn	ST+GI+Fn	2126	116	5.7
ST+SR	2107	Fn	ST+SR+Fn	2406	300	14.2
ST+SR+GI	2060	Fn	ST+SR+GI+Fn	2243	183	8.9
Empty	1710	ST	ST	1845	135	7.9
SR	2360	ST	ST+SR	2107	-254	-10.8
GI	1787	ST	ST+GI	2010	223	12.4
Fz	2072	ST	ST+Fz	1884	-187	-9.0
Fn	1902	ST	ST+Fn	2047	145	7.6
GI+Fn	1978	ST	ST+GI+Fn	2126	147	7.4
SR+GI	2022	ST	ST+SR+GI	2060	37	1.9
SR+Fn	2051	ST	ST+SR+Fn	2406	355	17.3
SR+GI+Fn	2327	ST	ST+SR+GI+Fn	2243	-84	-3.6
Empty	1710	SR	SR	2360	650	38.0
ST	1845	SR	ST+SR	2107	261	14.2
GI	1787	SR	SR+GI	2022	235	13.1
Fz	2072	SR	Fz+SR	2131	60	2.9

Fn	1902	SR	SR+Fn	2051	149	7.8
GI+Fn	1978	SR	SR+GI+Fn	2327	349	17.6
ST+GI	2010	SR	ST+SR+GI	2060	50	2.5
ST+Fn	2047	SR	ST+SR+Fn	2406	359	17.5
ST+GI+Fn	2126	SR	ST+SR+GI+Fn	2243	117	5.5
Empty	1710	GI	GI	1787	77	4.5
ST	1845	GI	ST+GI	2010	165	8.9
SR	2360	GI	SR+GI	2022	-338	-14.3
Fz	2072	GI	Fz+GI	1794	-277	-13.4
Fn	1902	GI	GI+Fn	1978	77	4.0
SR+Fn	2051	GI	SR+GI+Fn	2327	276	13.5
ST+Fn	2047	GI	ST+GI+Fn	2126	79	3.8
ST+SR	2107	GI	ST+SR+GI	2060	-47	-2.2
ST+SR+Fn	2406	GI	ST+SR+GI+Fn	2243	-163	-6.8

Appendix E

Economic Analysis

Table E.1. Cost of various inputs used in calculation of economic net return

Input	Product Cost[z]	Product Rate	Seeding Rate[y]	Cost ($/ha)
Seeding Rate				
Low seeding rate	$10.50/bu	-	132kg/ha	$50.94
High seeding rate	$10.50/bu	-	264kg/ha	$101.87
Foliar Fungicide				
Headline EC	$620/6.5L	0.160L/ac	-	$37.73
Priaxor DS	$1180/9.6L	0.160L/ac	-	$48.60
Application cost (2 applications)	$10/ac	-	-	$24.71
Total cost of fungicide application	-	-	-	$111.05
Inoculant				
Liquid (low seeding rate)	$55/3L bag	1089 kg seed/bag	132kg/ha	$6.67
Liquid (high seeding rate)	$55/3L bag	1089 kg seed/bag	264kg/ha	$13.33
Granular[x]	$72/25lb bag	3.3lbs/ac	-	$23.48
Seed Treatment				
Apron Maxx RTA (low seeding rate)	$460/10L	235mL/100kg seed	132kg/ha	$14.27
Apron Maxx RTA (high seeding rate)	$460/10L	235mL/100kg seed	264kg/ha	$28.54
Starter Nitrogen Fertilizer				
Granular urea (46-0-0)	$0.48/lb N	30 lbs N/ac	-	$35.58

[z]seed and nitrogen prices estimated using the Saskatchewan Ministry of Agriculture 2014 Crop Planning Guide. Fungicide, inoculant and seed treatment prices estimated using suggested local ag-retailer price

[y]based on CDC Meadow seed with thousand kernel weight of 220g per 1000 seeds and bushel weight of 60 lbs bu^{-1}

[x]based on row spacing of 10 inches

Table E.2. Net revenue for various treatments at high-yielding sites ranked from highest to lowest net revenue

Treatment	Grain Yield	Grain Price[z]	Gross Income	Seed	Seed Treatment	Nitrogen Fertilizer	Inoculant	Foliar Fungicide	Total Input Cost	Net Revenue
	kg/ha	$/kg	$/ha							
SR+GI+Fn	4757	0.26	1224	102	0	0	23	111	236	987
ST+SR+GI	4435	0.26	1141	102	29	0	23	0	154	987
SR+GI	4145	0.26	1066	102	0	0	23	0	125	941
SR+Fn	4513	0.26	1161	102	0	0	13	111	226	935
ST+SR+GI+Fn	4658	0.26	1198	102	29	0	23	111	265	933
GI+Fn	4300	0.26	1106	51	0	0	23	111	185	921
ST+GI+Fn	4341	0.26	1117	51	14	0	23	111	200	917
ST+GI	3864	0.26	994	51	14	0	23	0	89	905
GI	3800	0.26	978	51	0	0	23	0	74	903
SR	3958	0.26	1018	102	0	0	13	0	115	903
Full	4615	0.26	1187	102	29	36	23	111	301	887
Fz+SR	4027	0.26	1036	102	0	36	13	0	151	885
Fz	3777	0.26	972	51	0	36	7	0	93	878
Fz+GI	3826	0.26	984	51	0	36	23	0	110	874
Fz+Fn	4168	0.26	1072	51	0	36	7	111	204	868
ST+Fz	3724	0.26	958	51	14	36	7	0	107	851
ST+SR+Fn	4246	0.26	1092	102	29	0	13	111	255	838
Fn	3905	0.26	1005	51	0	0	7	111	169	836
ST	3512	0.26	903	51	14	0	7	0	72	832
ST+SR	3729	0.26	959	102	29	0	13	0	144	816
Empty	3375	0.26	868	51	0	0	7	0	58	811
ST+Fn	3739	0.26	962	51	14	0	7	111	183	779

[z]based on price from Saskatchewan Ministry of Agriculture 2014 Crop Planning Guide ($7.00 bu^{-1}) and bushel weight of 60 lbs bu^{-1}

Table E.3. Net revenue for various treatments at low-yielding sites ranked from highest to lowest net revenue

Treatment	Grain Yield	Grain Price[z]	Gross Income	Seed	Seed Treatment	Nitrogen Fertilizer	Inoculant	Foliar Fungicide	Total Input Cost	Net Revenue
	kg/ha	$/kg	-----	-----	-----	$/ha	-----	-----	-----	-----
SR	2360	0.26	607	102	0	0	13	0	115	492
Fz	2072	0.26	533	51	0	36	7	0	93	440
ST+GI	2010	0.26	517	51	14	0	23	0	89	428
ST	1845	0.26	475	51	14	0	7	0	72	403
ST+SR	2107	0.26	542	102	29	0	13	0	144	398
Fz+SR	2131	0.26	548	102	0	36	13	0	151	398
SR+GI	2022	0.26	520	102	0	0	23	0	125	395
GI	1787	0.26	460	51	0	0	23	0	74	385
Empty	1710	0.26	440	51	0	0	7	0	58	382
ST+Fz	1884	0.26	485	51	14	36	7	0	107	377
ST+SR+GI	2060	0.26	530	102	29	0	23	0	154	376
ST+SR+Fn	2406	0.26	619	102	29	0	13	111	255	364
SR+GI+Fn	2327	0.26	599	102	0	0	23	111	236	362
Fz+GI	1794	0.26	462	51	0	36	23	0	110	352
ST+GI+Fn	2126	0.26	547	51	14	0	23	111	200	347
ST+Fn	2047	0.26	527	51	14	0	7	111	183	344
GI+Fn	1978	0.26	509	51	0	0	23	111	185	323
Full	2415	0.26	621	102	29	36	23	111	301	321
Fn	1902	0.26	489	51	0	0	7	111	169	321
Fz+Fn	2016	0.26	519	51	0	36	7	111	204	314
ST+SR+GI+Fn	2243	0.26	577	102	29	0	23	111	265	312
SR+Fn	2051	0.26	528	102	0	0	13	111	226	301

[z]based on price from Saskatchewan Ministry of Agriculture 2014 Crop Planning Guide ($7.00 bu^{-1}) and bushel weight of 60 lbs bu^{-}