PROJECT NO: BJKT10, BDK111

TITLE: Managing soil acidity and aluminum toxicity in northern Idaho

PERSONNEL: Dr. Kurtis L. Schroeder, Cropping Systems Agronomist
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JUSTIFICATION: Soil pH has been on the decline in northern Idaho for several decades, primarily due to the use of ammonium-based nitrogen fertilizers. This coupled with the parent soils in many regions of northern Idaho being forest-derived, which means they have a lower starting pH and lower buffering capacity, makes them more susceptible to changes in pH. Acidification of soils in northern Idaho and eastern Washington was well documented during the 1980's by Dr. Mahler at the University of Idaho. Recently, there has been renewed interest in this topic and since a significant proportion of farmland in northern Idaho is forest-derived, there is a potential for long-term declines in crop production and soil quality. Reports from growers in northern Idaho suggest that critical thresholds of free aluminum may be present in many fields, particularly in the northern regions of the Camas prairie, north and east of Moscow and north of Coeur d'Alene. Another complication is that fact that as soils become more acidic, the availability of many plant nutrients declines. There is also evidence that even some of the historically grassland soils may be experiencing aluminum toxicity. Little information is available in northern Idaho to relate the nitrogen use efficiency of currently grown soft white winter wheat varieties to soil pH. Solutions for acid soils and aluminum toxicity include growing aluminum-tolerant crops, planting aluminum-tolerant wheat varieties and mitigation by application of calcium carbonate. The first two strategies are short-term solutions and may not be adequate for some growers. Ultimately, calcium carbonate applications will be needed to ameliorate the soil acidity and reduce the quantity of free aluminum ions in the soils. This would not only reduce or eliminate aluminum toxicity, but it would likely improve nutrient assimilation by plants and increase nitrogen fixation by *Rhizobium* spp. and *Mesorhizobium* spp. on legume crops. There are several types of lime available to growers, each with unique characteristics. Some products are very finely ground and highly reactive in soil, providing more of an immediate improvement in soil pH, but are also more costly. Others are coarser and less reactive, but may be more economical. Similar to the nitrogen fixing bacteria being impacted by pH, soil pH can also impact plant pathogens. A known example in northern Idaho is *Cephalosporium gramineum*, the causal agent of Cephalosporium stripe, being favored by acid soils. Less is known about other plant pathogens in wheat production. An added benefit of soil liming may be a reduction in disease.

HYPOTHESIS AND OBJECTIVES: The working hypotheses are that application of calcium carbonate, regardless of source, will increase soil pH and thereby yield, but finer products will provide a much quicker response. In addition, application of lime products will improve plant vigor, nodule formation on peas and yield. Secondly, the application of lime will improve the ability of plants to assimilate nitrogen, thereby lowering the quantity of nitrogen required to obtain optimal yields, and will decrease the severity and/or incidence of root and crown diseases. The goals of this project are to examine the benefits of calcium carbonate application to improve soil pH and improve the sustainability of production and yield in northern Idaho. The specific objectives of the project are:

1) Continue to monitor winter wheat and spring pea plots that had three different commercial liming products applied in the fall of 2013.
2) Evaluate the impact of calcium carbonate application on nitrogen use efficiency in soft white winter wheat.
3) Examine the impact of soil pH on cereal pathogens, focusing on root and crown diseases.
4) Conduct a regional survey in northern Idaho to access soil pH, total cation exchange capacity (CEC) and percentage of non-acid cations in the exchange.
5) Based on multi-year trial results, the profitability of liming products and rates for different regions and crops by computing the net present value for each scenario will be assessed.

PROCEDURES:

1. *Crop response to calcium carbonate application.* Field trials were established in the fall of 2013 at Potlatch, ID; Winchester, ID; and Pullman, WA. Products included Moses Lake sugar lime (Cascade Agronomics), ground limestone (Pioneer Enterprises), and NuCal liquid lime (Columbia River Carbonates) each applied at 500, 1000 and 2000 lbs $CaCO_3$/A. A combination of 500 lbs/A NuCal and 1500 lbs/A ground limestone was included along with a non-limed control. At each of the three locations, two trials containing all of the above treatments were established. During the 2013/2014 crop season, one was seeded to winter wheat and the second to spring pea. In 2013, Madsen winter wheat was seeded. For 2014, each plot was split, planting Madsen (aluminum tolerant) in one half and Eltan (aluminum sensitive) in the second half. In the fall of 2014, winter wheat was seeded into the spring pea stubble and in the spring of 2015, spring peas will be seeded into the winter wheat stubble. In mid to late May, samples will be collected from each plot to a depth of 30 cm to monitor changes in the soil pH. Samples will be collected from 0-7.5 cm, 7.5-15 cm and 15-30 cm. Pea plots will be assessed for nodule production and populations of *R. leguminosarum* will be monitored during late spring to early summer using real-time PCR. Plots will be evaluated to assess plant damage due to acid soil and/or aluminum toxicity. 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. *Fertilizer management in acid soils.* Two field trials were established at the Parker Farm in Moscow, ID to examine the impact of soil acidity on nitrogen use efficiency in winter wheat. The first consists of a split-split plot design with no lime or lime (NuCal at 14,000 lb/A as determined by lime requirement test), five nitrogen rates from 50 to 150 lbs/A applied at planting and four soft white wheat varieties with varying levels of tolerance to aluminum toxicity. Soil pH at this location is about 4.7. A second trial was established at the Parker Farm in a field with a pH of 4.1 to 4.3. In this trial, nitrogen was applied at the recommended rate to all plots and four varieties of wheat were seeded with and without NuCal lime at 20,000 lb/A. At harvest, plant tissue, grain and soils will be sampled to estimate the quantity of nitrogen in each to determine the fate of the applied nitrogen. In addition, total grain yield, test weights and grain protein will be determined from each plot.
3. *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 under greenhouse conditions. Depending on the outcome, field studies may be initiated in the fall of 2015 to examine the impact lime applicatoins. Soils will be collected from various sites on the Parker Farm in Moscow, ID that have soil pH from 4.0 to 6.0. Calcium carbonate will be added to portions of these soils to increase pH and soils will be inoculated with *Fusarium culmorum*, *F. pseudograminearum*, *Rhizoctonia solani*, *R. oryzae*, *Pythium ultimum* and *P. irregulare*.

After 3 to 4 four weeks, plants will be destructively harvested; disease incidence and severity scored; and first leaf length, plant height and dry plant weights recorded.

4. *Acid soil survey.* Soil samples will be collected throughout northern Idaho in the summer of 2014 to determine soil pH, non-acid base saturation and cation exchange capacity. In addition to soil pH, the percentage of non-acid base saturation can influence whether aluminum can be accumulated by plants in a quantity that will cause toxicity.
5. *Assessing profitability of lime applications.* Detailed costs of production will be needed for each site in order to determine costs and returns for each scenario. Since the positive effects of lime application extend over a long timeframe, we will account for the stream of costs and benefits over time by estimating the net present value of each treatment.

DURATION: This project is in the 2nd year of a 3 year project.

COOPERATON: This is a cooperative project with Dr. David Huggins, soil scientist with the USDA-ARS in Pullman, WA who is conducting similar liming source studies in Washington, but with an emphasis on direct seeding. Doug Finkelnburg, Extension Educator, will be assisting with various activities related to the field trials and collecting soils for the regional survey. Research plots will be conducted on University of Idaho research farms in Moscow and in cooperation with three local growers in Potlatch, ID; Winchester, ID; and Pullman, WA.

ANTICIPATED BENEFITS/EXPECTED OUTCOMES/INFORMATION TRANSFER: Results of this study will provide information on the potential benefit of liming in northern Idaho which could include improved yields, improved nitrogen efficiency, reduced plant disease, and increased profitability over time. Improvements in soil pH should lead to better root health, more plant available nitrogen and potentially reduce the nitrogen requirement for wheat in soils where pH has improved following the application of calcium carbonate. This important information will allow growers to make informed decisions about which products will work best for them and are most economical for their farming operation. The results of this study will be shared at field days and winter cereal schools, and incorporated into regional Extension crop budgets published on the University of Idaho Extension website. In addition, at least two extension articles are anticipated from this work along with possible popular press articles and peer-reviewed research publications.

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). Recently, there has been a 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). Recent research 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. However, under acidic conditions, independent of the base saturation of cations, nutrient availability is still impacted. Under historically forested soils, Mahler's research demonstrated an advantage to lime application to improve yields (Mahler and McDole 1985). Very little information exists on the impact of pH on Rhizoctonia root rot, *Pythium* spp. are known to be favored by slightly acidic conditions (5.0-5.5), 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.

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.

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

Allocated by	Idaho Wheat Commission	during FY 2014	$	-
Allocated by	Idaho Wheat Commission	during FY 2015	$	20,288

REQUESTED FY 2016 SUPPORT:

	Salary	Temporary Help	Fringe	Travel	OE	Grad Fees	TOTALS
Idaho Wheat Commission	$ -	$ 13,200	$ 1,188	$ 1,900	$ 4,000	$ -	$ 20,288

OTHER RESOURCES (not considered cost sharing or match):

TOTAL OTHER RESOURCES $ 19,400

TOTAL PROJECT ESTIMATE FOR FY 2016:	$ 20,288 *(Requested)*	$ 19,400 *(Other)*	$ 39,688 *(Total)*

BREAKDOWN FOR MULTIPLE SUB-BUDGETS:

	Kurtis Schroeder	*Kathleen Painter*	*(PI name)*	*(PI name)*
Salary	$ -	$ -	$ -	$ -
Temporary Help	$ 6,000	$ 7,200	$ -	$ -
Fringe Benefits	$ 540	$ 648	$ -	$ -
Travel	$ 900	$ 1,000	$ -	$ -
Operating Expenses	$ 4,000	$ -	$ -	$ -
Graduate Student Fees	$ -	$ -	$ -	$ -
TOTALS	$ 11,440	$ 8,848	$ -	$ -

Total Sub-budgets $ 20,288

10.24.2014 - Version