2017 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

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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, 2016, and 2017. A randomized complete block design arranged as an RCBD 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. In 2017 the crops were swapped again (i.e. canola on 2016 wheat stubble and wheat on 2016 canola stubble). Fertilizer was applied at seeding according to soil test recommendations for each crop during the project. 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 (0-6") were done prior to seeding, in-crop and after plots were harvested in 2015, 2016 and 2017 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, 2016, and 2017 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-Wilk. Treatment means were separated using Tukey’s Honestly Significant Difference (HSD) and considered significant at $P < 0.05$.

Results

Growing season weather conditions

Weather data was estimated from the nearest Environment Canada weather station (Table 2). In Scott, the 2015 growing season started very dry with only 4.1 mm 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. 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 were 38.5 mm more than the long-term total. In 2017, the growing season started with a slightly higher precipitation than the historical April and May had a 77% higher precipitation than the long-term average. However, June and July were dryer than the long-term average receiving only 34.3 mm and 22.4 mm respectively (Table 2). The mean monthly temperatures were comparable to the long-term values (Table 2). Growing degree days were rarely lower than the long-term average; there was a trend toward higher than normal values for all the years (Table 2).

Table 2. Mean monthly temperature, precipitation and accumulated growing degree days from April to October for 2015, 2016, and 2017 growing seasons at Scott, SK.

Year	April	May	June	July	August	Sept.	Oct	Average /Total
Temperature (°C)								
2015	5.1	9.3	16.1	18.1	16.8	10.9	-	14.2
2016	5.9	12.4	15.8	17.8	16.2	10.9	1.6	11.5
2017	3	11.5	15.1	18.3	16.6	11.5	3.8	11.4
Long-term^z	3.8	10.8	14.8	17.3	16.3	11.2	3.4	11.1
Precipitation (mm)								
2015	15.4*	4.1	19.4	46.4	74.5	49.6	69.8	194.0
2016	1.9	64.8	20.8	88.1	98.2	22.2	33.1	329.1
2017	30.9	69	34.3	22.4	53	18.9	20.9	228.5
Long-term^z	24.4	38.9	69.7	69.4	48.7	26.5	13.0	290.6
Growing Degree Days								
2015	55	140.3	332.0	405.1	365.8	179.8	69.8	1547.8
2016	58.9	224.9	303.0	398.7	343.8	176.2	12.5	1518.0
2017	16.6	202.7	283.3	399.1	348.4	194.8	33.8	1478.7
Long-term^z	44	170.6	294.5	380.7	350.3	192.3	42.5	1474.9

^{z}Long-term average (1985-2014) *one missing data point

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. However, in 2016 growing season, differences within treatments for plant density in canola and plant vigor (NDVI 2) in wheat at the second reading were all presumably due to environmental factors (Table 3). The differences observed in 2017 for NDVI 1 and 2 in canola were probably due to the low plant density observed during this year caused by the insect problem reported earlier rather than a treatment effect. The combined analyses from 2015 to 2017 showed no differences; therefore, these results indicated that liming did not improve overall plant growth as there was no NDVI response to the applied lime rates.

Table 3: Effects of liming rate treatments (lbs/ac) for plant density, NDVI, and yield 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	0.347	0.6575
2017	0.1553	***0.0476***	***0.0155***	0.7637
Combined	0.9886	0.5611	0.0636	0.2868
		Wheat		
2015	0.1526	0.1621	0.3671	0.2405
2016	0.9304	0.5846	***0.0489***	0.7354
2017	0.3998	0.4421	0.8591	0.1998
Combined	0.8719	0.7513	0.1522	0.2985

Soil pH change under both canola and wheat crops were not different due to the varying lime rates during the three 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 and that trend was also observed when 2016 and 2017 data were compared (Figures 1 and 2). Interestingly, the check plots also had a pH increase during the three-year study, particularly during the last year. The change was more conspicuous in canola than in wheat on the second year but as mentioned above in 2017 pH levels were increased in all plots (Figures 1 and 2). The trend of non-significance of the lime treatments relative to the control conforms to previous studies where a statistically significant increase in soil pH relative to the control to a depth of 15 cm (top 6 inches) was only found two years after lime was broadcasted. This was linked to greater pore continuity or enhanced earthworm and microbial activity in direct-seeded systems such as no-till systems (Blevins et al., 1983). Low pH values can reduce crop yields due to aluminum and manganese toxicity caused by an increased solubility of these elements inhibiting root growth and function. An added benefit of an increased pH is that toxic elements are reduced thus increasing phosphorus availability (Marschner, 1991; Kochian et al., 2006). We hypothesize that pH was increased in all the plots assessed probably because of the spring thaw and rains during the growing season. These factors probably helped dissolve the lime deposits observed in 2015 and distributed the lime in a homogeneous manner in the field. Also, distances among plots were narrow, that could explain the observed pH increase in the plots that were not treated.

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).

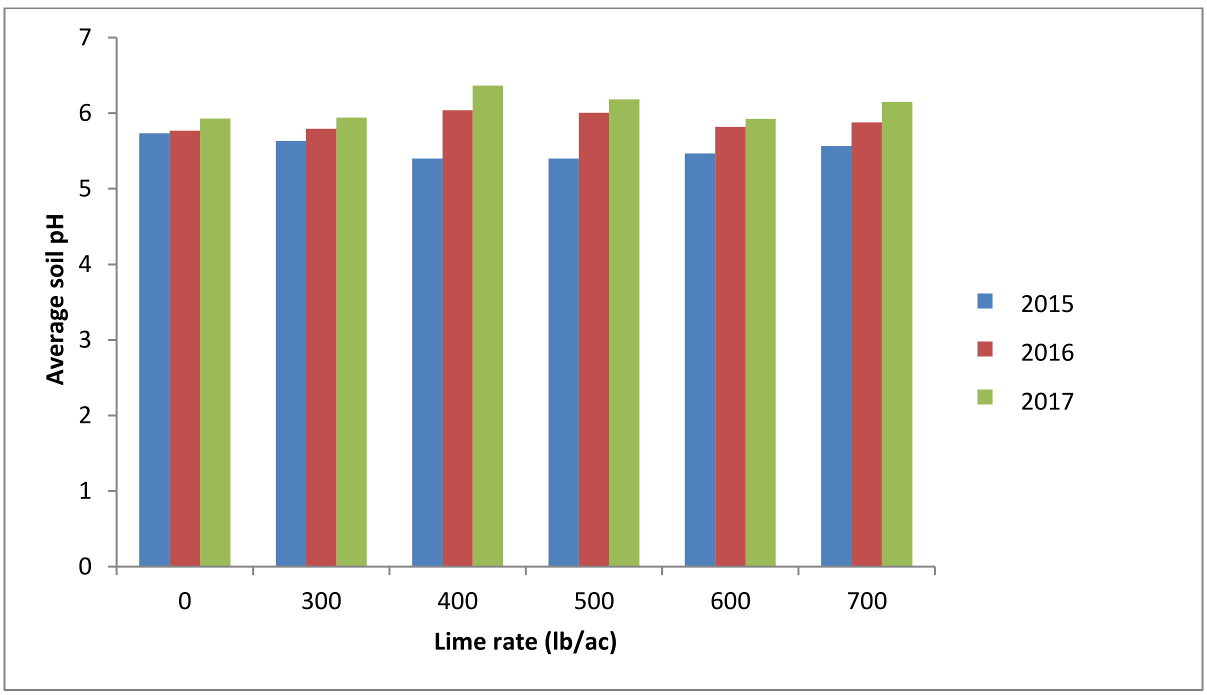

Figure 1: Changes in average soil pH (0-6") with respect to lime product rate (lbs/ac) under canola in the year of application (2015) and the year after application (2016 and 2017) at Scott, SK.

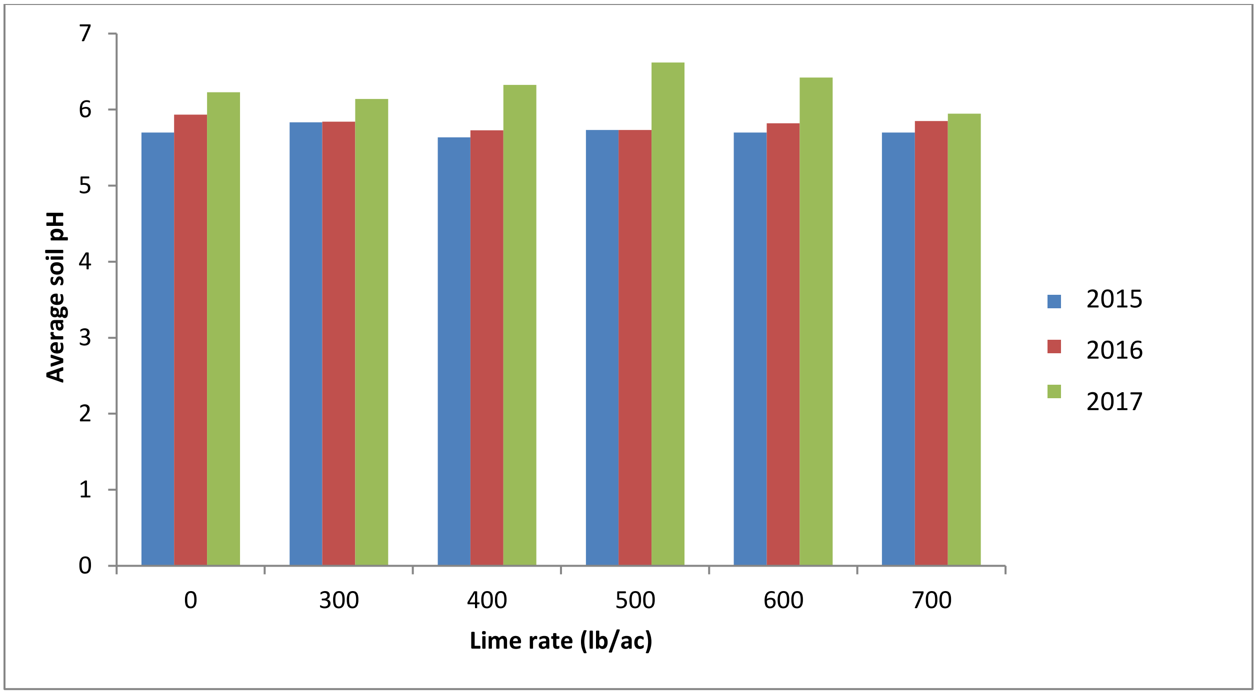

Figure 2. Changes in average soil pH (0-6") with respect to lime product rate (lbs/ac) under wheat in the year of application (2015) and the year after application (2016 and 2017) at Scott, SK.

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 the lime application or any other factor (Table 3). In the 2016 growing season, canola plant density had significant differences among the plots. However, these differences were attributed to environmental factors and not directly to the lime treatments. Plant density in 2017 was severely affected by flea beetles and cutworms and a corrective application of insecticide was necessary. However, most of the plants in all plots were not recovered.

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 effects of lime rates on NDVI in both crops at both timings in the 2015 and 2016 growing season (Table 3). In 2017, there were differences for NDVI on both measured stages in canola but those are not due to the lime treatments. NDVI measurements were affected by the low plant density during the growing season because of the pest problem described previously.

Grain Yield

There were no significant effects of lime rates on the yield of both canola and wheat both in 2015, 2016 and 2017 growing seasons and as a combined analysis. Although, when a comparison was made among years there were differences. The 2015 canola had the lowest yield with an overall average of 47 bu/ac and had an increase of 32% in 2016 with an average of 62 bu/ac, in 2017 yield decreased to 52 bu/ac but still was 11% higher than 2015. Wheat had an average yield of 59 bu/ac in 2015 this data is given as a base line but was not used for analysis as seeding rate (seeds m^{-2}) was 250 seeds m^{-2}, whereas in 2016 and 2017 was 300 seeds m^{-2}. In 2016 yield for wheat averaged 79 bu/ac and it was significantly increased to 92 bu/ac in 2017. 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 of 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 value is 5.5-5.8 (Brown et al., 2009; Lofton et al., 2010). Hence, a yield response was expected as the pH measured at the beginning of the 2015 season was 5.6 indicating that it was within the critical values. 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 higher in both crops regardless of the lime treatments in the 2016 growing season compared to the 2015 values and in wheat 2017 values were even greater exhibiting a consistent trend in yield with increased pH values (Figure 5). We hypothesize that in 2017 if canola plant density was not affected the yield response would exhibit the same trend as in wheat.

There were linear positive correlations between pH and average yield as a combined analysis for canola (r^2 = 0.28; P=0.01) and wheat (r^2 = 0.48; P = 0.0006). 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 an increased pH even though it remains in the upper limit of the critical pH values.

Finally, the correlation between average yield and pH after three years in canola and two years in wheat, showed an apparent yield advantage of lime application in 2016 and 2017 growing season. Despite the problems with the cutworms and flea beetles found. The non-significant differences among treatments could be due to the fact that the experimental plots were nearby and the observed lime residues in 2015 were dissolved by the spring thaw and rains during the growing season causing an overall increase in pH for all the plots and mitigating the differences among treatments.

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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.

From the economic analysis (Figures 5 and 6), application of SuperCal 98G may start yielding a positive return in the year following application relative to the negative returns in the year of application. However, there is no apparent initial benefit after lime application (0 lbs/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 a positive net return after several years following application. Beckie et al. (1995) suggest that a single liming application can last for several years. For both crops a positive return was obtained with a liming rate of 300 lbs/ac 2 years after application. No benefits are expected with lime rates higher than 300 lb/ac as the yield response and change in pH are not going to be greater and it does not justify the additional cost of applying the lime.

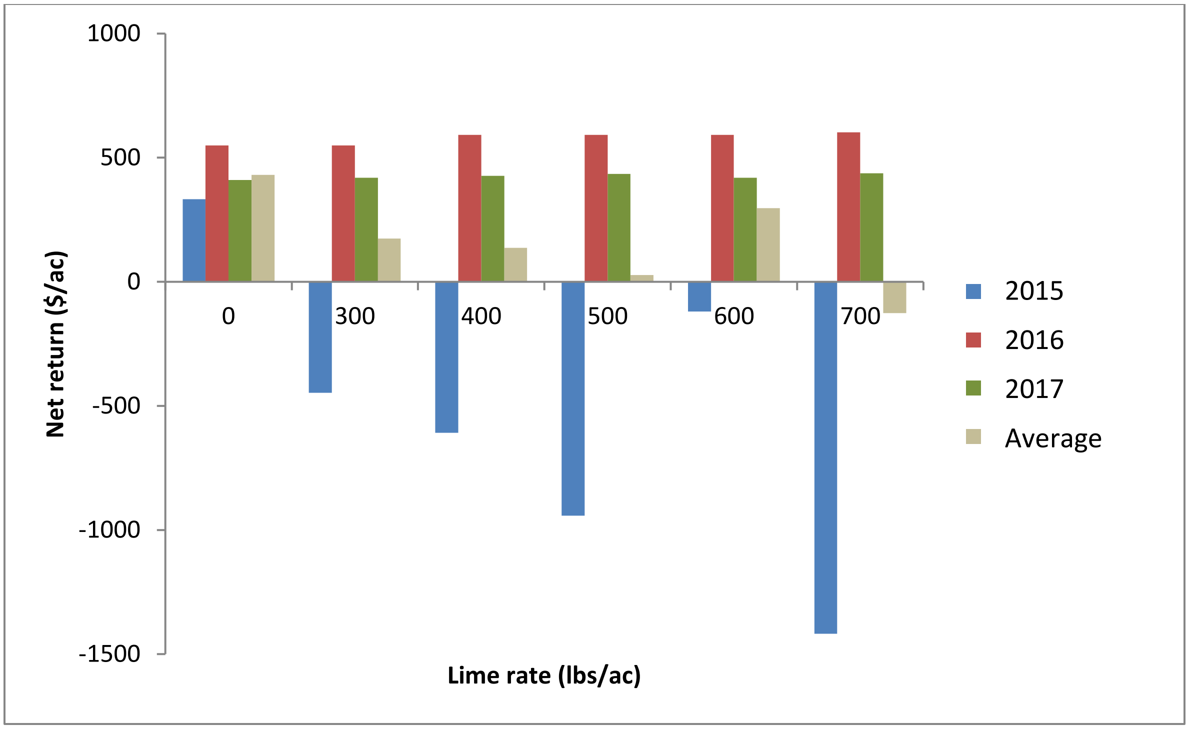

Figure 5: Net Economic return ($/ac) of lime application on slightly acidic soils under canola at Scott, SK

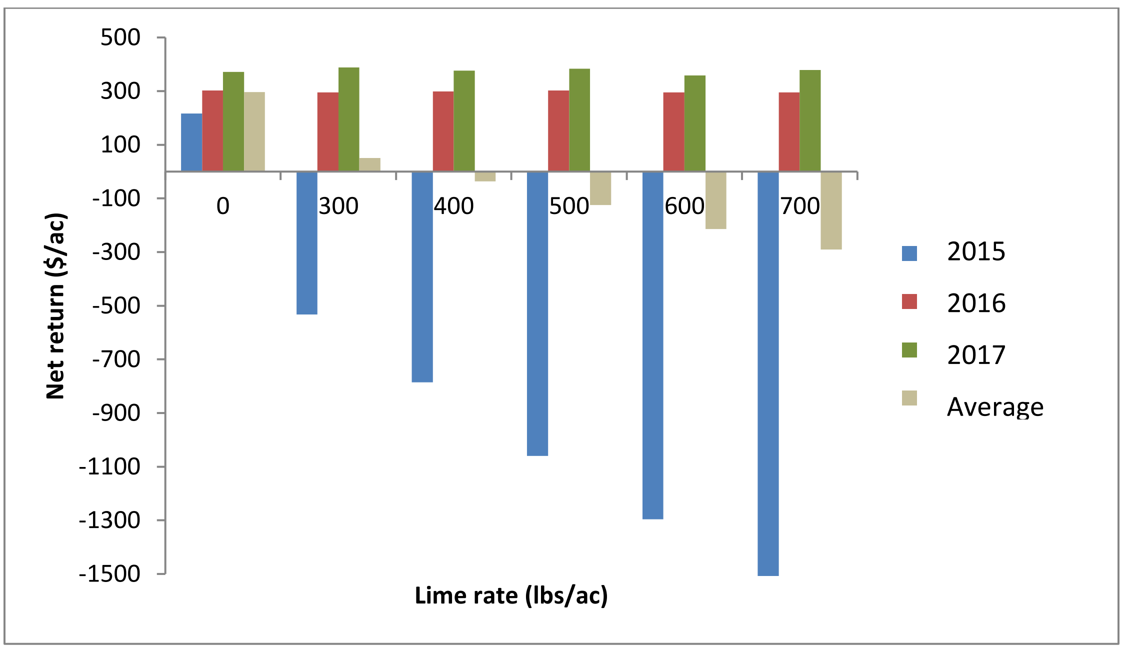

Figure 6: Net Economic return ($/ac) of lime application on slightly acidic soils under wheat at Scott, SK

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 compared to 2015. In 2017 canola yield was not as expected due to a low plant stand causes by insects, wheat was also affected but it was not as severe. 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 necessarily in crop yield responses, especially in the year of application the continued use of NH_4–based fertilizers and projected decline in soil pH suggest some form of pH control may be needed in the future assessing fields periodically and reapplying lime if necessary. Though the net economic gain may 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 farmers and producers be concerned about 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. As part of an integrated management, we suggest to monitor pH levels and apply or reapply lime when levels get close to the critical values for the planned crops.

Supporting Information

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 two years after. 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 in 2015. Soil pH (0-6") was estimated prior, during and after harvest to determine the effects of the incremental lime rate in 2015, 2016 and 2017. 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 the environmental conditions in 2016 rather than a 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 this trend was more evident in wheat. 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

Appendix A
Agronomic information for 2015, 2016 and 2017 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	2017
Liming application	04-May-15	N/A	N/A
Seeder	R-Tech Drill, 10-inch row spacing, knife openers	R-Tech Drill, 10-inch row spacing, knife openers	R- tech, Drill, 10-inch row Spacing, knife openers
Seeding Date	11-May-15	06-May-16	10-May-17
Cultivar	Wheat – Sadash; Canola– L130	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}	Wheat – 300 seeds m^{-2}; Canola 150 m^{-2}
Stubble Type	Wheat	Wheat stubble for canola and canola stubble for 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	146 lbs N ac^{-1} as urea mid-row and 31 lbs/ac P_2O_5 as MAP side-banded 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 canola	234 lbs ac^{-1} (Urea and AS in blend) mid-rowed and 31 lbs ac^{-1} P_2O_5 as MAP side-banded

<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	Glyphosate @ 1 L ac^{-1} and Bromoxynil @ 0.4 L ac^{-1} (May 6, 2017)
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	Axial @ 0.5 L ac^{-1} + Infinity @ 0.33 L ac^{-1} + Ammonium sulfate @ 0.4 L ac^{-1} (wheat). Liberty @ 0.81 L ac^{-1} on June 7th; Liberty @ 0.61 L ac^{-1} on June 21st; Liberty @ 1.35 L ac^{-1} on June 28th (canola)
Insecticide	N/A	N/A	Decis @ 6 mL ac^{-1} on May 29th
Fungicide	N/A	Priaxor @ 120mL/ac on June 29 2016(canola), July 5, 2016 (wheat)	N/A
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	Glyphosate @ 1 L/ac (August 30, 2017) – Wheat Reglone @ 0.8 L/ac (August 29, 2017) – Canola
<u>Data Collection</u>			
Emergence Counts	May 23 (wheat) & May 26(canola), 2015	May 26, 2016 (wheat) & June 26, 2016	June 6, 2017 (Wheat and canola)
Harvest Date	September 01, 2015(wheat) & August 27, 2015 (canola)	August 29, 2016 (canola) & September 6, 2016 (wheat)	September 12, 2017 (Wheat) & September 8, 2017 (Canola)

References

Blevins, R.L., G.W. Thomas, M.S. Smith, and W.W. Frye. 1983. Changes in soil properties after 10 years of no-tillage and conventionally tilled corn. Soil Till. Res. 3:135–146.

Brown, J., J. B. Davis, M. Lauver, and D. Wysocki. 2009. Canola grower's manual. United States Canola Association.

Kochian, L.V., Piñeros, M.A., Hoekenga, O.A. 2006. The physiology, genetics and molecular biology of plant aluminum resistance and toxicity. Plant Soil. 274: 175-195.

Lofton, J., C. B. Godsey, and H. Zhang.2010. Determining aluminum tolerance and critical soil pH for winter canola production for acidic soils in temperate regions. Agron. J. 102: 327–332.

Lukin V. V. and F. M. Epplin. 2003. Optimal frequency and quantity of agricultural lime applications. Agric. Syst. 76:949–967.

Mahler, R.L., and R.E. McDole. 1985. The influence of lime and phosphorous on crop production in northern Idaho. Commun. Soil Sci. Plant Anal. 16:485–499.

Mahler, R.L., and R.W. Harder. 1984. The influence of tillage methods, cropping sequence and N rates on the acidification of a northern Idaho soil. Soil Sci. 137:52–60.

Marschner, H., 1995. Mineral nutrition of higher plants, 2nd edition. Academic, London, pp 324–333. pp 605–626.

Robbins, S.G., and R.D. Voss. 1989. Acidic zones from ammonium application in conservation tillage systems. Soil Sci. Soc. Am. J. 53:1256–1263.

Wildey, T. I. 2003. The influence of seed-placed lime to reduce the acidifying effects of nitrogen fertilizers in direct seeding systems. M.S. thesis. Washington State Univ., Pullman.