PROJECT NO: BJKU91

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 Schroeder, Assistant Professor of Cropping Systems Agronomy

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JUSTIFICATION: 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majority of northern Idaho fields having a pH of 5.2 or lower (70%) in the upper 6 inches (Schroeder and Finkelnburg, unpublished).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lime/A revealed that liming will improve soil pH and reduce soluble aluminum quantities in the soil (Schroeder et al, unpublished).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. In addition, soil pH can impact plant pathogen populations and a classic example is *Cephalosporium gramineum* being favored by acid soil conditions. Preliminary studies suggest that soil pH may also influence other pathogens such as *Fusarium* spp. and *Rhizoctonia* spp. Knowledge about the impact of soil liming on diseases could be an added benefit of liming.

HYPOTHESIS AND OBJECTIVES: The hypotheses are that application of higher rates of calcium carbonate will incrementally increase soil pH and has a high likelihood of providing a significant improvement in yield. 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. Third, lime will decrease the severity and/or incidence of root and crown diseases. 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) Examine the impact of soil pH on cereal pathogens, focusing on root and crown diseases.

PROCEDURES:

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 two of the five locations in the fall of 2017. The other three locations will be seeded in the spring of 2018 to match the crop rotation in each field. These will likely consist of spring wheat at two locations and lentil or chickpea at the last site. 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. 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. *Impact of soil pH on root and crown diseases.* The impact of soil pH on the incidence and severity of root and crown diseases will be examined in field trials. These will include a location at the University of Idaho Kambitsch Farm near Genesee to assess Fusarium crown rot. At this location, elemental sulfur or calcium carbonate (NuCal fluid lime, Columbia River Carbonates, Woodland, WA) were added in the spring of 2017 to achieve a soil pH of approximately 4.5, 5.5 and 6.5. This site is more conducive to Fusarium crown rot than the Parker Farm and is more likely to yield symptoms, allowing the impact of soil pH on the disease to be more effectively assessed. Into this field will be planted spring wheat varieties WB-Hartline and Glee, with half of the plots containing inoculum of *Fusarium culmorum*. Plots will be evaluated for disease at tillering (about 6-7 weeks after planting) and again after harvest by evaluating the lower stem and crown tissue. If white heads are apparent later in the growing season, plots will also be evaluated for the incidence of this symptom. Plots will be harvested to obtain grain yield, test weight and protein. A similar study will be established at the University of Idaho Parker Farm in Moscow to assess Rhizoctonia root rot. A similar trial design with and without lime as well as with and without *Rhizoctonia oryzae* will be established using the spring wheat variety Seahawk. Roots will be assessed for symptoms about 6-7 weeks after planting and yield data will be collected.

DURATION: This liming project to examine higher rates of lime is expected to run for at least 6 years and is starting into year 2. 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. The interaction of soil pH and plant diseases should be completed in 2018.

COOPERATON: Research plots will be conducted on University of Idaho research farms in Moscow and Kambitsch, and 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. This project is currently part of a graduate student project (Andrew Leggett) and receives financial support from Limagrain Cereal Seed to support his assistantship.

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. Very little information exists on the impact of pH on Rhizoctonia root rot, and information on the impact of pH on Fusarium crown rot is mostly limited to studies examining ammonium versus nitrate forms of fertilizer, although Fusarium wilt diseases on other host crops are known to be favored by acidic conditions (Kirby et al 2017).

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.

IDAHO WHEAT COMMISSION - BUDGET FORM

Principal Investigator: K. Schroeder

Allocated by	Idaho Wheat Commission	during FY 2017	$ -
Allocated by	Idaho Wheat Commission	during FY 2018	$ 14,520

REQUESTED FY2019 SUPPORT:

	Salary (*staff, post-docs, etc.*)	Temporary Help	Fringe	Travel	OE	Graduate Tuition/Fees	TOTALS
Idaho Wheat Commission	$ -	$ 6,000	$ 144	$ 2,000	$ 16,000	$ -	$ 24,144

TOTAL BUDGET REQUEST FOR FY 2019: $ 24,144

BREAKDOWN FOR MULTIPLE SUB-BUDGETS:

	(Insert PI Name)	*(Insert CO-PI Name)*	*(Insert CO-PI Name)*	*(Insert CO-PI Name)*
Salary	$ -	$ -	$ -	$ -
Temporary Help	$ -	$ -	$ -	$ -
Fringe Benefits	$ -	$ -	$ -	$ -
Travel	$ -	$ -	$ -	$ -
Operating Expenses	$ -	$ -	$ -	$ -
Graduate Student Tuition/Fees	$ -	$ -	$ -	$ -
TOTALS	$ -	$ -	$ -	$ -

Total Sub-budgets $ -

Explanatory Comments: (see FY2019 RFP for definition)

Fall 2017 Version

ANNUAL REPORT

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

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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. Three of these sites were seeded to winter wheat in the fall of 2016 and the other two sites were seeded to winter wheat in the fall of 2017. All plots were seeded using the moderately aluminum-tolerant variety UI-WSU Huffman at a standard rate of 23 seeds/sq ft using a custom AgPro Conservation Plot Drill equipped with Bourgault paired-row openers on 12-inch spacing. Soil samples were collected in early June from each plot, removing two composite subsamples per plot at 3 inch increments to a depth of 12 inches. Plant tissue samples were collected to test for aluminum quantities in June. 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 below normal for the 2016-2017 growing season due to frequent rainstorms in October delaying the seeding of these trials until early November (Figure 1). At the Potlatch and Tensed1 locations, the 2 and 3 ton/A rates significantly increased the yield of winter wheat over the no lime control. There was about a 9 to 11 bu/A (13 to 15%) increase with these two higher rates. Despite the lack of a significant difference in yield at Tensed2, there was a slight upward trend with increasing lime rates. This location is situated near the top of a ridge and suffered from drought stress and Fusarium crown rot late in the growing season. With timelier planting at this location, greater responses to lime application are expected in subsequent years. There was no significant differences test weight or grain protein for any of these trials.

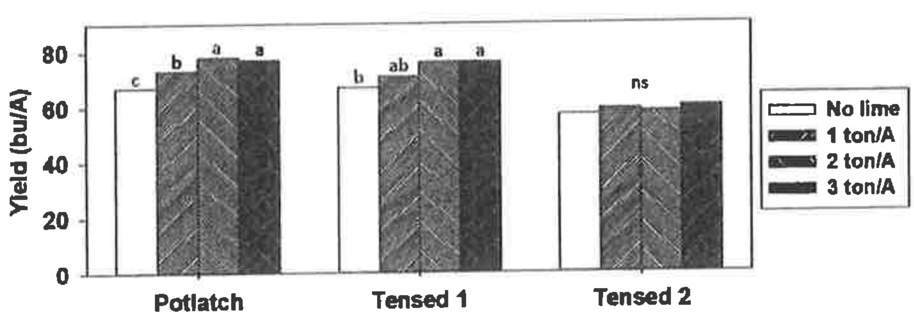

Figure 1. Yield response of soft white winter wheat to lime application in northern Idaho.

Soil samples from these sites are still being processed, but preliminary data is available for the Potlatch trial site (Figure 2). A significant reduction in aluminum quantities was observed with all lime treatments at the 0 to 3 inch depth, with the 2 and 3 ton/A lime rates resulting in nearly 0 KCl extractible aluminum. While not significant, there was also a trend of reduced aluminum in the 3 to 6 inch depth samples as well. There was a significant increase in the soil pH with all lime treatments at the 0 to 3 inch depth with over a 1 unit change in soil pH with the 3 ton/A rate compared to the control. Little to no change in pH was observed at the other depths. Corresponding to an increase in pH was a substantial increase in calcium concentration and a significant increase in the base saturation for all limed plots at the 0 to 3 inch depth. To limit aluminum from being taken up by plants, the base saturation should ideally be above 60%. The quantity of aluminum in tissue samples did not differ between treatments. This was somewhat surprising considering the yield response to lime, but may indicate that aluminum is not very effectively translocated from the roots of impacted plants to the foliar parts of aluminum-tolerant varieties of wheat.

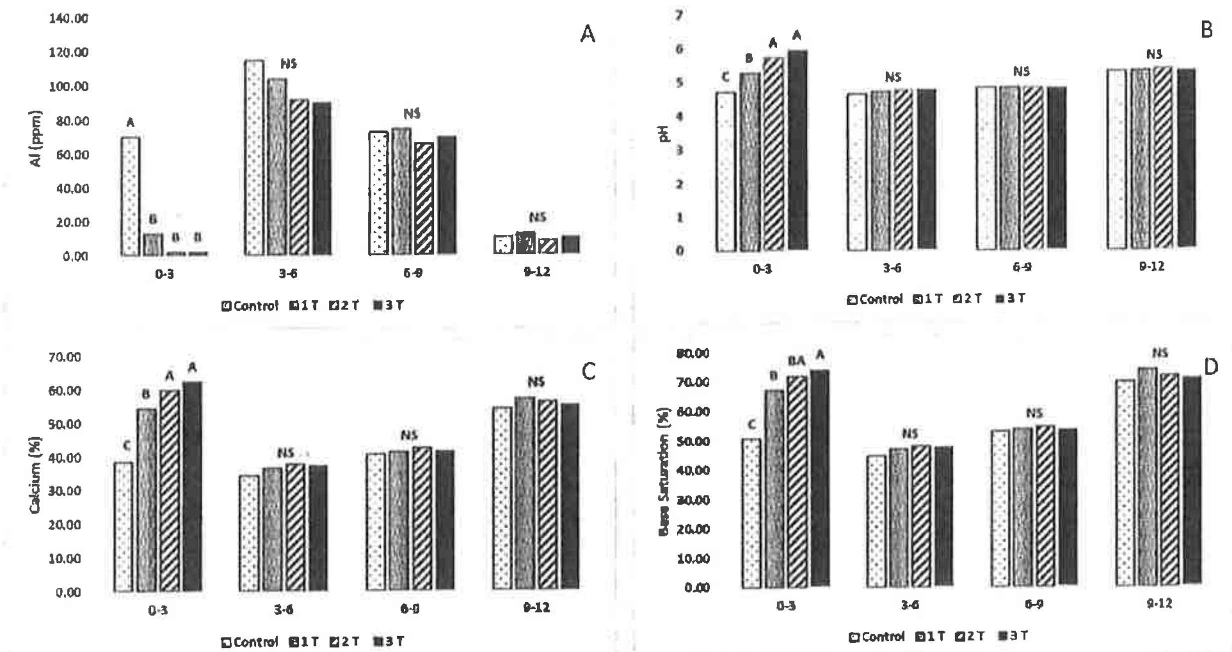

Figure 2. Soil analysis of samples collected from limed trials in Potlatch, ID, including KCl extractible aluminum (A), soil pH (B), percentage of calcium on of cation exchange capacity (C), and base saturation (D).

Using the data generated from this study, an economic analysis was conducted by Dr. Kate Painter. Table 1 lists the cost of lime application along with the anticipated timeframe for lime efficacy. The efficacy timeframe is a challenge due to uncertainty as to how long benefits will be realized following lime application, but these are thought to be conservative estimates. Using an annualized lime cost based on the estimated liming efficacy, a positive value of liming was realized for all lime treatments at Potlatch and Tensed1, particularly for the 2 and 3 ton/A rates. 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.

Work has continued on understanding the impact of lime application and soil pH on soilborne diseases of cereal crops, with a continued focus on Fusarium crown rot and Rhizoctonia root rot. A second field study to examine the impact of liming on *Fusarium culmorum* was conducted at the Parker farm east of Moscow,

Table 1. Economic value of lime application on winter wheat yield in northern Idaho.

Ground limestone applied per acre	Cost of treatment* $/acre	Timeframe for liming efficacy	Cost: Annualized value of liming	Yield (bu/acre)	Yield gain per acre	Benefit: Value of yield gain** $/acre
Potlatch						
Control	$0			67		
1 ton	$87	10	$12	73	6	$27
2 ton	$161	15	$17	78	11	$49
3 ton	$235	20	$20	77	10	$45
Tensed1						
Control	$0			67		
1 ton	$87	10	$12	71	4	$18
2 ton	$161	15	$17	76	9	$40
3 ton	$235	20	$20	76	9	$40
Tensed2						
Control	$0			57		
1 ton	$87	10	$12	59	2	$9
2 ton	$161	15	$17	58	1	$4
3 ton	$235	20	$20	60	3	$13

*Cost of ground limestone and delivery is $74 per ton plus $13 application.

**Assumed price of wheat is $4.45 per bushel, farmgate (USDA-NASS, WA & ID combined, average August – November 2017 prices received).

ID. Spring wheat varieties WB-Hartline and Glee were evaluated in a combination of limed/non-limed and inoculated/non-inoculated field trials. As observed in the previous year, there was very low disease severity, even within the inoculated plots. While the severity was low, there was an indication that *F. culmorum* may be favored by higher pH soils, indicating that this disease could become more problematic as the pH increases. There was a yield response to liming in the absence of *F. culmorum*, but the presence of the pathogen with or without lime did not influence yield. A similar study was conducted to evaluate the impact of pH on *Rhizoctonia oryzae* on the spring wheat variety Seahawk. There was no difference between limed and non-limed plots with respect to the incidence or severity of Rhizoctonia root rot during a seedling assessment and no impact of the disease on yield. Currently, it does not appear that soil pH and liming will substantially influence the incidence or severity of these two diseases.

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 two of the five trial locations in the fall of 2017 and spring wheat or spring pulses will be seeded at the remaining three locations in the spring of 2018. Disease assessments will continue in 2018 to confirm the results of trials conducted with Fusarium crown rot and Rhizoctonia root rot. Data will be shared at Cereal Schools and field days, and information from this study was recently shared at a soil pH workshop. Interest in soil pH in northern Idaho and Washington is high as was evident from a capacity crowd of 150 people at this event.

PUBLICATIONS:

1. Hagerty, C. H., Barroso, J., Machado, S., Wysocki, D., Schroeder, K., Wegner, G., Carter, P., Murray, T., and Van Vleet, S. 2017. Assessment of soil acidity on soil-borne pathogens, weed spectrum, herbicide activity, and yield on dryland wheat production. Pp. 20-21. In: 2017 Dryland Field Day Abstracts: Highlights of Research Progress. Idaho Agricultural Experiment Station, Technical Report UI-2017-1.
2. Leggett, A., and Schroeder, K. 2017. Impact of liming on Fusarium crown rot. Pp. 47. In: 2017 Dryland Field Day Abstracts: Highlights of Research Progress. Idaho Agricultural Experiment Station, Technical Report UI-2017-1.