2015 Annual Report
for the
Agriculture Demonstration of Practices and Technologies
(ADOPT) Program

Project Title: Wheat and canola response to liming on slightly acidic soils
Project Number: 20140347

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

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Objectives and Rationale

Project Objectives

The objective of this experiment was to determine if an application of SuperCal 98G (lime product) can provide an economic return to producers

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 due to increased availability of nutrients especially, phosphorus to the plant. SuperCal 98G is a 98% pure calcitic limestone source. It can be broadcast similar to a typical agricultural lime source. Traditional agricultural lime sources are required to be broadcast at rates well over 1000 lbs/ac to achieve any desirable soil pH change. However, SuperCal 98G has been shown to influence soil pH at rates as low as 400 lbs/ac to yield comparable soil pH change to higher rates of agricultural lime. In addition, SuperCal lime provides soil amendment benefits for up to five successive years. The goal of this demonstration is to show producers that lime applications with new products such as SuperCal 98G can improve crop yields without the requirement of spreading thousands of lbs/ac of a traditional agricultural lime source.

Methodology and Results

Methodology

This demonstration was conducted at the AAFC Scott Research Farm in spring 2015. A randomized complete block design arranged as a split-plot with four replicates was used. Crop type (wheat and canola) was considered as main plot factor and lime rates as sub-plot factor (Table 1). The lime product was applied in the seed row using seed drill, one week prior to seeding. Fertilizer was applied at seeding according to soil test recommendations for each crop. Weeds were controlled using a pre-seed burndown and registered in-crop herbicides (See **Appendix A** for complete details of field maintenance activities).

Soil analyses were done prior to seeding, two weeks after lime application and after plots were harvested. This was done to see the impacts of lime on pH change. 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 at two canola timings (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 wheat and canola were straight-combined using a wintersteiger plot combine after desiccation. The grain was cleaned and corrected for moisture content at 14.5 % and 10 % for wheat and canola, respectively.

Table 1: Demonstration treatment list for 2015 growing season

Treatment	Crop Type	Lime Rate (lbs/ac)
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 yield using the Mixed Procedure in SAS 9.3. 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 early 2015 growing season was 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 previous years. Furthermore, there was an increase in precipitation during August (74 mm), an increase of 27 % compared to the long term average (Table 2).

Table 2. Mean monthly temperature, precipitation and growing degree day accumulated from May to September 2015 at Scott, SK

Year	May	June	July	August	Sept.	Average /Total
			Temperature (°C)			
2015	9.3	16.1	18.1	16.8	10.9	14.24
Long-term^z	10.8	15.3	17.1	16.5	10.4	14.0
			Precipitation (mm)			
2015	4.1	19.4	46.4	74.5	49.6	194.0
Long-term^z	36.3	61.8	72.1	45.7	36.0	215.9
			Growing Degree Days			
2015	140.3	332.0	405.1	365.8	179.8	1423.0
Long-term^z	178.3	307.5	375.1	356.5	162.0	1379.4

^{z}Long-term average (1981-2010)

Table 3. Effects of lime rate (lbs/ac) on response variables in wheat and canola at Scott, SK (2015)

Effect	Plant Density		NDVI_1		NDVI_2		Yield (kg/ha)	
	Wheat	***Canola***	***Wheat***	***Canola***	***Wheat***	***Canola***	***Wheat***	***Canola***
			P values					
Lime rate	0.147	0.8868	0.6322	0.1255	0.3558	0.6693	0.3540	0.6474

Effects of liming on pH change in wheat and canola

From the ANOVA table (Table 3), there was no significant effects of lime application on soil pH change under both wheat and canola crops. The trend can also be seen in figures 1and 2. This was contrary to our expectation; however, at both in-crop and postharvest soil sampling, in almost all the lime rate plots, undissolved lime products were seen. Hence, relative to the 0 lbs/ac, there should not be any change in pH due to lime. Previous studies only found statistically significant increase in soil pH relative to the control to a depth of 15 cm (top 6 inch) 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 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).

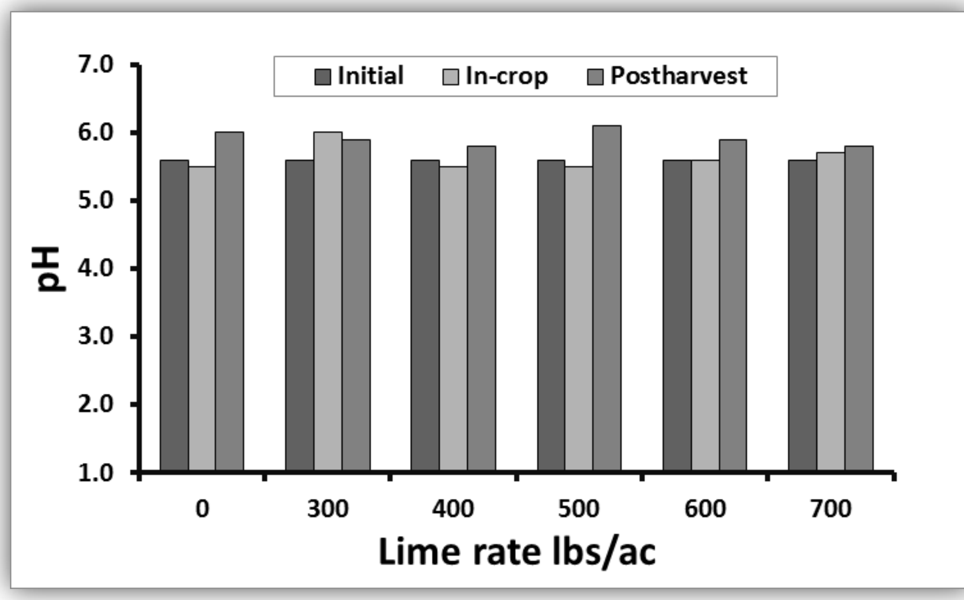

Figure 1: Changes in pH (top 6 inches) at three different timings with respect to lime product application in wheat plots

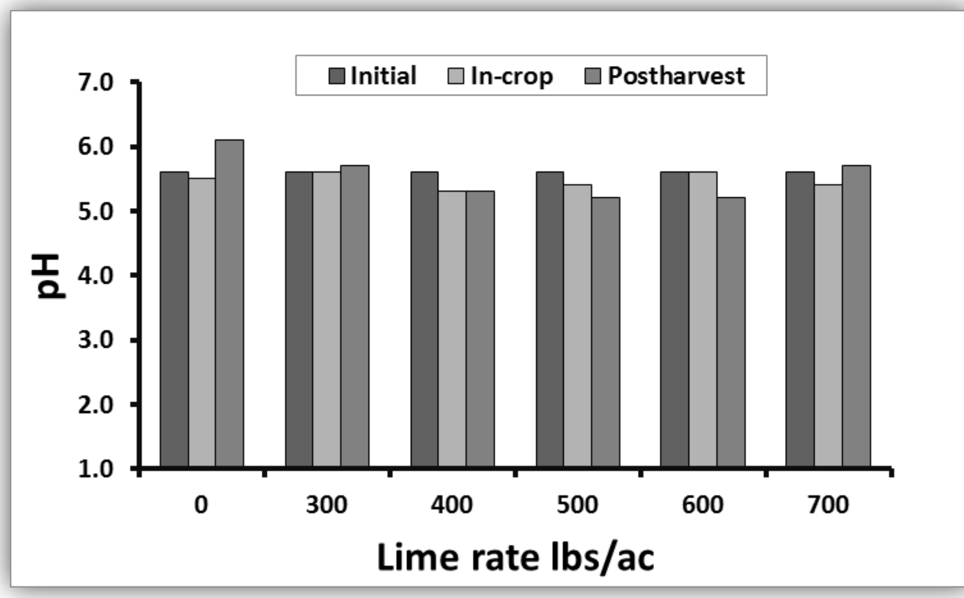

Figure 2: Changes in pH (top 6 inches) at three different timings with respect to lime product application in canola plots

Plant Emergence

Plant density was assessed following visible rows for both crops to determine the impacts of increasing liming rate on crop emergence. There was no significant differences in the plant population in both wheat (P = 0.147) and canola (P = 0.8868) crops due to lime application (Table 3). This was not anticipated as higher lime rate in seed-row 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 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 or the lime to dissolve. Based on our analysis, the effect of lime, especially in the year of application did not have an effect on plant density in wheat and canola.

Normalized Difference Vegetation Index (NDVI)

NDVI as a measure of plant vigour was determined at two canola timings (i.e. Four leaf stage and prior to bolting). There was no significant effect of lime rate on NDVI at both times in both crops (Table 3). When both crops were compared, there was no difference in NDVI values based on lime rate at the first reading (four canola leaf stage). However, during the second reading, the values from canola were relatively higher than that of the wheat. This can be related to crop physiology, because at four canola leaf stage, its biomass yield can be compared to the wheat crop. However, once it reached the bolting stage, the leave 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. This difference at the bolting stage in canola relative to the wheat indicated that the strongest growth was occurring in canola compared to the wheat, which was a physiological effect and not due to the liming effects.

Grain Yield

There was not significant effects of liming rate on the yield of both wheat (P = 0.3540) and canola (P = 0.6474) (Table 3 and Figure 3). This shows that pH is not a limiting factor to the performance of the both crops in terms of yield. There may be several possible explanations why liming rate did not affect yield of both crops even at elevated rates. One reason can 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 is 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 4). 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 4). 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 lack of correlation between pH and yield, especially in canola in this study runs parallel to a study which 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 author 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. The study concluded that, regardless of the difference between years, canola seed yield decreased linearly below a pH of 5.8 in both years (Lofton et al., 2010).

Our study, however, partially agrees with a study that found no grain yield response in one year of research of subsurface 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).

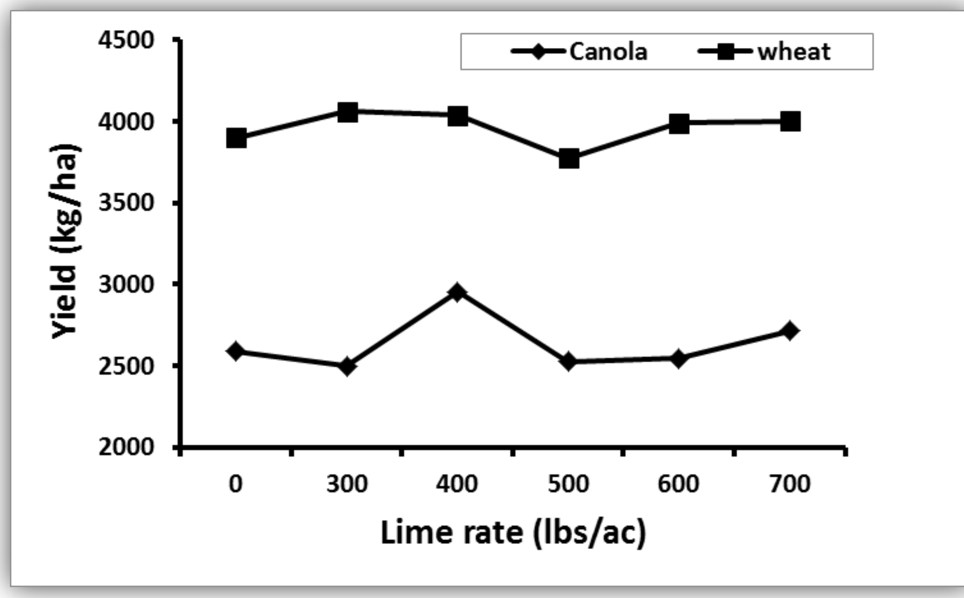

Figure 3: Effects of lime rate on the yield of canola and wheat in the year of application at Scott, SK

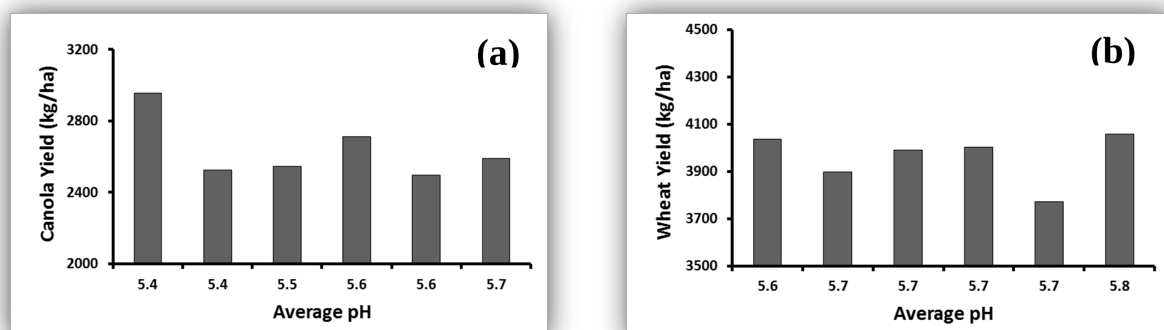

Figure 4: Effects of average pH on the yield of canola (**a**) and wheat (**b**) in the year of application at Scott, SK

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 of this study, because this lime product has a claim that its effects can be felt even five years after 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 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.

From the economic analyses (Tables 4 and 5), liming application rather resulted in negative returns in the year of application. This goes to support the idea that liming should be considered as a capital investment instead of an input cost.

Table 4. Net Economic gain of lime application on slightly acidic soils under canola in the year of application at Scott, SK (2015)

Liming rate (lbs/ac)	***0***	***300***	***400***	***500***	***600***	***700***
Yield (bu/ac)	46	44	53	45	45	48
Price ($/bu)	10.16	10.16	10.16	10.16	10.16	10.16
Gross Income ($/ac)	*467.36*	*447.04*	*538.48*	*457.20*	*457.20*	*487.68*
Seed cost ($/ac)	56.00	56.00	56.00	56.00	56.00	56.00
Fertilizer cost ($/ac)	78.68	78.68	78.68	78.68	78.68	78.68
Cost of lime ($/ac)	0.00	759.00	1012.00	1265.00	1518.00	1771.00
Total Cost ($/ac)	134.68	893.68	1146.68	1399.68	1652.68	1905.68
NET Gain ($/ac)	***332.68***	***-446.64***	***-608.20***	***-942.48***	***-1195.48***	***-1418.00***

Table 5. Net Economic gain of lime application on slightly acidic soils under wheat in the year of application at Scott, SK (2015)

Liming rate (lbs/ac)	***0***	***300***	***400***	***500***	***600***	***700***
Yield (bu/ac)	58	60	60	56	59	60
Price ($/bu)	5.36	5.36	5.36	5.36	5.36	5.36
Gross Income ($/ac)	*310.88*	*321.60*	*321.60*	*300.16*	*316.24*	*321.60*
Seed cost ($/ac)	23.25	23.25	23.25	23.25	23.25	23.25
Fertilizer cost ($/ac)	71.63	71.63	71.63	71.63	71.63	71.63
Cost of lime ($/ac)	0.00	759.00	1012.00	1265.00	1518.00	1771.00
Total Cost ($/ac)	94.88	853.88	1106.88	1359.88	1612.88	1865.88
NET Gain ($/ac)	***216.00***	***-532.28***	***-785.28***	***-1059.72***	***-1296.64***	***-1544.28***

Conclusions and Recommendations

Although the soil pH was generally below the critical levels for canola and above for wheat, there was no significant effect of that on all the measured parameters. 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, 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? We will recommend them to be more aware than concerned and keep the pH factor in mind when planning nutrient management programs.

Supporting Information

Acknowledgements

We would like to thank the Ministry of Agriculture for funding this project. 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 2016 during WARC's Crop Opportunity Update, results will be discussed with farmers and producers under the topic "*Soil pH and Liming*".

Appendices

Appendix A – Agronomic information for the demonstration

Abstract

Abstract/Summary

The continuous use ammonium based nitrogen fertilizers in crop production has the tendency to acidify soils and this might threaten crop production around NW SK in the long-term, leading to reduced crop yields. Conventional lime used to correct soil pH is an important cost to producers due to the higher rates of application. However, a lime product called, SuperCal 98G, is said to alter pH over a short period of time at lower rates relative to the conventional agricultural lime. This study was conducted to estimate soil pH change and its effects on crop yield, and determine the net economic return of lime application. The experiment was set up as a split-plot in a randomized complete block design with four replications. The main plot was crop type (canola and wheat) and the split-plots were the lime rate (0, 300, 400, 500, 600 and 700 lbs/ac). Lime product was subsurface banded in the seed-row, seven days prior to seeding. Soil pH was estimated prior, during and postharvest to determine the effects of incremental lime rate. The pH values were averaged at the end of the season and related to crop yield. There was no effect of lime rate on plants emergence and yield in both crops. Normalized Difference Vegetation Index (NDVI) was assessed twice in both crops when canola was at the four leaf and bolting stages. The slightly higher NDVI value at the bolting stage in canola relative to wheat was considered physiological, rather than a liming effect. Although soil pH is below the critical levels especially for canola, liming no-till systems may not result in crop yield responses at this time. In wheat, the soil pH values at all lime rates were above the critical level, hence the lack of significant effects on the measured parameters. From an economic perspective, liming is considered a capital investment rather than an operating input due to its long-term effect, so there wasn't an economic advantage of liming, especially in the year of application. Nevertheless, 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. Results from this demonstration will be presented at WARC's crop opportunity update in March 2016. This report will be distributed through WARC's website and included in WARC's annual report.

Appendix A
Agronomic information for 2015 demonstration

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

Seeding Information	2015
Liming application	May 4, 2015
Seeder	R-Tech Drill, 10 inch row spacing, knife openers
Seeding Date	May 11, 2015
Cultivar	Wheat – Sadash; Canola– L130
Seeding Rate	Wheat –250 seeds m^{-2}; Canola – 150 seeds m^{-2}
Stubble Type	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)
	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)
Plot Maintenance Information	
Pre-plant herbicide	Roundup ¾ L/ac + Pardner 0.4 L/ac (May 18, 2015)
In-crop herbicide	Buctril M 0.4 L/ac + Axial 0.48 L/ac (June 10, 2015)
Desiccation	Glyphosate @ 1L/ac (August 20, 2015) – Wheat Reglone @ 0.8 L/ac (August 18, 2015) – Canola
Data Collection	
Emergence Counts	May 23 (wheat) & May 26(canola), 2015
Harvest Date	September 01, 2015(wheat) & August 27, 2015 (canola)

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