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

Project Title: Wheat and canola response to liming on slightly acidic soils after application

Project Number: 20150380

Producer Group Sponsoring the Project: Western Applied Research Corporation

Project Location: AAFC Scott Research Farm, R.M. #380, NE 17-39-21 W3

Project start and end dates: May 2016 –January 2017

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Objectives and Rationale

Project Objectives

The objective of this experiment was to determine if an application of SuperCal 98G can provide an economic return to producers in the year following application.

Project Rationale

The application of lime to soils with low pH (4.0-6.0) has been shown to increase the pH of the soil. This may result in increased crop yields and health of the soil due to increased availability of nutrients to the plant, especially phosphorus (P). SuperCal 98G is a 98 % pure calcitic limestone source. It can be broadcast similar to a typical agricultural lime source. However, contrary to the fact that traditional agricultural lime sources are required to be broadcast at rates well over 1000 lbs/ac to achieve any desirable soil pH change, SuperCal 98G has been shown to influence soil pH at rates as low as 400 lbs/ac to yield comparable soil pH change. In addition, SuperCal lime provides soil amendment benefits for up to five successive years following its first application. The goal of this demonstration was to show producers that lime applications with new products such as SuperCal 98G can improve crop yields and increase soil pH following the year of application without the requirement of spreading higher rates of typical traditional agricultural lime source.

Methodology and Results

Methodology

This demonstration was conducted at the AAFC Scott Research Farm in spring 2015 and 2016. A randomized complete block design arranged as a split-plot with four replicates was used. Crop type (canola and wheat) was considered as main plot factor and lime rates as sub-plot factor (Table 1). The lime product was broadcast prior to seeding in 2015 growing season. In 2015 growing season, both canola and wheat were seeded on wheat stubble and in 2016 the crops were swapped (i.e. canola on 2015 wheat stubble and wheat on 2015 canola stubble) to determine the impact of residual lime applied in 2015 growing season on the yield and net return. Fertilizer was applied at seeding according to soil test recommendations for each crop in both growing seasons. Weeds were controlled using a pre-seed burn down and registered in-crop herbicides (See Appendix A for complete details of field maintenance activities for 2015 and 2016).

Soil analyses (0-6") were done prior to seeding, in-crop and after plots were harvested in both 2015 and 2016 growing seasons. This was done to see the impacts of lime on pH change in application year and a year after that. Following visible rows, spring plant densities were assessed for both crops to determine the impacts of different liming rates on crop emergence. This was assessed by counting two 1 m rows in the front and back of the plot for a total of four rows per plot. The average of the four rows was converted to plants m^{-2} based on 10 inch row spacing.

Normalized Difference Vegetation Index (NDVI) as a measure of plant vigour was done in both crops at two timings using canola growth stages (i.e. Four leaf stage and prior to bolting). Grain yields were also measured to determine if lime rates provided an economic benefit to producers. Both canola and wheat were straight-combined using a wintersteiger plot combine after desiccation. Both grains were cleaned and corrected to 10 % and 14.5 % moisture content for canola and wheat, respectively.

Table 1: Demonstration treatment list for 2015 and 2016 growing seasons

Treatment	**Crop type**	**Lime rate (lbs/ac)-SuperCal 98G**
1	canola	0
2	canola	300
3	canola	400
4	canola	500
5	canola	600
6	canola	700
7	wheat	0
8	wheat	300
9	wheat	400
10	wheat	500
11	wheat	600
12	wheat	700

Statistical Analysis

An analysis of variance (ANOVA) was conducted on plants emergence, NDVI and grain yield using the Proc Mixed in SAS 9.4. Lime rate and crop were considered fixed effect factors and replication was considered a random effect factor. The assumptions of ANOVA (equal variance and normally distributed) were tested using a Levene’s test, and Shapiro-Wilks. The data was normally distributed;

therefore, no data transformation was necessary. Treatment means were separated using Tukey's Honestly Significant Difference (HSD) and considered significant at $P < 0.05$. Weather data was estimated from the nearest Environment Canada weather station (Table 2).

Results

Growing season weather conditions

In Scott, the 2015 growing season started very dry with only 4.1mm and 19.4 mm accumulated precipitation during the month of May and June, respectively. In contrast, August received approximately 39 % more moisture compared to the long-term average. The mean monthly temperatures were comparable to the long-term values (Table 2). Also, the 2016 growing season started out very dry in April with only 1.9 mm of precipitation. However, 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 accumulated growing degree days from April to October for the 2015 and 2016 growing seasons at Scott, SK

Year	April	May	June	July	August	Sept.	Oct.	Average /Total
	Temperature (°C)							
2015	-	9.3	16.1	18.1	16.8	10.9	-	14.24
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)							
2015	-	4.1	19.4	46.4	74.5	49.6	-	194.0
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	13.0	290.6
	Growing Degree Days							
2015	-	140.3	332.0	405.1	365.8	179.8	-	1423.0
2016	58.9	224.9	303.0	398.7	343.8	176.2	12.5	1518.0
Long-term[z]	44.0	170.6	294.5	380.7	350.3	192.3	42.5	1474.9

[z]Long-term average (1985-2014)

Table 3: Effects of liming rate (Ibs/ac) on measured response variables in canola and wheat at Scott, SK.

Year /Effects	Plant density (plants/m^2)	NDVI_1 (4 leaf stage)	NDVI_2 (Bolting stage)	Yield (bu/ac)
	---------*Canola*---------			
2015	0.8868	0.5823	0.7226	0.6273
2016	***0.0309***	0.8321	0.3470	0.6575
Combined	0.9548	0.5611	0.4774	0.4528
	---------*Wheat*---------			
2015	0.1526	0.1621	0.3671	0.2405
2016	0.9304	0.5846	***0.0489***	0.7354
Combined	0.4463	0.8380	0.2374	0.9591

Effects of liming on pH change in canola and wheat

From the ANOVA table (Table 3), there were no significant effects of lime on all the response variables in 2015 growing season and the combined analysis. However, in 2016 growing season, plant density in canola and plant vigor (NDVI_2) in wheat at the second reading were all significantly different due to lime rates (Table 3).

Soil pH change under both canola and wheat crops were not significantly different due to the different lime rates in both growing seasons (Figures 1 and 2). This was contrary to our expectation; however, at both in-crop and postharvest soil sampling in the 2015 growing season, in almost all the lime rate plots, undissolved lime products were seen. In the 2016 growing season, despite the lack of significance among the lime rates on average soil pH, the respective rates had higher pH values compared to their 2015 counterparts in both crops (Figures 1and 2). The change was more conspicuous in canola than in wheat (Figures 1 and 2). The trend of non-significance of the lime treatments relative to the control conforms to previous studies where statistically significant increase in soil pH relative to the control to a depth of 15 cm (top 6 inch) were only found two years after lime was broadcast. This was linked to greater pore continuity or enhanced earth-worm activity in direct seeded systems such as no-till systems (Blevins et al., 1983).

The focus of our pH measurements was restricted to only the top six inches (0-6″) of the soil profile. This is because soil acidity develops more rapidly at the depth of N fertilizer placement in direct-seeded (e.g. no-tillage) compared with conventionally tilled soils due to the absence of mechanical mixing and repeated N fertilizer application in the same zone (Mahler and Harder, 1984; Robbins and Voss, 1989).

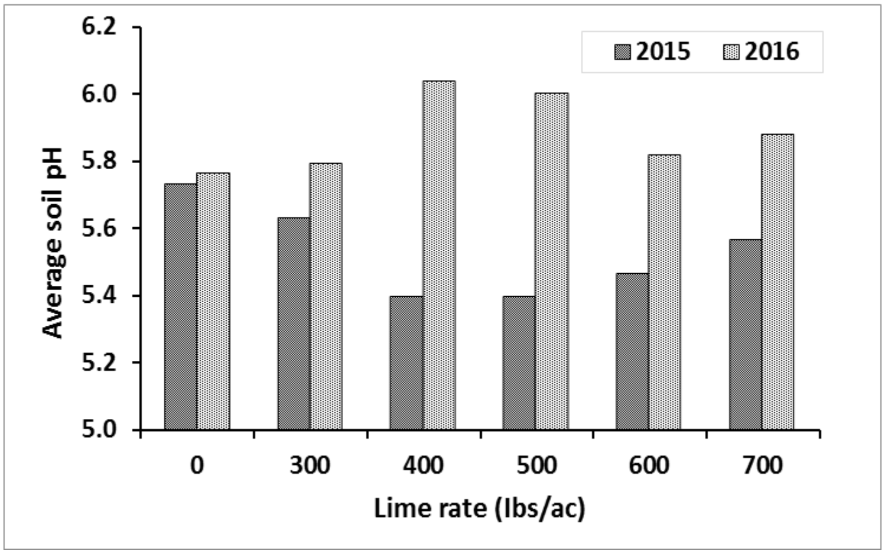

Figure 1: Changes in average soil pH (0-6") with respect to lime product rate (lbs/ac) under canola in the year of application (2015) and the year after application (2016) at Scott, SK.

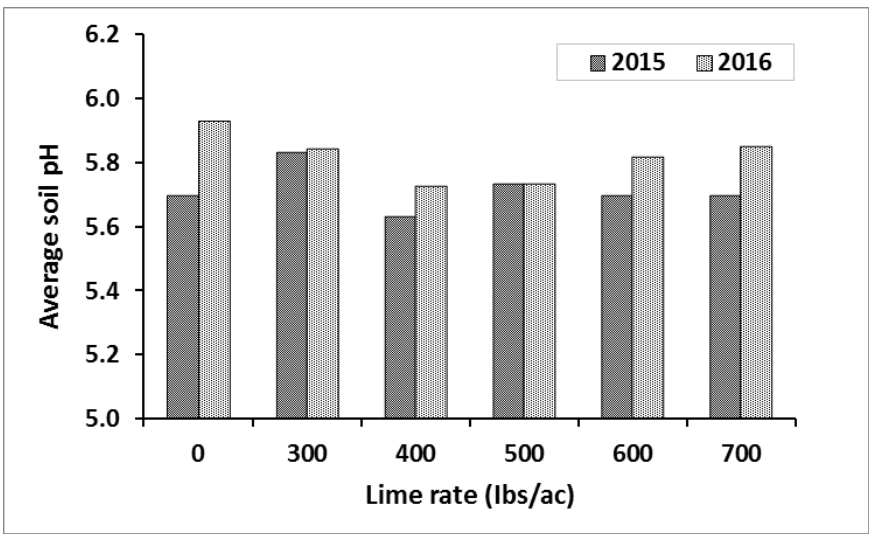

Figure 2: Changes in average soil pH (0-6") with respect to lime product rate (lbs/ac) under wheat in the year of application (2015) and the year after application (2016) at Scott, SK.

Plant Emergence

Plant density was assessed following visible rows for both crops to determine the impacts of increasing liming rate and or/residual lime on crop emergence. There were no significant differences in the plant population in both canola and wheat in the 2015 growing season and a combined data due to lime application (Table 3). However, in the 2016 growing season, canola plant density was significantly affected by lime rate (P = 0.0309) despite the non-significance of lime rate on wheat plant density (P = 0.9304) (Table 3). This was not anticipated as higher lime rate incorporated in addition to P fertilizer at seeding in the same seed-row should have shown some burning effects on the seed. However, at both in-crop and postharvest soil sampling in 2015, in almost all the lime rate plots, undissolved lime products were seen. This can be linked to the dry periods within the growing season, making it hard for the lime to dissolve. The significant effects of lime in 2016 especially in canola could be attributed to the amount of moisture received during the growing season. Based on our analysis, the effect of lime, especially in the year of application did not have an effect on plant density in canola and wheat; however, there is the tendency for increased pH following the year of application.

Normalized Difference Vegetation Index (NDVI)

NDVI as a measure of plant vigour was determined in both canola and wheat using two canola timings (i.e. Four leaf stage and prior to bolting). There were no significant effects of lime rates on NDVI in both crops at both timings in the 2015 growing season and as a combined analysis (Table 3). The trend in 2016 growing was similar except in wheat at the second timing where lime rates subtly ($P = 0.0489$) (Table 3) affected the vigour of the plants. When both crops were compared based on plant vigour, there was no difference in NDVI values based on lime rate at the first timing (data not shown). However, during the second timing, the values from canola were relatively higher than that of the wheat. This can be related to crop physiology, because at four leaf stage in canola, its biomass yield can be compared to the wheat crop. However, once it reached the bolting stage, the leaf diameter covers the soil surface, as opposed to the wheat plant, which grows vertically. Therefore, any measure of vigour will show the canola being more vigorous relative to the wheat. Again, due to the favourable growing conditions in the 2016 growing season, both plants were vigorous compared to their 2015 counterparts. This difference in vigor at the bolting stage in canola relative to the wheat may be attributed to the fact that it coincided with the strongest growth stage in canola compared to wheat, which was a physiological effect and not due to the liming effects.

Grain Yield

There were no significant effects of lime rates on the yield of both canola and wheat both in 2015 or 2016 growing seasons and as a combined analysis (Table 3). This shows that pH might not have been the limiting factor to yield in both crops. There may be several possible explanations why liming did not affect yield of both crops even at elevated rates in 2015 growing season. One reason may be due to the fact that the lime did not fully dissolve to effect any change in pH in order to affect yield. Another reason has to do with the critical pH range for both wheat and canola. Based on the critical pH for wheat of 5.1-5.4 (Mahler and McDole, 1987), the soil pH was above the critical limit for wheat. Therefore, the lime applied might have acted to maintain that plateau rather than to elevate pH to economically affect yield (Figure 2). In canola, the critical pH is 5.5-5.8 (Brown et al., 2009; Lofton et al., 2010). However, there was no yield advantage of lime application despite the fact that most of the pH at the different lime rates were below the 5.5-5.8 critical point (Figure 1). This was not anticipated, as canola yield reductions will most likely be realized if soil pH falls below 5.8 (Brown et al., 2009). The 2016 growing season saw a similar trend of non-significance of lime on the yield of both canola and wheat despite the consistently higher soil pH relative to the 2015 growing season (Figures 1 and 2). Yield, was, however, consistently higher at the respective lime rates in both crops in the 2016 growing season relative to the 2015 values (Figure 5).

There were linear strong positive correlations between pH and average yield as a combined analysis for canola ($r^2 = 0.56$; P< .0001) and wheat ($r^2 = 0.37$; P = 0.0098). The finding from this study conforms to a study by Lofton et al. (2010) who found a strong linear relationship between canola seed yield and soil pH (r^2= 0.70; P< 0.01) and for every 0.1 increase in soil pH canola seed yield increased by 157 kg ha^{-1}. The same authors found a linear relationship between canola seed yields and soil pH (r^2= 0.55; P< 0.01), where for every 0.1 increase in soil pH, canola seed yields increased 22.2 kg $ha^{-1}$the following year. Lofton et al. (2010) further concluded that, regardless of the difference between years, canola seed yield decreased linearly below a pH of 5.8 in both years. However, in this study, there is an increase in yield in canola in the year following application due to increased pH above 5.8.

Finally, despite the correlation between average yield and pH after two years, this study found no yield advantage of lime application in either 2015 or 2016 growing season, although there is increase in pH values from the initial values. This finding agrees with a study that found no grain yield response in one year of research of sub-surface banded lime at a rate of 220 kg ha^{-1} despite reduced soil acidity in the surface 10 cm at an eastern Washington location (Wildey, 2003).

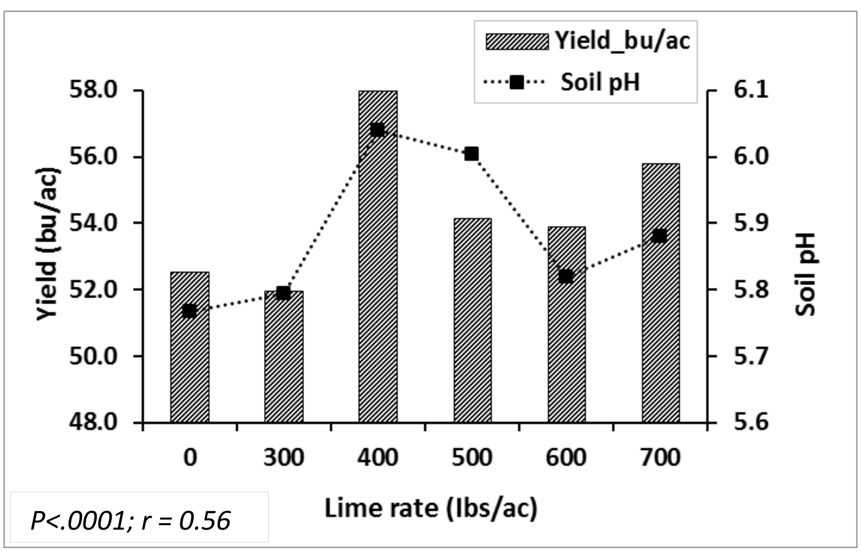

Figure 3: Correlation between average yield (bu/ac) and soil pH in canola with respect to lime product rate (lbs/ac) in the year following application at Scott, SK.

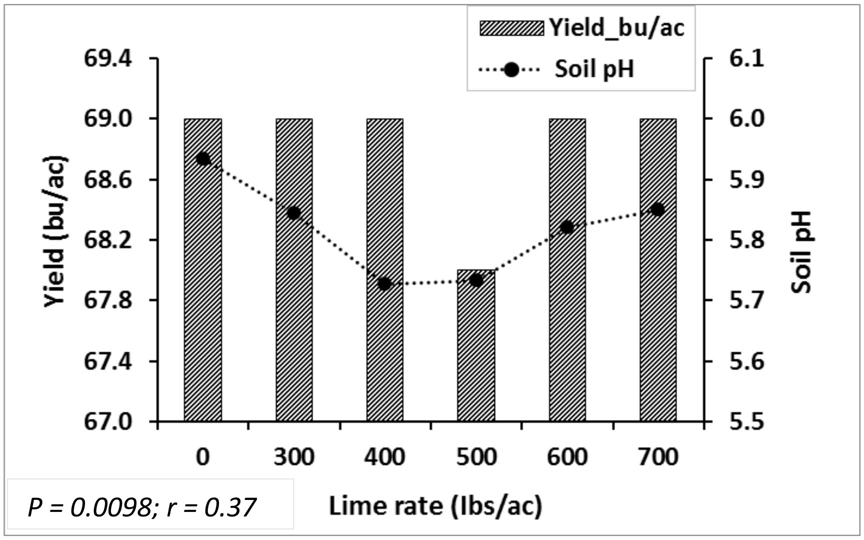

Figure 4: Correlation between average yield (bu/ac) and soil pH in wheat with respect to lime product rate (lbs/ac) in the year following application at Scott, SK.

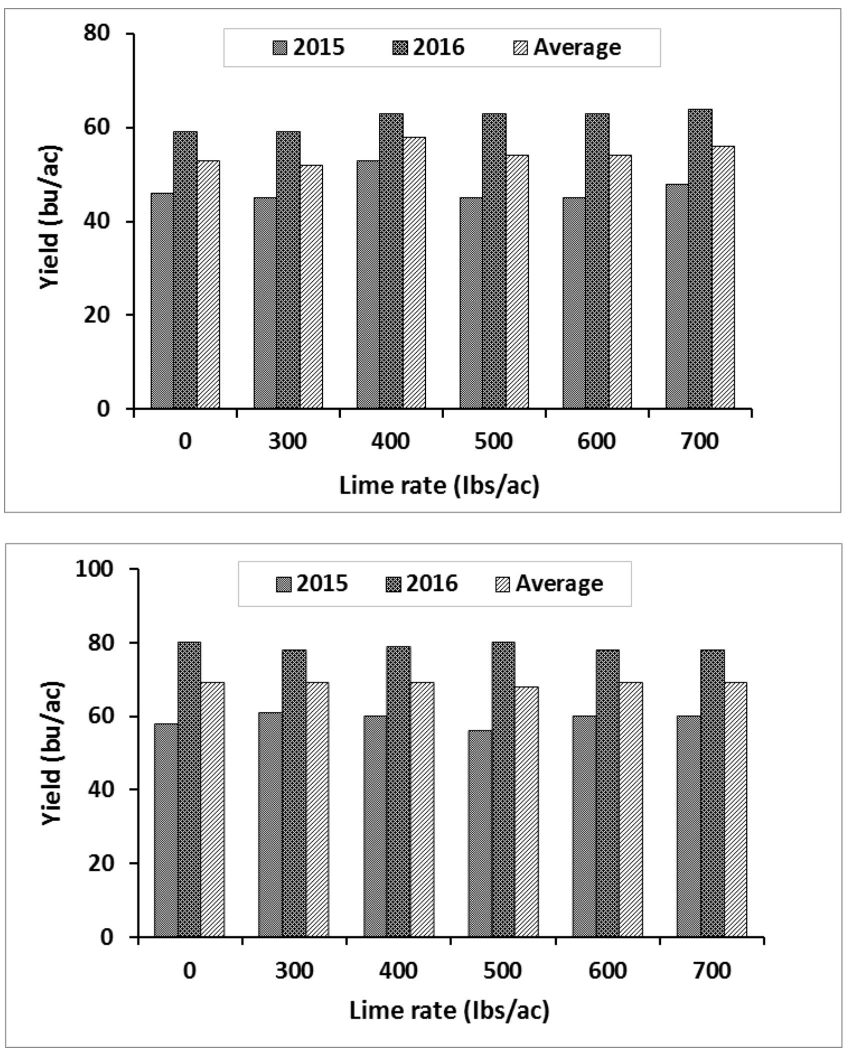

Figure 5: Variation in yield (bu/ac) at different lime rates (lbs/ac) in the year of application (2015), a year after application (2016) and the average in canola (top) and wheat (bottom) at Scott, SK.

Economic returns of lime application

From an economic perspective, liming is considered a capital investment rather than an operating input because of its long-term effect (Lukin and Epplin, 2003). In previous research, economic optimization was modeled under the limiting assumption that only a single application of lime could be made at the beginning of a fixed time period. The underlying result of the 'economic model' is that when soil pH level is below the critical point for crop yield, an initial application of lime is warranted to increase the pH to reach the plateau level, a level at which crop yield is maximized and maintained. Any subsequent applications are made to maintain the soil pH near that level so as not to impact yield negatively. This was the adopted assumption in this study, because this lime product has a claim of residual effects even five years following the application year.

In this study, based on the critical pH for wheat of 5.1-5.4 (Mahler and McDole, 1987), the soil pH is above the critical limit for wheat in both growing seasons and so the lime applied acted to maintain that plateau rather that elevate pH to economically affect yield. In canola, the critical pH is 5.5-5.8 (Brown et al., 2009; Lofton et al., 2010), however, there was no yield advantage of lime application despite the fact that most of the pH at the different lime rates were below the 5.5-5.8 critical point, especially in the 2015 growing season. The higher correlation coefficient in canola (r^2 = 0.56) compared to wheat (r^2 = 0.37) at the end of the second year between pH and yield may be explained by the huge improvement in pH under canola than under wheat (Figures 1, 2, 3 and 4).

From the economic analysis (Figures 6 and 7), application of SuperCal 98G may start yielding positive return in the year following application relative to the negative returns in the year of application. However, there is no huge gain of its application (0 Ibs/ac vs. other rates). This goes to support the idea that liming should be considered as a capital investment instead of an input cost and expect positive net return after several years following application.

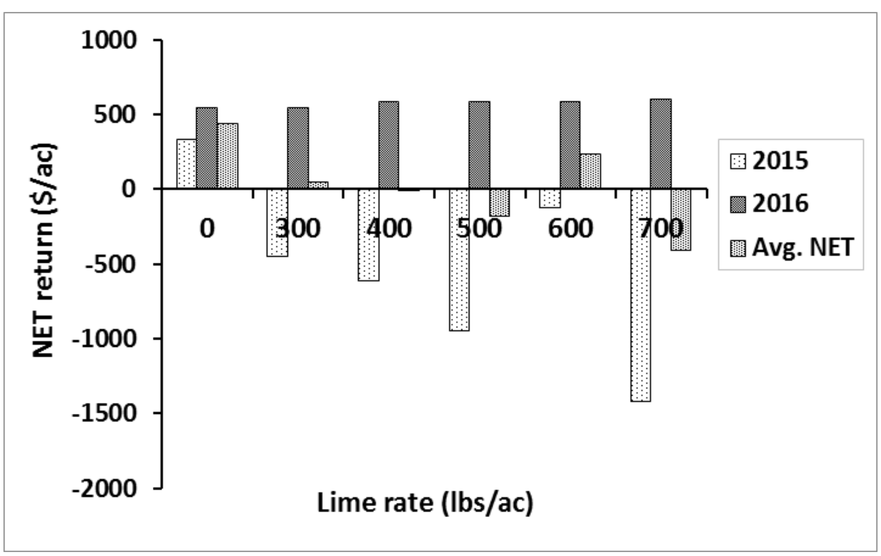

Figure 6: Net Economic return ($/ac) of lime application on slightly acidic soils under canola at Scott, SK

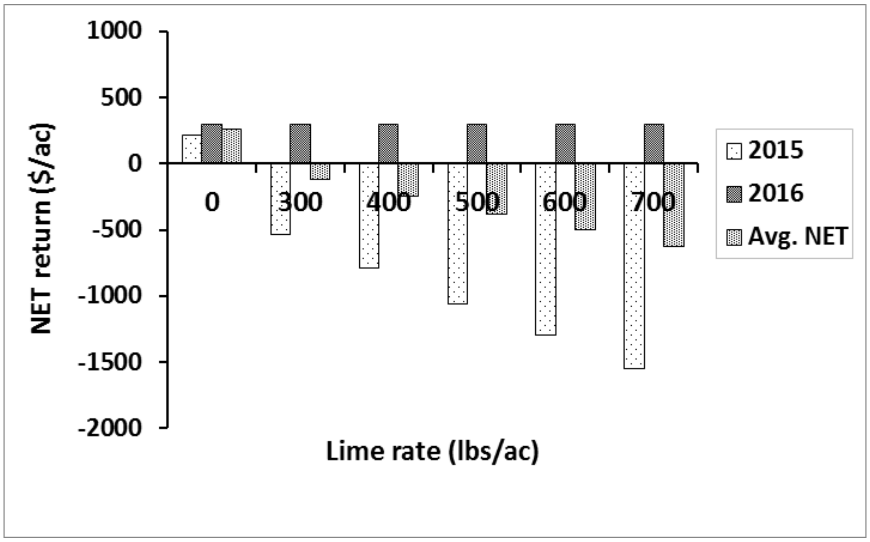

Figure 7: Net Economic return ($/ac) of lime application on slightly acidic soils under wheat at Scott, SK

Conclusions and Recommendations

Although the soil pH was generally below the critical levels for canola especially in 2015 growing season and above for wheat, there was no significant effect of that on all the measured parameters. Crop yield despite not directly impacted by lime rates, was higher in 2016 relative to 2015. This trend may be due to improved growing conditions in 2016 rather than change in pH. However, there is a propensity of increased pH to positively affect yield in subsequent years due to the significant positive correlation between yield and soil pH. Though liming in no-till systems may not result in crop yield responses, especially in the year of application, the continued use of NH_4–based fertilizers and projected decline in soil pH suggests some form of pH control may be needed in the future. Though the net economic gain may be not be worthwhile in the year of application and even a year following application, farmers should bear in mind that it is a capital investment rather than an input and expect a net return after few years following application! Should famers and producers be concerned on their farms? Based on the results and the current management practices, we will recommend farmers to be more aware than concerned and keep the pH factor in mind when planning nutrient management programs.

<u>Supporting Information</u>

Acknowledgements

We would like to thank the Ministry of Agriculture for funding this project through the ADOPT program. We would like to acknowledge Herb Schell and our summer staff for their technical assistance with project development and implementation. This report will be distributed through WARC's website and included in WARC's annual report. In March 2017 results was discussed with farmers and producers under the topic "*Soil health and rotational benefits"* during WARC's Crop Opportunity Update and a poster presentation and a poster presented at Soils and Crops Conference.

Appendices

Appendix A – Agronomic information for the demonstration in the 2015 and 2016 growing seasons

Abstract

Abstract/Summary

The continuous use NH_4-based fertilizers in crop production have the tendency to acidify soils and threatened crop production in the long-term, leading to reduced crop yields. Conventional lime products used to remediate acidic soils are important costs to producers due to the higher rates of application. However, a lime product, SuperCal 98G, is said to alter pH over a short period of time even at lower application rates. This study was conducted to determine the impact of SuperCal 98G on soil pH, crop yield and net economic return both in the year of application and the year after that. The experiment was set up as a split-plot in a randomized complete block design with four replications. The one-time lime rates were 0, 300, 400, 500, 600 and 700 lbs/ac on canola and wheat (main plots) in 2015 and 2016 growing seasons. Soil pH (0-6") was estimated prior, during and after harvest to determine the effects of incremental lime rate in 2015 and 2016. Generally, there were no significant effects of lime on all the response variables in 2015 growing season and the combined analysis. However, in the 2016 growing season, plant density in canola and plant vigor in wheat at the second reading were all significantly different. This trend may be due to improved growing conditions in 2016 rather than change in soil pH. However, there is a propensity of increased pH to positively affect yield in the subsequent years due to the significant positive correlation between yield and soil pH. Although liming in no-till systems may not result in crop yield responses, especially in the year of application, the continued use of NH_4–based fertilizers and projected decline in soil pH suggests some form of pH control may be needed in the future. Finally, despite the net economic gain not being a worthwhile in the year of application and even a year following application, farmers should bear in mind that liming is a capital investment rather than an input and expect a net return after few years following application

Finances

Expenditure Statement

Majority of expenses associated with this project ($5,500) went towards labor required for the establishment of this field trial, including field operations, data collection, extension, sample analyses and contractual services. An amount of $500 was requested for materials and supplies to cover costs of miscellaneous 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, $300 was requested for administration costs (see attached expenditure statement for details).

Expenditure information for Wheat and canola response to liming on slightly acidic soils following application at Scott, SK in 2016 (ADOPT 20150380).				
	Year 1 ($)	Year 2 ($)	Year 3 ($)	Total ($)
Salaries & Benefits				
Students	1,500			1,500
Postdoctoral / Research Associates				
Technical / Professional Assistants	3,500			3,500
Consultant Fees / Contractual Services	500			500
Rental Costs				
Materials & Supplies	500			500
Project Travel				
Field Work				
Collaborations / consultations				
Other				
Field Day	400			400
Administration	300			300
Miscellaneous				
Total	**6,700**			**6,700**

Appendix A
Agronomic information for 2015 and 2016 demonstrations

Table A.1. Selected agronomic information for the 'Wheat and canola response to liming on slightly acidic soils following application' trial at Scott, SK.

Seeding Information	2015	2016
Liming application	May 4, 2015	N/A
Seeder	R-Tech Drill, 10 inch row spacing, knife openers	R-Tech Drill, 10 inch row spacing, knife openers
Seeding Date	May 11, 2015	May 6, 2016
Cultivar	Wheat – Sadash; Canola– L130	Wheat – Sadash; Canola– L130
Seeding Rate	Wheat –250 seeds m^{-2}; Canola – 150 seeds m^{-2}	Wheat –300 seeds m^{-2}; Canola – 150 seeds m^{-2}
Stubble Type	Wheat	Wheat stubble for canola and canola stubble for wheat
Fertilizer applied	100 lbs N ac^{-1} as Urea, (balanced with MAP and AS in blend)- Mid-rowed and 40 lbs P_2O_5 ac^{-1} as MAP/AS with seed (wheat)	80 lbs of 12-20-10-13 mid-row and 58 lbs of 11-52-0 seed-placed for wheat
	110 lbs N ac^{-1} as Urea, (balanced with MAP and AS in blend)- Mid-rowed and 25 lbs P_2O_5 ac^{-1} as MAP/AS with seed (canola)	80 lbs of 12-20-10-13 mid-row and 24 lbs of 11-52-0 seed-placed for wheat
<u>Plot Maintenance Information</u>		
Pre-plant herbicide	Roundup ¾ L/ac + Pardner 0.4 L/ac (May 18, 2015)	Roundup RT 540 @ ¾ L/ac
In-crop herbicide	Buctril M 0.4 L/ac + Axial 0.48 L/ac (June 10, 2015)	Buctril M 0.4 L/ac + Axial 0.48 L/ac
Fungicide	N/A	Priaxor @ 120mL/ac on June 29 2016(canola), July 5, 2016 (wheat)
Desiccation	Glyphosate @ 1L/ac (August 20, 2015) – Wheat Reglone @ 0.8 L/ac (August 18, 2015) – Canola	Glyphosate @ 1L/ac (August 24, 2016) – Wheat Reglone @ 0.8 L/ac (August 24, 2016) – Canola
<u>Data Collection</u>		
Emergence Counts	May 23 (wheat) & May 26(canola), 2015	May 26, 2016 (wheat) & June 26, 2016
Harvest Date	September 01, 2015(wheat) & August 27, 2015 (canola)	August 29, 2016 (canola) & September 6, 2016 (wheat)

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