Grant Code: AP2733

Title: Exploring the feasibility of using high lime rates on crop performance in northern Idaho

Personnel: Dr. Kurtis Schroeder, Assistant Professor of Cropping Systems Agronomy

Address: Plant Sciences Department, University of Idaho, 875 Perimeter Drive MS 2333, Moscow, ID 83844-2333; 208-885-5020; kschroeder@uidaho.edu

Justification/Rationale: Soil pH is declining in northern Idaho due mainly to the long-term use of ammonium-based nitrogen fertilizers. The parent soils in many regions of northern Idaho are forest-derived, which means they have a lower starting pH and lower buffering capacity, making them more susceptible to changes in pH. However, this does not preclude historically prairie soils from having low soil pH as well. Acidification of soils in northern Idaho and eastern Washington was well documented during the 1980's by Dr. Mahler at the University of Idaho. A recent survey revealed that soils have continued to decline in pH, with the majority of northern Idaho fields having a pH of 5.2 or lower (76%) in the upper 6 inches (Schroeder and Finkelnburg, unpublished). Furthermore, 34% of fields sampled were below a pH of 5. These soils are at risk of or are experiencing aluminum toxicity and remediation by liming is necessary. While other solutions include growing aluminum-tolerant crops or planting aluminum-tolerant wheat, these strategies limit options for diverse rotations and may not be adequate solutions for some fields that are experiencing more serious pH issues. Previous research to compare liming products and rates of up to 1 ton lime/A revealed that liming will improve soil pH and reduce soluble aluminum quantities in the soil (Schroeder et al, unpublished). Unfortunately, improved crop yield following lime application was inconsistent and not observed at all locations. Furthermore, the rates used were well below the lime requirement rates calculated from soil tests. There is a need for testing using higher rates of lime and determining the economic feasibility of such treatments. Soil acidification is being documented in dryland or rainfed regions throughout the northwest and there are now confirmed reports of aluminum toxicity from Idaho, Washington, Oregon and Montana. Acidification is a growing concern in these areas and must be addressed.

Hypothesis & Objectives: The hypotheses are that application of higher rates of calcium carbonate will incrementally increase soil pH and will provide a significant improvement in yield of wheat and rotation crops. Secondly, the cost of applying higher rates of lime will be offset by a more durable and substantial shift in soil pH and a long-term improvement in yield.

Specific objectives are to:

1) Replant and continue to monitor crop response and changes in soil chemistry at the five locations limed with up to 3 tons/A in the fall of 2016 and 2017.
2) Continue building upon the economic models to determine the feasibility of applying higher rates of lime in northern Idaho.

Procedures/Plan of Work:

1. *Crop response to calcium carbonate application.* In the fall of 2016, liming studies were established at four locations in northern Idaho to evaluate higher rates of lime based on the lime requirement tests. A fifth site was identified and developed during the summer of 2017. The sites include one location east of Moscow and two locations in each the Potlatch and Tensed areas of northern Idaho. Liming treatments consist of ground limestone (Pioneer Enterprises, Lewiston, ID) applied at rates of 1, 2 and 3 ton calcium carbonate/A along with a no lime

control. After liming, the material was incorporated to a depth of 4 to 6 inches. The trials at each location consist of a randomized, complete block design with four replication and each plot measuring 8 ft wide by 100 ft long. Winter wheat variety UI-WSU Huffman was seeded into four of the five locations in the fall of 2018. The final location will be seeded in the spring of 2019 with a spring cereal or legume. In mid to late May, samples will be collected from each plot to a depth of 12 inches at 3 inch increments to monitor changes in the soil pH, soluble aluminum and other soil chemicals. Tissue samples will be collected from each plot to assess aluminum accumulation in the plants. Plots will be visually inspected and assessed for plant damage due to acid soil and/or aluminum toxicity. Plant vigor and health also will be assessed by measurements using a GreenSeeker at regular intervals throughout the spring and summer. As the opportunity arises, diseases will be assessed in these trials to identify any differential response of the pathogens. At the end of the growing season, each plot will be harvested. Yield information will be used to generate an economic analysis of the lime application over the course of the study

2. *Economics of lime application.* The net present value was used to calculate annualized costs of liming using a discount rate of 6% and a cost of $74 per ton for material and transportation plus $13 per acre for application. The annualized cost of material and application were calculated to be $12, 17 and 20 per acre for the 1, 2 and 3 ton/A rates of lime, respectively. The increased economic return will be compared to the annualized cost to determine the annual benefit. Two and three year returns will be calculated follow data collection in the fall of 2019.

Duration: This liming project to examine higher rates of lime is expected to run for at least 6 years and is starting into year 3. However, there has been interest expressed among growers in the area to extend these to 10 year plots, which will depend of the availability of funding and the desire of the individual cooperators.

Cooperation/Collaboration: Research plots will be conducted in cooperation with local growers in Potlatch, ID; Tensed, ID; and Moscow, ID. Dr. Kate Painter will assist with economic analysis of this data as it is generated. A new graduate student is expected to join my program in the fall of 2019 and will contribute to this research project.

Anticipated Benefits, Expected Outcomes and Impacts, and Transfer of Information:
Results of this study will provide information on the potential benefit and strategies for using higher rates of lime that are close to recommended lime rates. The benefits of liming include the potential for improved yields, greater plant available nitrogen, improved microbial activity, improved fertilizer efficiency, improved soil health, reduced plant disease, and increased profitability. This study will provide growers with information on how best to apply lime to their operations and highlight additional advantages of improving soil health and reducing disease. It is anticipated that the yield gains during the 2017-2018 crop season will be higher than those observed during the previous season, and soil chemical properties will continue to improve, particularly in the highest rate treatments. The results of this study will be shared at field days and winter cereal schools.

Literature Review: Acidification of soils in northern Idaho was well documented during the 1980's by Dr. Mahler at the University of Idaho. As part of his research, the critical soil pH levels for pea, lentil, barley and wheat were determined, varying between a pH of 5.2 to 5.6 (Mahler and McDole 1987). There is renewed interest in this topic due to continued acidification and the discovery of associated acute aluminum toxicity in some areas of Spokane Co. in eastern

Washington (Koenig et al. 2011). A recent survey of soils in northern Idaho revealed that soil pH is continuing to decline and that 34% of the 116 fields surveyed had a soil pH below 5 and average soluble aluminum concentrations of 53 ppm (Schroeder and Finkelnburg, unpublished). Recent research in Washington State into the use of liming did not demonstrate an improvement in yield (Brown et al. 2008). However, the soils examined in this particular study were in soils historically covered by grass vegetation and have a high non-acid base saturation, preventing high quantities of aluminum from impacting plant health. In a separate study, winter wheat seeded into limed soils that had an initial pH below 5 and high quantities of soluble aluminum in the upper 6 inches responded to lime application at 2 of 3 locations (Schroeder et al, unpublished). Likewise, Mahler and McDole (1985) demonstrated an increase in yields following lime application to field that were historically forested. Acidification in dryland or rainfed regions is a growing concern throughout the northwest US. Recently, soils in parts of Montana were shown be exhibiting symptoms of aluminum toxicity (Clain Jones, personnel communication) as a result of decades of using elevated rates of ammonium based nitrogen fertilizers to produce high yielding grain crops.

Brown, T.T., Koenig, R.T., Huggins, D.R., Harsh, J.B., and Rossi, R.E. 2008. Lime effects on soil acidity, crop yield and aluminum chemistry in direct-seeded cropping systems. Soil Science Society of America Journal 72:634-640.

Kirby, E. M., Paulitz, T. C., Murray, T. D., Schroeder, K. L., and Chen, X. M. 2017. Disease Management for Wheat and Barley. In: Yorgey, G. and C. Kruger, eds. Advances in Sustainable Dryland Farming in the Inland Pacific Northwest, Washington State University Extension, Extension Publication EM108.

Koenig, R., Schroeder, K., Carter, A., Pumphrey, M., Paulitz, T., Campbell, K., and Huggins, D. 2011. Soil acidity and aluminum toxicity in the Palouse region of the Pacific Northwest. Washington State University, Extension Bulletin FS050E.

Mahler, R.L., and McDole, R.E. 1985. The influence of lime and phosphorus on crop production in northern Idaho. Communications in Soil Science and Plant Analysis 16:485-499.

Mahler, R.L., and McDole, R.E. 1987. Effect of soil pH on crop yield in northern Idaho. Agronomy Journal 79:751-755.

FY2020

IDAHO WHEAT COMMISSION - BUDGET FORM

Principal Investigator: Kurtis Schroeder

Allocated by	Idaho Wheat Commission	during FY 2018	$ 14,520
Allocated by	Idaho Wheat Commission	during FY 2019	$ 24,144

REQUESTED FY2020 SUPPORT:

Budget Categories	(10) Salaries (*staff, post-docs, etc.*)	(12) Temp Help	(11) Fringe	(20) Travel	(30) OE	(70) Graduate Tuition/ Fees	TOTALS
Idaho Wheat Commission	$ -	$ 6,000	$ 228	$ 2,000	$ 16,000	$ -	$ 24,228

TOTAL BUDGET REQUEST FOR FY 2020: $ 24,288

BREAKDOWN FOR MULTIPLE SUB-BUDGETS:

Budget Categories	*(Insert PI Name)*	*(Insert CO-PI Name)*	*(Insert CO-PI Name)*	*(Insert CO-PI Name)*
(10) Salaries	$ -	$ -	$ -	$ -
(12) Temp Help	$ -	$ -	$ -	$ -
(11) Fringe Benefits	$ -	$ -	$ -	$ -
(20) Travel	$ -	$ -	$ -	$ -
(30) Other Expenses	$ -	$ -	$ -	$ -
(70) Graduate Student Tuition/F	$ -	$ -	$ -	$ -
TOTALS	$ -	$ -	$ -	$ -

Total Sub-budgets $ -

Explanatory Comments:

Fall 2018 Version

ANNUAL REPORT

Grant Code: AP2733

Title: Exploring the feasibility of using high lime rates on crop performance in northern Idaho and examining the impact of liming and soil pH on soilborne pathogens of wheat

Personnel: Dr. Kurtis L. Schroeder, Cropping Systems Agronomist, Moscow

Address: Plant Sciences Department, University of Idaho, 875 Perimeter Drive MS 2333, Moscow, ID 83844-2333; 208-885-5020; kschroeder@uidaho.edu

Accomplishments: Five trial sites were established to assess the impact of higher liming rates on aluminum toxicity and crop performance. Previous work by my program and others in eastern Washington and northern Idaho have found inconsistent crop responses to rates of lime up to 1 ton per acre. Part of the reason for this lack of response is variation in the soil pH within the trial site, but insufficient rates of lime being applied is likely responsible as well. Upon examining the samples from the previous soil survey conducted in northern Idaho, those soils with a pH below 5.2 would require an average of about 3.5 ton calcium carbonate/A to increase the soil pH to 6.0 in the upper 6 inches. Once a soil drops below a pH of 5.2, the quantity of potassium chloride (KCL) extractible aluminum increases substantially and the yield of wheat will decline. In the current study, rates of ground limestone were applied to achieve calcium carbonate quantities of 0, 1, 2 and 3 ton/A. Strip trial locations include a site east of Moscow, two locations near Potlatch and two locations north of Tensed. Two of these sites were seeded to winter wheat cv UI-WSU Huffman (23 seeds/sq ft) in the fall of 2017 and the other sites were seeded to either chickpea cv Bronic, lentil cv Morena or canola cv HyClass 125 RR in the spring of 2018. All plots were seeded using a custom AgPro Conservation Plot Drill equipped with Bourgault paired-row openers on 12-inch spacing. Winter wheat and canola plots were fertilized at the time of planting following standard, recommended rates. Soil samples were collected in late May from each plot, removing two composite subsamples per plot at 3-inch increments to a depth of 12 inches. All analyses were performed by Best Test Analytical Services (Moses Lake, WA). During the growing season, the plants were monitored for disease and plots were harvested at the end of the growing season to determine grain yield, test weight and protein.

Yields were average to above average for the 2017-2018 growing season (Table 1). Although lime application resulted in a significant increase in yield only with winter wheat at Potlatch #1, there was an incremental increase in yield with higher rates of lime application for the second winter wheat location and lentils. There was significant herbicide injury at the Potlatch #2 location so the chickpea crop was lost and there was variable seedling emergence at Tensed #1, likely a result of a seeding issue. The variability in seeding rate along with high yielding spring canola masked the response to lime application. There was a 1 to 15% increase in yield with the 1 ton/A rate and 5 to 22% increase in yield with the 3 ton/A rate of lime.

Soil samples were collected from each plot at all five locations in May of 2018 (8 or 20 months post liming). Data is presented in Figure 1 showing the change in soil pH and aluminum concentration for the Potlatch#1 trial location. Similar results were observed for the other locations. For those locations that were limed in 2016, there was greater change in soil pH and reduction in the quantity of soluble (KCl extractible aluminum) observed in 2018 compared to 2017 samples, particularly in the 3 to 6 inch zone. This suggests that lime in continuing to react within the soil and there is some vertical movement of the lime or higher pH soil into the 3 to 6 inch layer. There was nearly a 1.2 unit difference in pH between the no lime and the 3 ton/A rate in the 0 to 3 inch soil layer (Figure 1A) that was highly significant. There also was a significant and noticeable increase in soil pH at the 3 to 6 inch depth that was not apparent in 2017. Likewise the quantity of soluble aluminum has nearly reached background levels in the 2 and 3 ton/A rates at the 0 to 3 inch depth (Figure 1B) and the quantity of soluble aluminum was dramatically lower in the 3 to 6 inch layer. These changes and trends were consistent across the four locations that were limed in the fall of 2016 (Tensed and Potlatch sites).

Table 1. Increase in seed yield following application of ground limestone in the fall of 2016 or 2017 (Moscow), 2018.

	Seed Yield				
Lime (ton/A)	Moscow W. Wheat	Potlatch#1 W. Wheat	Potlatch#2 Chickpea	Tensed#1 S. Canola	Tensed#2 Lentil
	--------- bu/A ---------			--------- lb/A---------	
0	102	127 c	--	2351	911
1	103	131 bc	--	2558	1045
2	106	135 ab	--	2318	1065
3	109	136 a	--	2466	1109
	Percent Increase in Yield				
1	1	3	--	9	15
2	4	6	--	-1	17
3	7	7	--	5	22

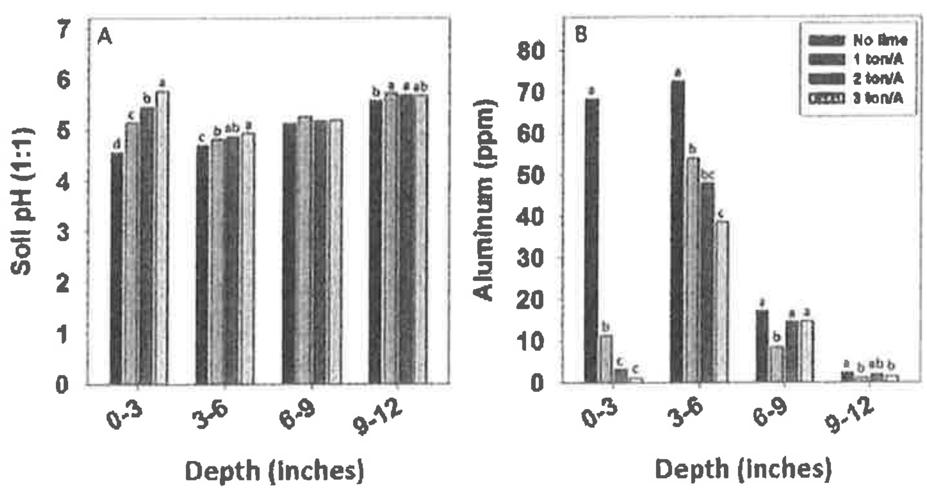

Figure 1. Soil analysis of samples collected from limed trials in Potlatch, ID 20 months after lime application. Soil pH (A) and KCl extractible aluminum (B).

Using the data generated from this study, an economic analysis was conducted to determine evaluate the economic feasibility of annualized lime applications in 2018. The original cost of the ground limestone used in this study in 2016 was $74 per ton which included the cost of the product and transportation plus $13 per acre for application. The annualized cost of lime application assuming a 10 (1 ton/A), 15 (2 ton/A) or 20 (3 ton/A) year time frame for efficacy was $12 (1 ton/A), $17 (2 ton/A) and $20 per acre (3 ton/A). Using the 2018 commodity prices for wheat, canola and lentil, the return over the annualized cost was calculated (Table 2). Lime application was highly advantageous for winter wheat and lentil with the greatest return occurring for the 3 ton/A rate ($19 to $28 per acre). However, due to variability in the canola yield, only the 1 ton/A rate was economical. Overall average returns across all studies (including the chickpea crop failure) were $6, $3 and $11 per acre for the 1, 2 and 3 ton per acre rates, respectively.

One key to the success of liming in northern Idaho is to document the long-term impact of liming on soil health and crop performance. It is also critical to understand how this long-term investment figures into the economics of the farm operation. The positive gains in grain yield along with the improvements in soil health and preliminary economic analysis all point to high rates as being the best possible solution for management of soil acidity in northern Idaho. Continuation of this project will help to solidify this model and provide valuable evidence for the need to lime using higher rates equivalent or close to the lime requirement.

Table 1. Economic value of lime application on crop yield in northern Idaho after accounting for annualized cost of lime application.

Ground Limestone	Moscow W. Wheat	Potlatch#1 W. Wheat	Potlatch#2 Chickpea (crop failure)	Tensed#1 S. Canola	Tensed#2 Lentil	Average
(ton/A)	---------------------------- Net Return Over Annualized Cost Per Acre ------------					
1	(-$7)	$10	(-$12)	$19	$20	$6
2	$5	$27	(-$17)	(-$22)	$20	$3
3	$19	$30	(-$20)	(-3)	$28	$11

*Annualized cost of lime application is $12 (1 ton/A), $17 (2 ton/A) and $20 (3 ton/A) assuming an efficacy of 10, 15 and 20 years for the 1, 2 and 3 ton/A rates, respectively.
**Assumed price of wheat is $5.50 per bushel, price for lentil is $0.24 per pound and canola is $0.15 per pound.

A field trial was established at the Parker farm to continue assessing the impact of liming and soil pH on Rhizoctonia root rot. The trial was inoculated with *Rhizoctonia oryzae* and seeded into field plots that were either limed or not limed in the spring of 2017. Preliminary data analysis suggests that there was no difference in disease incidence or severity between limed and non-limed portions of the field, similar to the results obtained in 2017. This contrasts to greenhouse studies with *R. oryzae* that suggested that disease severity increased as the pH of the soil increased from 4 to 6, indicating the importance of confirming greenhouse results under field conditions. While lime application may increase the incidence of Fusarium crown rot on some varieties of wheat, Rhizoctonia root rot does not appear to be impacted.

Projections: Understanding the long-term benefits of lime application on crop productivity and profit are vital to the success of liming in northern Idaho. Continuation of this project will add very valuable data that is currently missing with respect to the long-term value of this practice. Winter wheat was planted at four of the five trial locations in the fall of 2018 and a spring wheat or spring pulse will be seeded at the remaining Potlatch location in the spring of 2019. Disease assessments from the 2018 trial will be completed in the spring of 2019. Data will be shared at field days and will be featured as part of the upcoming Acid Soils Workshop in Pullman, WA.

Publications:

1. Finkelnburg, D., and Schroeder, K. 2018. Addressing soil acidity on Nez Perce tribe agricultural lands. Journal of NACAA volume 11, issue 1.
2. Leggett, A., and Schroeder, K. 2018. Optimizing liming rates for low pH soils in northern Idaho. In: *2018 Dryland Field Day Abstracts: Highlights of Research Progress* (pp. 27-28). Idaho Agricultural Experiment Station, Technical Report UI-2018-1.
3. Painter, K., and Schroeder, K. 2018. Economics of liming acidic soils on the Palouse. In: *2018 Dryland Field Day Abstracts: Highlights of Research Progress* (pp. 30-31). Idaho Agricultural Experiment Station, Technical Report UI-2018-1.
4. Leggett, A., and Schroeder, K. L. 2018. Optimizing liming rates for low pH soils in northern Idaho. ASA and CSSA annual meeting, Nov. 4-7, Baltimore, MD.
5. Schroeder, K., and Leggett, A. 2018. Influence of soil pH and liming on Fusarium crown rot of wheat. International Congress of Plant Pathology, Phytopathology 108:S1.124.