

Grant Code: AP6314

Title: Liming for Improved Nutrient Utilization and Weed Management in Wheat

Personnel: Jared Spackman, Assistant Professor, UI Aberdeen; Albert Adjesiwor, Assistant Professor UI Kimberly; Jared Gibbons, Madison County; Tom Jacobsen, Fremont County, Joseph Sagers, Jefferson County; Kurt Schroeder, Associate Professor, Moscow

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Justification/Rationale: The optimal soil pH for most agronomic crops is 6.2 to 7.3 when nutrient availability is maximized. Most southern Idaho agricultural soils are neutral to alkaline (pH 7 to 8.5) but naturally slowly acidify due to precipitation. Agricultural production accelerates acidification when ammonium-containing fertilizers are applied and as cations are removed at harvest³. Because soil pH change is gradual, yield reductions are often not observed until a soil pH threshold is reached. The critical threshold for sugar beets, barley, potatoes, and wheat are 6.0, 5.8, 5.5, and 5.4, respectively. Below these thresholds, root growth is inhibited negatively impacting nutrient and water uptake. While most southern Idaho soils are above these thresholds, soil acidity is becoming increasingly problematic from Ashton to Driggs, as well as other pockets across southern Idaho. Sugar beet lime is a readily available amendment, but the current University of Idaho and soil testing lab liming recommendations are based on other Midwest and Pacific Northwest states' recommendations that do not reflect southern Idaho soils' physical, chemical, and climatic properties.

In addition to improving nutrient availability and crop growth, scientific experiments have shown that lime applications can reduce weed seed germination and vigor and make crops more competitive. Liming acidic soils in Idaho could provide additional benefits of improving wheat competitiveness against weeds, reducing weed pressure, decreasing the overall impact of weeds on wheat yield, and reducing the number of weed seeds in the soil. Weed seeds in the soil remain the major source of weed infestation in crops. Thus, the best indication of the "next" weed problem is the composition of weed seeds in the soil. We are proposing a multi-disciplinary study that evaluates the effect of liming on nutrient availability, crop growth, weed density, and weed seed composition in the soil.

Objectives:

Hypothesis: Liming will improve soil nutrient availability, crop growth, and reduce weed pressure on agronomic crops.

Objective 1: Evaluate how liming modifies soil nutrient availability, plant nutrient uptake, and grain quality and yield.

Objective 2: Evaluate the effect of liming on weed pressure.

Objective 3: Perform a survey of southern Idaho's acidic soils' physical and chemical properties and weed seed census.

Methods/Plan of Work: Four on-farm field experiments were established in Ashton (3) and Swan Valley (1) in the fall of 2021. Four replications of four sugar beet lime rates were applied at 0, 2, 4, and 6 tons per acre using Valley Ag's spreader to 50 x 100' plots. In 2022, the plots

were planted to wheat or barley and will be planted to wheat or a rotational crop in 2023 (wheat, seed potatoes, barley, canola, etc.) The plots will be managed according to the grower practices. Soil samples will be collected at the 0-2, 2-4, 4-6, 6-8, and 8-12" depths in the fall of 2023. These samples will be analyzed for soil pH, electrical conductivity, and free lime (when soil pH>7). Additional soil samples will be collected at 0-6 and 6-12" depths and analyzed for extractable aluminum (a source of soil acidity and root toxicity). At maturity, yield, yield components (test weight, grain protein), aboveground biomass, weed biomass, and weed density will be measured from within each plot. The aboveground biomass will be analyzed for complete nutrient analysis.

Lime requirement recommendations for Idaho soils are being conducted by collecting ten gallons of acidic soils (pH<6) from the 0-6" depth in Ashton, Driggs, Soda Springs, Grace, Moscow, Potlatch, and other sites identified by agronomists and soil testing labs. A 90-day lime incubation has been initiated by adding calcium carbonate lime to each soil at rates of 0, 0.5, 1, 2, 4, 6, 8, and 10 tons per acre. Soil pH, electrical conductivity, free carbonate, and nitrate and ammonium content will be measured at the beginning and end of the incubation. The non-limed soils will be evaluated for lime requirement using the Sikora buffer, the modified Mehlich buffer, single addition calcium hydroxide, and sequential addition of calcium hydroxide methods.

The modified lime incubation soils will be subdivided into 3 or 4 pots each and planted with red root pigweed, wild oat, Kochia, and/or corn spurry. Seedling emergence and vigor will be assessed to determine if these noxious weed species are affected by soil pH. Additional weed species may also be assessed.

Duration: Four years (2021, 2022, 2023, 2024) Year 3 of 4

Cooperation/Complementation: The last national push to conduct liming research was in the 1970s and 1980s. Interest in liming research has been renewed in the last decade, especially in the western states. Lime incubation studies or field trials were recently conducted in the Palouse region, Montana, Washington, and Oregon due to soil acidification.

This study supports the research and trial and error testing done by Valley Wide Ag in Ashton over the last 20 years. The IWC study is a collaborative effort to provide research-based lime requirement recommendations to agronomists and the farmers they work with.

Dr. Spackman's lab is working with a national research group (Fertilizer Research Support Tool <https://soiltestfrst.org/lime/>) to reevaluate liming recommendations and practices. Drs. Spackman and Schroeder joined this research team in 2022. Dr. Spackman has submitted acidic soils from Ashton and Soda Springs for inclusion in a national lime incubation study.

Dr. Spackman's lab is working with Dr. Dave Tarkalson at USDA ARS in Kimberly and Amalgamated Sugar on ways to utilize precipitated calcium carbonate (spent sugar beet lime) as an agronomic amendment in both acidic and alkaline soils. Through this relationship, Dr. Spackman will help convert some of Dr. Tarkalson's research articles into Extension bulletins.

Dr. Spackman is conducting a lime incubation study with undergraduate students at Brigham Young University – Idaho. These students are evaluating precipitated calcium carbonate, calcium hydroxide, and calcium carbonate as liming agents and determining how long it takes for these lime products to neutralize acidic soils.

Anticipated Benefits/Expected Outcomes: The on-farm study will generate two peer-reviewed journal articles and two Extension bulletins. Both the on-farm and the incubation studies will

contribute data to Dr. Adjesiwor's database of herbicide-resistant weeds and weed seed bank density across southern Idaho. Because Idaho's lime guidelines were developed using research from other Pacific Northwest states' datasets, this lime recommendation study will be the only dataset to our knowledge that is specific to the lime requirements of southern Idaho soils. The data from this study will help growers know how long a single lime application lasts in southern Idaho irrigated conditions and what rate is most effective.

Transfer of Information/Technology: One graduate student will use the data generated from this study in her thesis. The results were presented at the Tri-Societies meetings in 2022 and will be presented at the Western Nutrient Management Conference in 2023. This information will also be shared at Extension events (Cereal School, field days) and the PI's websites. The raw dataset will be published in a publicly available data repository to ensure the longevity of the dataset and its availability for future research applications. This project will be used to inform growers and crop advisors about the potential benefits of liming for a competitive advantage over weed pressure, improved crop health, and nutrient availability and uptake.

Literature review

Soil acidification is an increasingly common problem for Idaho wheat producers. Formerly neutral to slightly alkaline agricultural soils in Montana, Idaho, Oregon, and Washington have acidified following repeated applications of ammonium-containing fertilizers, cation leaching with irrigation water, and cation removal with harvest^{2,3}. Additionally, sandy soils acidify more rapidly than clayey soils due to less organic matter and cation exchange capacity. Acidic soils reduce soil nutrient availability to crops and increase aluminum and manganese solubility which reduces crop growth by killing the root tips³. Lime is required to neutralize soil acidity and includes a variety of sources including limestone, sugar beet lime, and wood ash among others⁶. Sugar beet lime is a readily available source in southern Idaho and is commonly used on acidic soils in Ashton and other southern Idaho fields. In a Montana study, 2.5 tons ac⁻¹ of sugar beet lime was required to raise soil pH from 4.7 to 6.0 in the top 4 inches of the soil profile². Most of the pH change occurred in the first year following tillage.

In addition to improving crop growth and nutrient availability, liming acidic soils increases the competitiveness of the crop against weeds^{4,5}. Healthy crops effectively compete with weeds for water and nutrient resources reducing weed density and the number of weed seeds produced annually. This is especially important for managing herbicide-resistant weeds. A recent study demonstrated that lime application to acidic soil increased tiller number in wheat and the overall competitiveness of wheat against rigid ryegrass¹. This reduced rigid ryegrass growth and weed seed production. In the Ashton area, a local agronomist often observes reduced barnyard grass and corn spurry pressure following liming (Personal communication with Bryan Miller, 2020).

References

1. Borger CPD, Azam G, Gazey C, van Burgel A, Scanlan CA (2020) Ameliorating soil acidity–reduced growth of rigid ryegrass (*Lolium rigidum*) in wheat. *Weed Sci.* 68: 426–433. <https://doi.org/10.1017/wsc.2020.38>
2. Engel, R., C. Jones, and R. Wallander. 2020. Soil acidification: Remediation with sugar beet lime. Montana State University–Extension. <https://landresources.montana.edu/fertilizerfacts/html/FF80.html>

3. Hart, J.M., D.M. Sullivan, N.P. Anderson et al. (2013). Soil acidity in Oregon: Understanding and using concepts for crop production. Oregon State Extension EM 9061.
<https://catalog.extension.oregonstate.edu/em9061>
4. Lemerle D, Verbeek B, Coombes N (1995) Losses in grain yield of winter crops from *Lolium rigidum* competition depend on crop species, cultivar and season. *Weed Res* 35:503–509 <https://doi.org/10.1111/j.1365-3180.1995.tb01648.x>
5. Li Y, Cui S, Chang SX, Zhang Q (2019) Liming effects on soil pH and crop yield depend on lime material type, application method and rate, and crop species: a global meta-analysis. *J Soil Sediment* 19:1393–1406 <https://link.springer.com/article/10.1007/s11368-018-2120-2>
6. Mahler, RL, and RE McDole (1994). Liming materials. University of Idaho, Cooperative Extension Service, Agricultural Experiment Station, College of Agriculture.
https://drive.google.com/file/d/1tZ5ujnwvNB1J_C3TGAPShYJTK5Wz3p6h/view

FY2024

COMMODITY COMMISSION BUDGET

Principal Investigator: Jared Spackman

Allocated by <u>Idaho Wheat Commission</u>	during FY2022	\$	30,894
(Commission/Organization)			
Allocated by <u>Idaho Wheat Commission</u>	during FY2023	\$	33,247
(Commission/Organization)			

REQUESTED SUPPORT:	<i>Awarded for FY2023</i>	<i>Requested for FY2024</i>
Budget Categories		
(10) Salary (<i>staff, post-docs, et NOTE: Faculty salary/fringe not allowed</i>)	\$ 11,438	\$ 10,904
(12) Temporary Help/IH	\$ 2,400	\$ 1,800
(11) Fringe Benefits	\$ 1,970	\$ 5,336
(20) Travel	\$ 4,490	\$ 5,396
(30) Other Expenses	\$ 8,500	\$ 5,979
(40) Capital Outlay >\$5k	\$ -	\$ -
(45) Capital Outlay <\$5k	\$ -	\$ -
(70) Graduate Student Tuition/Fees	\$ 4,449	\$ -
TOTALS	\$ 33,247	\$ 29,415
TOTAL BUDGET REQUESTED FOR FY2024:		\$ 29,415

BREAKDOWN FOR MULTIPLE INDEXES:	<i>Jared Spackman</i>	<i>(Insert Co-PI Name)</i>	<i>(Insert Co-PI Name)</i>	<i>(Insert Co-PI Name)</i>
Budget Categories				
(10) Salary (<i>staff, post-docs, et</i>)	\$ 10,904	\$ -	\$ -	\$ -
(12) Temporary Help	\$ 1,800	\$ -	\$ -	\$ -
(11) Fringe Benefits	\$ 5,336	\$ -	\$ -	\$ -
(20) Travel	\$ 5,396	\$ -	\$ -	\$ -
(30) Other Expenses	\$ 5,979	\$ -	\$ -	\$ -
(40) Capital Outlay >\$5k	\$ -	\$ -	\$ -	\$ -
(45) Capital Outlay <\$5k	\$ -	\$ -	\$ -	\$ -
(70) Graduate Student Tuition/Fees	\$ -	\$ -	\$ -	\$ -
TOTALS	\$ 29,415	\$ -	\$ -	\$ -
Total Sub-budgets				\$ 29,415

Budget Justification		
\$	10,904	Technicians, \$19.91, 548 hours
\$	1,800	\$15/hr @ 120 hours
\$	5,336	42% for technician, 42% for temporary help with PERSI benefits 3 trips from Aberdeen to Swan Valley, 4 travelers, 220 miles, 1 day each, UI Aberdeen vehicle mileage rates \$0.80/mile (\$528); 9 trips from Aberdeen to Ashton, 4 travelers, 256 miles, 1 day each, UI Aberdeen vehicle mileage rates \$0.80/mile (\$1843.20); Lunch per diem (4 persons x 12 days x \$18 = \$864), 3 trips from UI Aberdeen to Kimberly RE, 1 traveler, 205 miles, 1 day each, UI Aberdeen RE vehicle mileage rates are \$0.80/mile = \$492, Tri-Societies Annual Conference St. Louis, MO. postdoc, hotel 3 days @ \$149/day = \$447, flight \$350, roundtrip mileage to SLC airport 400 miles x \$0.80/mile=\$320, airport parking 4 days at \$35/day=\$140, per diem 4 days at \$55/day= \$220;
\$	5,396	Travel to field day in Ashton, 239 miles roundtrip, UI Aberdeen RE vehicle mileage rates are \$0.80/mile \$674.14 for cups, bags, labels, rubber bands, gloves, rice knives, pH probe; 128 soil samples analyzed for extractable Aluminum at \$12/sample=\$1536; 128 plant tissue samples analyzed for complete nutrient analysis at \$12.75/sample=\$1632; shipping \$572; trailer rental 3 trips to 4 locations with a daily charge fee of \$40 = \$480; pots, trays, labels \$300; Tri-Societies Conference Postdoc Registration \$30 and \$60 Poster Printing.
\$	5,979	

ANNUAL REPORT

Grant Code: AP6314

Title: Liming for Improved Nutrient Utilization and Weed Management in Wheat

Personnel: Drs. Jared Spackman, Albert Adjesiwor, Kurt Schroeder, and Mr. Joseph Sagers

Collaborators: Jacob Bevan, Kaone Mookodi, Joseph Sagers, Sean Maupin, Alan Baum, Nathan Scafe, Clark Hamilton, Greg Blaser, Paul Stukenholtz

Address: Dr. Jared Spackman, University of Idaho (UI) Aberdeen Research & Extension Center, Aberdeen, ID 83210; 208-312-2454; jspackman@uidaho.edu

Abstract:

The optimal soil pH for most agronomic crops is 6.2 to 7.3 when nutrient availability is maximized. Most southern Idaho agricultural soils are neutral to alkaline (pH 7 to 8.5) but agricultural production accelerates acidification when ammonium-containing fertilizers are applied and as cations are removed at harvest. While most southern Idaho soils are above these thresholds, soil acidity is becoming increasingly problematic from Ashton to Driggs, Swan Valley/Antelope Flats, and Soda Springs. Sugar beet lime is a readily available amendment, but the current University of Idaho and soil testing lab liming recommendations are based on other Midwest and Pacific Northwest states' recommendations that do not reflect southern Idaho soils' physical, chemical, and climatic properties. The objectives of this study are to evaluate the effect of liming on soil nutrient availability, plant nutrient uptake, grain quality and yield, and weed pressure. An additional objective is to conduct a lime requirement incubation study to determine how acidic Idaho soils respond to liming.

Background/Objectives:

The optimal soil pH for most agronomic crops is 6.2 to 7.3 when nutrient availability is maximized. Most southern Idaho agricultural soils are neutral to alkaline (pH 7 to 8.5) but naturally slowly acidify due to precipitation. Agricultural production accelerates acidification when ammonium-containing fertilizers are applied and as cations are removed at harvest. Because soil pH change is gradual, yield reductions are often not observed until a soil pH threshold is reached. The critical threshold for sugar beets, potatoes, wheat, and barley are 6.0, 5.5, 5.4, and 5.2, respectively. Below these thresholds, root growth is inhibited negatively impacting nutrient and water uptake. While most southern Idaho soils are above these thresholds, soil acidity is becoming increasingly problematic from Ashton to Driggs, Swan Valley/Antelope Flats, and Soda Springs. Sugar beet lime is a readily available amendment, but the current University of Idaho and soil testing lab liming recommendations are based on other Midwest and Pacific Northwest states' recommendations that do not reflect southern Idaho soils' physical, chemical, and climatic properties.

In addition to improving nutrient availability and crop growth, scientific experiments have shown that lime applications can reduce weed seed germination and vigor and make crops more competitive. Liming acidic soils in Idaho could provide additional benefits of improving wheat

competitiveness against weeds, reducing weed pressure, decreasing the overall impact of weeds on wheat yield, and reducing the number of weed seeds in the soil. The objectives of this study were to evaluate the effect of liming on soil nutrient availability, plant nutrient uptake, grain quality and yield, and weed pressure. An additional objective was to conduct a lime requirement incubation study to determine how acidic Idaho soils respond to liming.

Results/Accomplishments :

Three on-farm field experiments were established in the fall of 2021 in Ashton and one at Swan Valley. Four replications of four sugar beet lime rates were applied at rates of 0, 2, 4, and 6 tons per acre on 50'x100' plots. Other than liming, the plots were managed according to the grower practices. During the 2022 growing season, irrigated spring wheat was grown at the Ashton sites and dryland barley was grown at the Swan Valley location. The centers of each plot were geo-referenced. Soil samples were collected at the 0-2, 2-4, 4-6, 6-8, and 8-12" depths in the spring and after grain harvest in 2022. These samples were dried and ground and are in the process of being analyzed for soil pH (1:1 soil: water, 1:2 soil: water, 1:1 soil:0.01 M calcium chloride), electrical conductivity, and free lime. Additional soil samples were collected at 0-6 and 6-12" depths and are awaiting analysis by Agvise Laboratories for extractable aluminum (a source of soil acidity and root toxicity). At grain maturity, grain yield, yield components (test weight, grain protein), aboveground biomass, weed biomass, and weed density were measured from a 5x5' section of each plot. My graduate student is in the final stages of preparing straw and grain samples to be sent for a complete nutrient analysis at Brookside Laboratories.

For the incubated lime requirement study, we collected 10 gallons of acidic soils from 16 field sites in southern (10) and northern Idaho (6) from Ashton, Swan Valley, Soda Springs, Moscow, and Potlatch. For this study, my graduate student (Kaone Mookodi) dried, ground, and homogenized each soil. The soil was then subdivided into 32 containers and treated with 0, 0.5, 1, 2, 4, 6, 8, and 10 tons per acre of calcium carbonate (lime). Water was added to each pot to bring the soil moisture content to 80% and then the pots were incubated for 90 days. The soils were dried and are in the process of being ground. Each soil will be analyzed for soil pH, electrical conductivity, free carbonate, and nitrate and ammonium content. We will then analyze the soils for lime requirement using the Sikora buffer, the modified Mehlich buffer, single addition calcium hydroxide, and sequential addition of calcium hydroxide methods.

At the end of the incubation, each pot will be subdivided into 3 or 4 smaller pots and planted to either wild oat, Kochia, cheatgrass, common lambsquarters, or redroot pigweed seeds. Germination and seedling vigor will be assessed for five weeks at the Kimberly R&E Center.

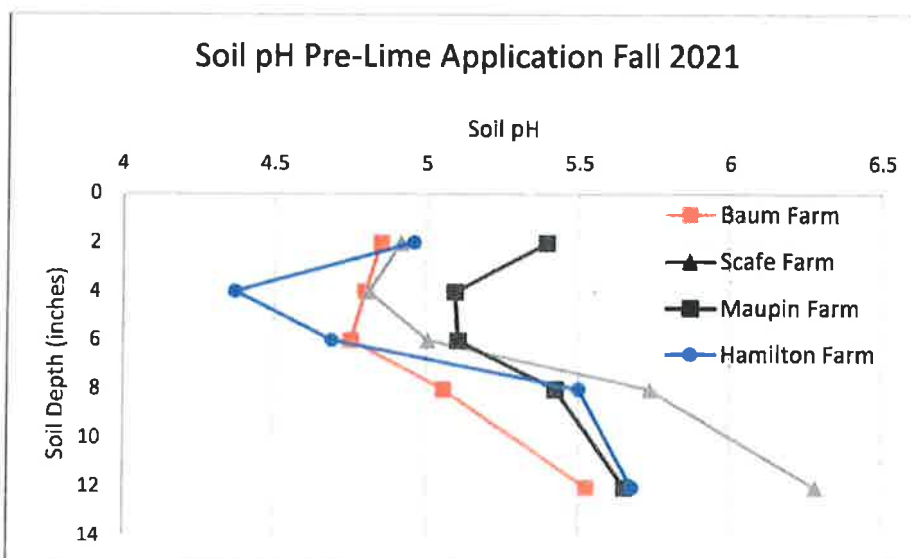


Figure 1: Soil pH changes by depth before lime application. Soil pH followed a pattern of decreasing from the 0-2" depth to the 2-4" and 4-6" depths and increasing in the 6-8" and 8-12" depths. Historically, these soils had more alkaline soils but over 100 years of farming, applying nitrogen fertilizers, and withdrawing base cations at harvest, the surface soil pH has declined while the deeper depths have greater soil pH values. Calcium carbonate deposits can still be found at deeper depths in these soils.

Outreach/Applications/Adoptions:

The on-farm study will generate two peer-reviewed journal articles and two Extension bulletins. In collaboration with Dr. Dave Tarkalson from USDA ARS in Kimberly, Dr. Spackman's graduate student, Kaone Mookodi, is working on a journal article to address how soil pH and liming impact small grain seedling vigor.

This study supports the research and trial and error testing done by Valley Wide Ag in Ashton over the last 20 years. The IWC study is a collaborative effort to provide research-based lime requirement recommendations to agronomists and the farmers they work with.

In September 2022, Dr. Spackman and Tom Jacobsen had an informal meeting with several small grain growers in Ashton and Soda Springs to talk about liming principles, nutrient management, and the current status of the IWC-funded liming study. These growers expressed interest in conducting additional lime research and are currently collaborating on a Western SARE grant that will supplement the IWC-funded study.

Dr. Spackman's lab is working with a national research group (Fertilizer Research Support Tool <https://soiltestfrst.org/lime/>) to reevaluate liming recommendations and practices. Drs. Spackman and Schroeder joined this research team in 2022. Dr. Spackman has submitted acidic soils from Ashton and Soda Springs for inclusion in a national lime incubation study.

Dr. Spackman's lab is working with Dr. Dave Tarkalson at USDA ARS in Kimberly and Amalgamated Sugar on ways to utilize precipitated calcium carbonate (spent sugar beet lime) as an agronomic amendment in both acidic and alkaline soils. Through this relationship, Dr.

Spackman will help convert some of Dr. Tarkalson's research articles into Extension bulletins.

Dr. Spackman is conducting a lime incubation study with undergraduate students at Brigham Young University – Idaho. These students are evaluating precipitated calcium carbonate, calcium hydroxide, and calcium carbonate as liming agents and determining how long it takes for these lime products to neutralize acidic soils. They are also examining the impact of soil moisture at the time of lime application on how readily soil pH is neutralized.

Next Steps/Projections:

For the on-farm field trials, we will continue to monitor changes in soil pH in each plot over the next two years.

After Kaone finishes analyzing the lime incubation samples, we will use the modified soils to evaluate the effect of soil pH on weed vigor. We will likely evaluate red root pigweed, wild oat, Kochia, and/or corn spurry.

Kaone will continue to analyze the soil sample results and will write them up as part of her thesis.

Publications/Presentations/Popular Articles/News Releases/Variety Releases:

We have presented information about the liming study at the University of Idaho Forage Schools held in March 2022 at Mudlake, Preston, and Idaho Falls and Cereal Schools in Soda Springs. Despite many of these locations having alkaline soils, the topic generated significant interest. Kaone will present a poster at the Western Nutrient Management Conference in March 2023. We also anticipate presenting the first year of data at the 2023 American Society of Agronomy-Crop Science Society of America-Soil Science Society of America annual conference.