2016 Annual Report for the Agriculture Demonstration of Practices and Technologies (ADOPT) Program

Project Title: Determining the Economic Value of Lentil Inputs and Their Effect on Yield

Project Number: 20150378

Producer Group Sponsoring the Project: Western Applied Research Corporation

Project Location(s):

- Scott Saskatchewan, R.M. #380 Legal land description: NE 17-39-20 W3
- Swift Current, Saskatchewan RM #137

Project start and end dates (month & year): May 2016 and completed December 2016

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Objectives and Rationale

Project objectives:

The objective of this trial was to determine which combination of the main agronomic practices produce the greatest lentil yield and provide the best economic return to producers.

Project Rationale:

Lentils are a main component of the Canadian pulse market and serve as an alternative to peas due to their profitability and rotational benefits. However, due to the high cost of inputs associated with lentil production, producers are increasingly interested in improving their profit margins. By examining the main agronomic inputs and their effect on yield, producers will be able to better understand what is required to produce higher yields with a greater return. This project provides a visual demonstration of the interactive role on grain yield and seed quality between large and small red lentil varieties with differing inoculants, and the presence and absence of fungicide application. Producers will learn if there is a benefit to seeding rate increase, inoculant product selection and the use of fungicide to improve lentil seed quality. This trial will also investigate an interactive effect among agronomic inputs. Furthermore, the economic analysis will assist producers in their decision making processes.

Methodology and Results

Methodology:

At Scott and Swift Current the demonstrations were set up as randomized complete block design with four replicates. The trial consisted of 18 treatments designed as a three- way factorial including: three seeding rates (130, 190 and 260 seeds m^{-2}), three inoculants (liquid, granular and none) and two fungicide treatments (fungicide and no fungicide) for both small and large red lentils (Table 1).

Table 1: Treatment list representing treatment numbers, seeding rates, inoculant, and fungicides. The trials are split to separate the small (CDC Maxim), and large (CDC KR-2) red lentils.

	Trial 1: CDC Maxim Lentils			**Trial 2: CDC KR-2 Lentils**		
Treatment	**Seeding rate (seeds/m^2)**	**Inoculant**	**Fungicide**	**Seeding rate (seeds/m^2)**	**Inoculant**	**Fungicide**
1	130	None	No	130	None	No
2	130	Liquid	No	130	Liquid	No
3	130	Granular	No	130	Granular	No
4	130	Liquid	Yes	130	Liquid	Yes
5	130	Granular	Yes	130	Granular	Yes
6	130	None	Yes	130	None	Yes
7	190	None	No	190	None	No
8	190	Liquid	No	190	Liquid	No
9	190	Granular	No	190	Granular	No
10	190	Liquid	Yes	190	Liquid	Yes
11	190	Granular	Yes	190	Granular	Yes
12	190	None	Yes	190	None	Yes
13	260	None	No	260	None	No
14	260	Liquid	No	260	Liquid	No
15	260	Granular	No	260	Granular	No
16	260	Liquid	Yes	260	Liquid	Yes
17	260	Granular	Yes	260	Granular	Yes
18	260	None	Yes	260	None	Yes

At Scott and prior to seeding, soil samples were collected at three depth increments (0-15cm, 15-30cm and 30-60 cm) in order to determine fertilizer rates. CDC Maxim and KR-2 lentils were seeded as per the protocol at 130, 190, and 260 seeds/m^2, on May 5th. Plots were seeded at a 10-inch row spacing with an R-tech seeder. A blend of 20-25-10-13 was placed mid-row at 110 lbs/acre. The inoculant treatments consisted of Granular Nodulator XL SCG at a rate of 3.3 lbs/acre, and Liquid Nodulator XL treated at 75mL/27.2 kg of seed. A fungicide application of Priaxor (180 mL/acre) was applied on June 28th. A disease rating was done one week prior to this application. Reglone (0.7 L/acre) was applied on August 15th and plots were harvested on August 22nd.

At Swift Current, plots were seeded on May 16th on a 9- inch row spacing with a Fabro built plot drill with Atom-Jet knife openers. Both lentil varieties were seeded per protocol: 130, 190, and 260 seeds/m^2. Based on the soil test recommendations MAP (11-52-0) at 46.5 lbs/acre was applied. The inoculant treatments consisted of Granular Nodulator XL SCG at a rate of 3.3 lbs/acre, and Liquid Nodulator XL treated at 75 mL/27.2kg of seed. Priaxor (180 mL/acre) and Bravo 500 (1.6 L/acre) were applied on June 29th and July 25th, respectively. Disease ratings were done between 1-2 weeks after the fungicide applications. On August 16th, all plots were desiccated with Reglone (0.7 L/acre) + LI 700 (0.25 L/100 L), and plots were then harvested with a Zürn combine on August 31st.

Data Collection:

At both the Scott and Swift Current locations, the plant densities were determined by counting numbers of emerged plants on 2 x 1 meter row lengths per plot about a week after the first rows became visible. Disease ratings were conducted when there was a disease presence, and plots were sprayed shortly afterwards. Plots were scouted weekly to see if further disease ratings were needed. Yields were determined from clean harvested grain samples and corrected to the required moisture content. Seed quality analyses were done to determine thousand kernel weight and test weights. Lastly, economics of the main inputs were calculated. Weather data was recorded from the online database of Environment Canada weather station for both Scott and Swift Current.

Growing Conditions:

In Scott, the 2016 growing season started out very dry in April with only 1.9 mm of precipitation. May, July, and August were far above the long-term average, with 40 %, 21 %, and 50 % increase, respectively. Overall, when looking at the accumulated amount of precipitation in 2016 from April to October, there was 38.5 mm more than the long-term total. Throughout the growing season the temperature was very similar to the long-term average. Growing degree days were higher than the long-term average for the months of April – July, and lower for the remaining months (Table 2).

Table 2. Mean monthly temperature, precipitation and growing degree day accumulated from April to October 2016 at Scott, SK

Year	April	May	June	July	August	Sept.	Oct.	Average /Total
				Temperature (°C)				
2016	5.9	12.4	15.8	17.8	16.2	10.9	1.6	11.5
Long-term^z	3.8	10.8	14.8	17.3	16.3	11.2	3.4	11.1
				Precipitation (mm)				
2016	1.9	64.8	20.8	88.1	98.2	22.2	33.1	329.1
Long-term^z	24.4	38.9	69.7	69.4	48.7	26.5	13	290.6
				Growing Degree Days				
2016	58.9	224.9	303	398.7	343.8	176.2	12.5	1518.0
Long-term^z	44	170.6	294.5	380.7	350.3	192.3	42.5	1474.9

^{z}Long-term average (1985-2014)

In Swift Current, the 2016 average temperatures are very similar to that of the long-term average. The total precipitation was 43 % higher overall for April – October combined. May, July, and October are the months with the greatest amount of precipitation when compared to the long-term averages, with 62 %, 60 %, and 78 % greater values, respectively. Growing degree days were higher than the long-term average for the months of April, May, and June, but lower for the remaining months. The total growing degree days for the growing season was lower than the average total by 2 % (Table 3).

Table 3. Swift Current's mean monthly temperature, precipitation and growing degree days for the 2016 months of April – October.

Year	April	May	June	July	August	Sept.	Oct.	Average /Total
				Temperature (°C)				
2016	6.6	12.3	16.5	17.8	17	12.4	3.9	12.3
Long-term^z	4.9	10.9	15.4	18.4	17.9	12.7	5.4	12.2
				Precipitation (mm)				
2016	25.9	134.9	87.2	124.8	50.3	40.9	85	549
Long-term^z	24.0	50.9	85.1	50.3	48.2	36.0	18.6	313.2
				Growing Degree Days				
2016	68.9	233.8	346.4	396.4	371.2	220.6	-	1637.3
Long-term^z	66.1	198.2	321.6	430.2	414.5	242.6	-	1673.2

^{z}Long-term average (1985-2014)

<u>**Analysis**</u>:

All data was statistically analysed using the PROC MIXED in SAS 9.4. The residuals were tested for normality and equal variance to meet the assumptions of ANOVA. If these assumptions were not met, the data was transformed using either square root or LOG transformation. All data presented was back- transformed for ease of reporting. The means were separated using a Tukey's Honestly Significant Difference (HSD) test with level of significance at 0.05. Both site and replications were treated as random effect factors whiles treatments (seeding rate, inoculant and fungicide) as fixed effect factors.

Data for small and large red lentil plant density were combined between sites as there was no significant interaction between replications nested in sites nor a site and fixed effect interaction. However, a significant interaction for both small and large red lentils was documented for yield, thousand kernel weights (TKW) and test weight (TW). Yield, TKW and TW data will be presented based on individual sites.

Results

Plant Emergence

Seeding rate significantly influenced the plant density of small red lentils ($P<0.0001$) as 260, 190 and 130 seeds m^{-2} resulted in a corresponding plant densities of 226, 171, and 121 plants m^{-2}, respectively (Table A.1). Large red lentil plant densities were also significantly influenced by seed rating ($P<0.0001$) with 260, 190 and 130 seeds m^{-2} resulting in a total of 195, 151 and 106 plants m^{-2} (Table A.2). Swift Current had a slightly lower plant density compared to Scott, this could be attributed to the excessive moisture during the month of May, in which Swift Current received 52 % more precipitation compared to Scott (134.9 mm vs 64.8 mm) (Table 2; 3). There was no significant difference in plant density among inoculant treatments at either site, suggesting that inoculant, regardless of product type, had no direct impact on plant establishment of lentil in a semiarid region.

Grain Yield and Seed Quality

Small Red Lentils

Seeding rate did not significantly affect yield, TKW or TW at Scott and Swift Current (Table 4). Although not significant, the seeding rate of 190 seeds m^{-2} resulted in the highest yield with a 1 bu ac^{-1} increase compared to the lowest (130 seeds m^{-2}) and highest seeding rate (260 seeds m^{-2}). At Swift Current, 190 seeds m^{-2} resulted in a similar yield to 130 seeds m^{-2}, however, both seeding rates produced a 3 bu ac^{-1} increase compared to 260 seeds m^{-2} (Table 5).

Table 4. The P values were generated using the Tukey's HSD test (P< 0.05) to determine the effect of seeding rate (seeds m^{-2}), inoculant, fungicide and their interactions on SMALL red lentils seed yield (bu ac^{-1}), thousand kernel weights (TKW) (g 1000 $seed^{-1}$), and test weight (TW) (kg $hL^{-1)}$ at Scott and Swift Current, 2016.

	Yield (bu ac^{-1})		**TKW (g 1000 $seed^{-1}$)**		**TW (kg $hL^{-1)}$**	
	Scott	Swift Current	Scott	Swift Current	Scott	Swift Current
Seeding Rate (SR)	0.673	0.375	0.803	0.411	0.213	0.2433
Inoculant (I)	0.033**	<0.0001***	0.007***	<0.0001***	0.659	0.005**
Fungicide (F)	0.225	0.955	0.0003***	0.081	0.1882	0.988
SR*I	0.869	0.953	0.962	0.659	0.719	0.652
SR*F	0.260	0.454	0.537	0.467	0.731	0.797
I*F	0.407	0.167	0.178	0.3056	0.819	0.081
SR*I*F	0.696	0.640	0.490	0.541	0.977	0.379

*, **, *** Significant at P < 0.05, P < 0.01, and P < 0.001, respectively.

Inoculant had the greatest effect on yield (P= 0.033, <0.0001) and thousand kernel weights (TKW) (P=0.007, <0.0001) at both Scott and Swift Current, respectively. The effect of inoculant was also significant on test weight (TW) (P=0.005) at Swift Current (Table 4). Although both sites indicated an inoculant effect, the inoculant treatment effect was site dependent. At Scott, granular inoculant resulted in the highest yield of 54 bu ac^{-1}, compared to liquid and non-inoculated of 52 and 51 bu ac^{-1}, respectively. In contrast, non-inoculated out-performed liquid and granular inoculate resulting in 42, 34 and 32 bu ac^{-1}, respectively, at Swift Current.

Fungicide applications did not significantly affect yield at Scott and Swift Current, regardless of a single and dual applications, respectively (Table 4). It is interesting to note, that although disease was present within the lentils, particularily at the Swift Current site, that the effect of fungicide sprayed singular and dual did not significantly effect yield. The effect of fungicide also did not significantly influence TKW and TW at Swift Current. However, a significantly (P=0.0003) effect was noted on TKW at Scott (single fungicide application) (Table 4).

Table 5. The effect of seeding rate (seeds m^{-2}), inoculant, fungicide and their interactions on SMALL red lentils seed yield (bu ac^{-1}), thousand kernel weights (TKW) (g 1000 $seed^{-1}$), and test weight (TW) (kg hL^{-1}). Treatment means were calculated using the means generated from a single field season at Scott and Swift Current, 2016.

	Yield (bu ac^{-1})		**TKW (g 1000 $seed^{-1}$)**		**TW (kg hL^{-1})**	
	Scott	Swift Current	Scott	Swift Current	Scott	Swift Current
Seeding Rate (SR)						
260	52 A§	34 A	35 A	27 A	81 A	79 A
190	53 A	37 A	36 A	27 A	81 A	79 A
130	52 A	37 A	36 A	27 A	82 A	79 A
Inoculant (I)						
Granular	54 A	32 B	36 A	27 B	81 A	79 B
Liquid	52 B	34 B	35 B	27 B	82 A	79 B
None	51 B	42 A	35 B	28 A	81 A	80 A
Fungicide (F)						
Sprayed	53 A	36 A	36 A	27 A	82 A	79 A
Unsprayed	52 A	36 A	35 B	27 A	81 A	79 A

§Different lettering indicates significant difference between treatments, respectively.

Large Red Lentils

The effect of seeding rate on yield was significant (P<0.0001) at Swift Current, in which 260 seeds m^{-2} greatly out-yielded the lower seeding rates (190; 130 seeds m^{-2}) by 25% and 40%, respectively. In contrast, seeding rate at Scott had a non -significant (P= 0.202) effect on yield with 190 seeds m^{-2} producing 2; 1 bu ac^{-1} more compared to 130 and 260 seeds m^{-2}, respectively (Tables 6 and 7).

Similar results were noted for seed weight (thousand kernel weight), in which seeding rate had a significant (P <0.0001) effect at Swift Current and a non-significant effect at Scott (Table 6). The results at Swift Current indicated that the higher seeding rate of 260 seeds m^{-2} resulted in the greatest seed weight of 36 g compared to 34: 32 g at 190: 130 seed m^{-2}, respectively. In contrast, increasing the seeding rate had a negligible effect on seed weight at Scott, as all three seeding rates resulted in a 50 g TKW. The test weight at both Scott and Swift Current were not influenced by seeding rate, however, the test weight at Scott was significantly higher compared to Swift Current: 79 vs. 75 kg hL^{-1} (Table 7).

Table 6. The P values were generated using the Tukey's HSD test (P< 0.05) to determine the effect of seeding rate (seeds m^{-2}), inoculant, fungicide and their interactions on LARGE red lentils seed yield (bu

ac^{-1}), thousand kernel weights (TKW) (g 1000 seed^{-1}), and test weight (TW) (kg hL^{-1}) at Scott and Swift Current, 2016.

	Yield (bu ac^{-1})		**TKW (g 1000 seed^{-1})**		**TW (kg hL^{-1})**	
	Scott	Swift Current	Scott	Swift Current	Scott	Swift Current
Seeding Rate (SR)	0.202	<0.0001***	0.9417	<0.0001***	0.274	0.7073
Inoculant (I)	0.012**	0.018**	0.023*	0.256	0.328	0.847
Fungicide (F)	0.526	0.281	0.0005***	0.006**	0.080	0.121
SR*I	0.459	0.264	0.8503	0.869	0.807	0.187
SR*F	0.127	0.327	0.078	0.102	0.779	0.763
I*F	0.006**	0.257	0.370	0.204	0.262	0.033*
SR*I*F	0.781	0.773	0.393	0.601	0.754	0.683

The effect of inoculant was significant (P=0.012; 0.018) at both Scott and Swift Current, however, product efficacy varied between sites (Tables 6 and 7). Although granular formulation was most effective at Scott, the liquid formulation out-performed both granular and non-inoculated at Swift Current. Overall, both granular and liquid treatments produced a 4 bu ac^{-1} advantage compared to the non-inoculated treatments at their respective sites. The effect of inoculant was also significant (P= 0.023) on seed weight at Scott, in which granular formulation resulted in a thousand kernel weight of 51g compared to 50g (liquid and non-inoculated) (Table 7).

There was a significant (P=0.006) interaction of inoculant x fungicide on yield at Scott, in which granular inoculant, regardless of fungicide, resulted in a 7 bu ac^{-1} increase compared to liquid without fungicide application (Table 7). Similarly, a significant (P= 0.033) interaction between inoculant x fungicide at Swift Current was detected for seed test weight. In this interaction, granular with fungicide produced a significantly higher test weight of 76 kg hL^{-1} compared to liquid and granular without fungicide (75 kg hL^{-1}) (Table 7).

Table 7. The effect of seeding rate (seeds m^{-2}), inoculant, fungicide and their interactions on LARGE red lentils seed yield (bu ac^{-1}), thousand kernel weights (TKW) (g 1000 $seed^{-1}$), and test weight (TW) (kg hL^{-1}). Treatment means were calculated using the means generated from a single field season at Scott and Swift Current, 2016.

	Yield (bu ac^{-1})		**TKW (g 1000 $seed^{-1}$)**		**TW (kg hL^{-1})**	
	Scott	Swift Current	Scott	Swift Current	Scott	Swift Current
Seeding Rate (SR)						
260	55 A§	20 A	50 A	36 A	79 A	76 A
190	56 A	15 B	50 A	34 B	79 A	75 A
130	54 A	12 C	50 A	32 C	79 A	75 A
Inoculant (I)						
Granular	57 A	16 AB	51 A	34 A	79 A	75 A
Liquid	56 A	17 A	50 B	34 A	79 A	75 A
None	53 B	13 B	50 B	34 A	79 A	75 A
Fungicide (F)						
Sprayed	55 A	16 A	51 A	35 A	79 A	76 A
Unsprayed	55 A	15 A	50 B	33 B	79 A	75 A
I*F						
Granular x Sprayed	57 A	NS	NS	NS	NS	76 A
Granular x Unsprayed	57 A	NS	NS	NS	NS	75 B
None x Unsprayed	57 A	NS	NS	NS	NS	76 AB
Liquid x Sprayed	56 A	NS	NS	NS	NS	75 AB
None x Sprayed	54 A	NS	NS	NS	NS	75 AB
Liquid x Unsprayed	50 B	NS	NS	NS	NS	75 B

A yield benefit associated with fungicide applications was anticipated, as there was continuous precipitation events throughout the growing season that resulted in ideal environmental conditions for disease. Moreover, we expected a seeding rate x fungicide interaction, as a denser canopy typically encourages greater disease pressure. However, fungicide had a non-significant effect on yield, regardless of a single and dual application, at Scott and Swift Current, respectively (Table 6).

The effect of fungicide on seed weight contrasted the yield trend observed at Scott and Swift Current, as both sites documented a significant (P=0.0005; 0.006) effect on thousand kernel weights (Table 6). At Scott, a single fungicide application resulted in a seed weight of 51 g compared to 50 g when unsprayed. At Swift Current, a dual fungicide application resulted in a seed weight of 35g compared to 33g when unsprayed. These results suggest that fungicide can improve seed weight, however, at Swift Current even the sprayed treatments where much lower compared to the Scott (sprayed and unsprayed) TKW. This suggests that in high disease years, fungicide may only limit the effect of disease but not inhibit seed quality reductions.

Discussion

Inoculation played a large role in yield production and overall seed quality, however, the inoculant formulation varied significant between sites and varieties. Granular inoculant resulted in the best yields and highest seed weight for both small and large red lentils at Scott, however, non-inoculated small red lentils out-yielded granular inoculant treatments at Swift Current. The proven effects of granular inoculant over seed-applied inoculant have been well documented (Clayton et al. 2004; Kyei-Boahen et al. 2002). In particular, Gan et al. (2005) reported that granular inoculants increased lentil seed yield by 19% over seed-applied inoculants. Granular inoculants applied to the soil allow *Rhizobium* to become more uniformly distributed in the rooting zone and allow for greater root-*Rhizobium* contact. This allows for greater inoculation which promotes better nodule formation and consequentially results in greater yields and seed mass (Gan et al. 2005).

Gan et al. (2005) also reported that in some site-years, nodules were found on non-inoculated lentil roots which indicated that indigenous populations of *Rhizobia* may exist in certain soils. This may help explain why the non-inoculated small red lentils at Swift Current produced comparable yields to the liquid and granular inoculated lentils. However, it does not explain why the granular inoculant was statistically lower than the non-inoculated, as these treatments should have been of equal production. Although the results at Swift Current cannot be completely explained, an underlying theme in which granular inoculant produced the greatest yields can be confidently determined at Scott. The economics also support the use of granular inoculant over seed-applied, as on average, a net gain of $ 42 ac^{-1} is associated with granular inoculant over seed-applied based on the current recommended seeding rate (130 seeds m^{-2}).

Yield was significantly influenced by several factors during this trial, many of them were site dependent, including the effect of seeding rate. Although the significance level varied between sites, a seeding rate greater than 130 seeds m^{-2} typically resulted in a higher yield. These results are relatively consistent with the findings of Shirtliffe (2015, unpublished) who reported preliminary results indicating that the optimal seeding rate for small red lentils was approximately 240 seeds m^{-2}. Furthermore, several studies (Silim et al. 1990; Paolini et al. 2003; Baird et al. 2009) have indicated that a higher lentil seeding rate resulted in greater yield due to reduced crop-weed competition. Increased seeding rates improve crop competitive ability and allow for faster canopy closure; therefore, limiting the duration in which lentils are competing with neighbouring weed species (Redlick, 2015). Overall, the findings of this study concur with the current literature which suggest that an increased recommended seeding rate may improve lentil production

While several studies (Shirtliffe, 2015 unpublished; Silim et al. 1990; Paolini et al. 2003; Baird et al. 2009) indicated that a higher seeding rate resulted in a yield and net profit gain, the yield at Scott declined when seeding rates exceeded 190 seeds m^{-2}. Seeding rates exceeding 190 seeds m^{-2} could have resulted in excessive vegetative growth that may have limited essential nutrients, space and available water required for reproductive growth. The cost associated with seeding rates of 260 seeds m^{-2} typically resulted in slight net losses compared to 190 seeds m^{-2} at Scott. For example, a net loss of \$39 ac^{-1} was calculated when comparing 260 (52 bu ac^{-1}) vs. 190 seeds m^{-2} (53 bu ac^{-1}) of small red lentils at Scott (Table 5).

A general trend of seeding rate effect on yield was consistent between sites, however, it is interesting to note that overall yield production varied largely between sites (52 vs 34; 55 vs 20 bu ac^{-1} at 260 seeds m^{-2}) (Table 5; 7). This is particularly interesting since the initial plant densities at Scott and Swift Current were similar (Tables A.1; A.2). The differences in overall yield could be attributed to the excessive moisture at Swift Current, as precipitation was 43% greater than the 30 year long-term average compared to 13% at Scott (Table 2; 3). Due to this high precipitation volume, plant stand health was diminished compared to Scott.

In response to these environmental conditions, we expected a yield response from fungicide applications, however, a non-significant effect was documented at both sites for each variety. Moreover, a seeding rate x fungicide interaction was expected, as a denser canopy typically encourages greater disease pressure. However, fungicide had a non- significant effect on yield, regardless of a single and dual application, at Scott and Swift Current, respectively. This lack of response could be attributed to several factors, as Grenkow (2014, unpublished) found that a fungicide response in peas was only significant when applied to high yielding stands plant stands. This could explain the lack of fungicide response at Swift Current, but not at Scott as yields were achieved as high as 61 bu ac^{-1}. Another point to note, is that most diseases in lentils begin at the base and move upwards, so penetrating a dense canopy would be difficult and therefore may not be efficacious.

To determine if fungicide is an economically profitable decision, we based our calculation on the average yield mean generated by both variety and site. In total, the cost of fungicide for a single application would result in a net loss of approximately \$1.50 ac^{-1} excluding the cost of fuel and time. When analysed as an individual factor, the application of fungicide based on economics for the 2016 growing season was not profitable.

When comparing the economics of seeding rate with all agronomic factors included, a net loss of \$110; \$82 ac^{-1} was accrued with the seeding rate of 130 seeds m^{-2}; 260 seeds m^{-2} compared to 190 seeds m^{-2}, respectively (Table 8). Therefore, the optimal seeding rate based on economics alone suggest a seeding rate of 190 seeds m^{-2}.

The greatest yielding and most profitable combination of agronomic practices based on the average yield of both large and small red lentils at Scott was 190 seeds m^{-2}; granular inoculant; fungicide sprayed resulting in a yield of 60 bu ac^{-1}. The effect of fungicide was non-significant on yield (Table 4; 6) and resulted in a \$1.50 ac^{-1} loss when individually calculated for economic analysis. However, when fungicide is used in combination with 190 seeds m^{-2} and granular inoculant, it resulted in a net profit of \$72 ac^{-1} compared to the unsprayed, 190 seeds m^{-2} and granular inoculant treatment (Table 8). These results indicate that a possible, yet not statistically significant, yield benefit associated with a higher seeding rate, granular inoculant and fungicide applications.

Table 8. Economic analysis of seeding rate x inoculant x fungicide treatments based on the average yield of small and large red lentil at Scott, SK in 2016 to determine net profit (\$ ac^{-1}).

Seeding Rate (seeds m^{-2})	**Inoculant**	**Fungicide**	**Net Profit (\$ ac^{-1})**
190 seeds m^{-2}	Granular	Sprayed	\$1114.00
190 seeds m^{-2}	Granular	Unsprayed	\$1042.00
130 seeds m^{-2}	Granular	Sprayed	\$1005.00
260 seeds m^{-2}	Granular	Sprayed	\$1032.00

Conclusions and Recommendations

The results from this trial have provided several interesting insights to improve lentil production. Although overall yield and seed production as well as results differed between variety and sites, there are several underlying trends that can be concluded. Seeding rates, regardless of its significant and non-significant effect on yield, that exceed the current recommend rate of 130 seeds m^{-2} will result in greater yields and typically provides better profit margin. Secondly, the effect of inoculant consistently has a significant effect on lentil yield, however, the overall performance of each formulation varied significantly between sites. At Scott, granular inoculant provided the best yields and the greatest net profit compared to liquid formulation and non-inoculated treatments. These results coincide with several published results which indicated that granular inoculant resulted in better nodule formation and overall greater yields. In contrast, the effect of fungicide was highly non-significant for most of the parameters measured, with the exception of its effect on seed weight (TKW). When fungicide applications were analysed on an individual basis for an economic analysis, fungicide applications rarely result in a profit gain. However, when determining the best combination of agronomic practices, the use of fungicide with a seeding rate of 190 seeds m^{-2} and granular inoculant consistently provided the best yield and overall profit margin. These results suggest that although there was not a significant three-way interaction, a synergistic effect may occur under certain conditions. Overall, this study supports the use of granular inoculant as well as an increased recommended seeding rate greater than 130 seeds m^{-2} to reduce crop-weed competition and to improve overall profit gains.

Supporting Information

Acknowledgements

We would like to thank the Ministry of Agriculture for the funding support on this project. We would like to acknowledge Herb Schell and our summer staff for their technical assistance with project development and implementation for the 2016 growing season. This report will be distributed through WARC's website and included in WARC's and Agri-ARM annual reports.

Appendices

Appendix A

Table A.1. The P values were generated using the Tukey's HSD test ($P < 0.05$) to determine the effect of seeding rate (seeds m^{-2}), inoculant, and their interaction on SMALL red lentil plant densities (plants m^{-2}). Treatment means were generated from the pooled means of 2 site-years at Scott and Swift Current, 2016.

Seeding Rate (SR)	<0.0001
Inoculant (I)	0.7473
SR*I	0.143
Seeding Rate (seeds m^{-2})	*Treatment Means (plants m^{-2})*
260	226 [A§]
190	171 [B]
130	121 [C]

§Different lettering indicates significant difference between treatments, respectively.

Table A.2. The P values were generated using the Tukey's HSD test ($P < 0.05$) to determine the effect of seeding rate (seeds m^{-2}), inoculant, and their interaction on LARGE red lentil plant densities (plants m^{-2}). Treatment means were generated from the pooled means of 2 site-years at Scott and Swift Current, 2016.

Seeding Rate (SR)	<0.0001
Inoculant (I)	0.6688
SR*I	0.8536
Seeding Rate (seeds m^{-2})	*Treatment Means (plants m^{-2})*
260	195 [A§]
190	151 [B]
130	106 [C]

§Different lettering indicates significant difference between treatments, respectively.

Abstract

Abstract/Summary

Due to the role of lentils as a main component of the Canadian pulse market and the fact that producers are interested in improving their profit margins, this trial was set up to determine which combination of the main agronomic inputs produced the greatest lentil yield while providing the best economic return to producers. This demonstration was set up at Scott and Swift Current as a randomized complete block design with four replicates with 18 treatments with three factors: seeding rates: (130, 190 and 260 seeds /m^2), inoculants: (liquid, granular and none) and fungicide treatments: (fungicide and no fungicide) for both small and large red lentils. The underlying findings from the study suggest that 1) granular inoculant resulted in the best yield and net profit gains, 2) the effect of fungicide on yield was non-significant and typically resulted in net profit losses and 3) a seeding rate greater than 130 seeds m^{-2} typically resulted in a higher yield and greater net profits. Lastly, the best management practice that resulted in the greatest yield and net profits gains was a combination of granular inoculant, fungicide applications with a seeding rate of 190 seeds m^{-2}.

Extension Activities:

This project was shown to producers and agronomists at the Scott Field Day in July 2016, with an attendance of approximately 175 people. Jessica Weber discussed the effects of inoculants and the different inoculant formulations, as well as the possible changes in recommended seeding rates. It was also featured in the Scott Field Day pamphlet and posters that were distributed throughout the surrounding Wilkie, Landis, and Unity areas. Signs stating the objective of this demonstration with acknowledgement of the ADOPT program and the Saskatchewan Ministry of Agriculture were posted in front of the plots. A presentation will also be given at the Agri-ARM update during the Crop Production Week with an attendance around 50 people. A fact sheet will be generated and distributed on the WARC website as well as all Agri-ARM and WARC events to ensure the information will be transferred to producers.

WARC and WCA would like to express their appreciation for ADOPT funding provided by the Ministry of Agriculture for the project.

Finances

Expenditure Statement

Expenditure Statement

Majority of expenses associated with this project went towards labor ($8,000) required for the establishment of this field trial, including field operations, data collection, extension, data analyses and reporting. An amount of $1000 was requested for materials and supplies to cover costs of research supplies, fuel, crop inputs etc. There was a request for $400 for the Field Day and other tech transfer alternatives such as pamphlets and fact sheets. In addition, a $300 each was requested for administration costs and miscellaneous expenses, respectively (see attached expenditure statement for details).

Expenditure information for *Determining the Economic Value of Lentil Inputs and their Effect on Yield* at Scott, SK in 2016 (ADOPT 20150378).

	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total ($)
Salaries & Benefits				
Students	3,000			3,000
Postdoctoral / Research Associates	5,000			5,000
Technical / Professional Assistants				
Consultant Fees / Contractual Services				
Rental Costs				
Materials & Supplies	1,000			1,000
Project Travel				
Field Work				
Collaborations / consultations				
Other				
Field Day	400			400
Administration	300			300
Miscellaneous	300			300
Total	**10,000**			**10,000**

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