Grant Code: AP5458

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

Personnel: Jared Spackman, Assistant Professor, UI Aberdeen; Albert Adjesiwor, Assistant Professor UI Kimberly; Joseph Sagers, Jefferson and Clark County Area Extension Educator, Kurt Schroeder, Associate Professor, UI 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 harvest (Hart et al., 2013). 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, 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, as well as other pockets across southern Idaho. Sugar beet lime is a readily available amendment, but 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 acidic soils' physical and chemical properties and weed seed census.

Procedures/Plan of Work: 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 will be managed according to the grower practices. Sites were characterized for micro and macronutrient content and soil physical properties by analyzing soil samples from the top foot of each plot. Additional soil samples were collected at the 0-2, 2-4, 4-6, 6-8, and 8-12" depths in the fall of 2021 before liming; and will be collected again in the spring after planting, summer (Feekes 10), and fall (late September to early October) of 2022; and each subsequent spring and fall until 2024. These samples will be analyzed for soil pH, electrical conductivity, and free lime. Each fall, 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). The 0-6" soil samples will also be analyzed for weed seed bank density, weed diversity, and resistance to at least five herbicide sites of action. At maturity, wheat 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 southern Idaho soils will be done by analyzing 10 gallons of acidic soils (pH<6) from the 0-6" depth increments in Ashton, Driggs, Grace, Oakley, Lake Channel (west of American Falls), Carey, Jerome, and other sites identified by agronomists and soil testing labs. A 90-day lime incubation will be performed by adding calcium carbonate lime to each soil at rates of 0, 1, 2, 4, 6, and 8 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. At the end of the incubation, the contents of each bag will be subdivided into five pots and planted with 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.

Duration: Year 2 of a 4-year study (2021, 2022, 2023, 2024).

Cooperation/Collaboration: Dr. Jared Spackman and Dr. Albert Adjesiwor's teams will work together to collect soil and tissue data from the on-farm trials and to advise Kaone Mookodi, a new MS graduate student. Dr. Spackman's team will perform the soil pH, electrical conductivity, free lime, and extractable aluminum analyses while Dr. Adjesiwor's team will perform the weed seed bank and weed herbicide tolerance analysis. Mr. Joseph Sagers will assist with sample collection and organizing grower field days.

Anticipated Benefits, Expected Outcomes and Impacts, and Transfer of Information: The on-farm study will generate two peer-reviewed journal articles and two Extension bulletins. Both the on-farm and the lime recommendation 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. Kaone Mookodi will use this data for her MS theses. The results will be shared at professional meetings (e.g., Weed Science Society, Tri-Societies meetings, Western Nutrient Management Conference), 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 (Hart et al., 2013; Engel et al., 2020). 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 that reduces crop growth by killing the root tips (Hart et al., 2013). Lime is required to neutralize soil acidity and includes a variety of sources including limestone, sugar beet lime, and wood ash among others (Mahler and McDole, 1994). 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 increase soil pH from 4.7 to 6.0 in the top 4 inches of the soil profile (Engel et al., 2020). 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 (Lemerle et al. 1995; Li et al. 2019). 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 an acidic soil increased tiller number in wheat and the overall competitiveness of wheat against rigid ryegrass (Borger et al. 2020). 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. doi: 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.
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.
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
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
6. Mahler, RL, and RE McDole (1994). Liming materials. University of Idaho, Cooperative Extension Service, Agricultural Experiment Station, College of Agriculture.

FY2023

COMMODITY COMMISSION BUDGET

Principal Investigator: ***Jared Spackman***

Allocated by _____ *(Commission/Organization)*	during FY2021	$	-
Allocated by Idaho Wheat Commission *(Commission/Organization)*	during FY2022	$	30,894

REQUESTED SUPPORT: Budget Categories	*Awarded for FY2022*	*Requested for FY2023*
(10) Salary *(staff, post-docs, et NOTE: Faculty salary/fringe not allowed*	$ 16,849	$ 11,438
(12) Temporary Help	$ -	$ 2,400
(11) Fringe Benefits	$ 354	$ 1,970
(20) Travel	$ 6,091	$ 4,214
(30) Other Expenses	$ 7,600	$ 8,500
(40) Capital Outlay >$5k	$ -	$ -
(45) Capital Outlay <$5k	$ -	$ -
(70) Graduate Student Tuition/Fees	$ -	$ 4,726
TOTALS	$ 30,894	$ 33,247

TOTAL BUDGET REQUESTED FOR FY2023:	$ 33,247

BREAKDOWN FOR MULTIPLE INDEXES:

Budget Categories	*Jared Spackman*	*Albert Adjesiwor*	*Joseph Sagers*	*(Insert Co-PI Name)*
(10) Salary *(staff, post-docs, et*	$ 11,438		$ -	$ -
(12) Temporary Help		$ 2,400	$ -	$ -
(11) Fringe Benefits	$ 1,764	$ 206	$ -	$ -
(20) Travel	$ 2,724	$ 952	$ 538	$ -
(30) Other Expenses	$ 7,000	$ 1,500	$ -	$ -
(40) Capital Outlay >$5k	$ -	$ -	$ -	$ -
(45) Capital Outlay <$5k	$ -	$ -	$ -	$ -
(70) Graduate Student Tuition/Fees	$ 4,726	$ -	$ -	$ -
TOTALS	$ 27,651	$ 5,058	$ 538	$ -
			Total Sub-budgets	$ 33,247

ANNUAL REPORT

Grant Code: AP5458
Title: Liming for Improved Nutrient Utilization and Weed Management in Wheat
Personnel: Drs. Jared Spackman and Albert Adjesiwor
Collaborators: Jacob Bevan, Kaone Mookodi, Joseph Sagers, Sean Maupin, Alan Baum, Nathan Scafe, Clark Hamilton, Greg Blaser, Paul Stukenholtz
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Accomplishments

The objectives of this study were:
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 acidic soils' physical and chemical properties and weed seed census.

This fall, Joseph Sagers, Jacob Bevan, Albert Adjesiwor, and Jared Spackman were able to successfully establish four on-farm field experiments. Three experiments are in Ashton on irrigated fields, and one is in Swan Valley under dryland conditions. We applied lime at rates of 0, 2, 4, and 6 ton/ac to 50x100 ft plots. Prior to the lime application, we took soil samples from the 0-2, 2-4, 4-6, 6-8, and 8-12" depths. These samples were dried and ground to pass through a 2 mm sieve. They will be analyzed for soil pH and electrical conductivity after we collect our spring soil samples. We also took soil samples at the 0-12" depths and analyzed them for a complete nutrient analysis. A 0-6" soil sample was collected and will be analyzed for the weed seed census and herbicide resistance. A subsample of the lime applied to each field was collected and analyzed for nutrient composition and lime composition. We found that the sugar beet lime had a fine particle size, contains 61% calcium carbonate, and supplies 20, 420, and 40 lb of nitrogen, P2O5, and K2O, respectively per ton of applied lime (Stukenholtz lime analysis, 2021).

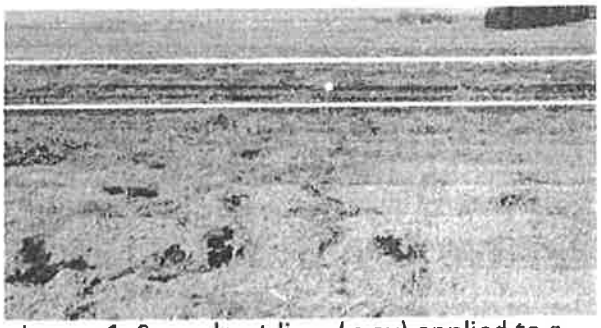

Image 1. Sugar beet lime (gray) applied to a recently harvested potato field in Ashton, Idaho on October 11, 2021 with a surface soil pH of 5.4. The liming rates were 4, 0, and 2 tons/acre (closest to furthest plots, respectively).

In our interactions with small grain producers across southern Idaho, we have identified 5 locations that have low soil pH including sites in Soda Springs, Swan Valley, Ashton, Lake Channel, and Freedom. Dr. Jared Spackman is continuing to work with Paul Stukenholtz and

Bryan Miller from Valley Wide in Ashton to identify additional locations that have soils with a pH <5.5. This spring, we will collect 10 gallons of soil from the 0-6" depth at each location to include in our lime requirement study.

We successfully hired one graduate student, Kaone Mookodi, in January of 2022. She will use these projects for her Master's thesis. She is currently conducting a literature review and will begin collecting soil samples in May. She is a bright student and we are looking forward to working with her to successfully conduct these long-term studies.

Image 2. A sugar beet lime pile ready for application at Alan Baum's field site.

We hired Jacob Bevan as a research technician in July 2021. He had recently completed his MS at the University of Idaho in Jianli Chen's wheat breeding program. Because of his research background and experience with wheat, he was able to rapidly adjust to the Barley Agronomy program and hit the ground running. He is an essential member of the Barley Agronomy research program and is doing an excellent job of keeping the project samples organized and processed in a timely manner. He has shown dedication to the program by putting in early mornings and late nights with Dr. Spackman to travel to and from Ashton and Swan Valley collecting soil samples and assisting in the lime applications, even in snowy and windy conditions.

Projections: To increase the scope of this project, we have written supporting grants for the Idaho Potato, Barley, and Alfalfa commissions to support additional on-farm field sites and soil analyses. The grant written to the Potato Commission would add two field sites in the Chester-Plano region that have sandier soils and weaker buffering capacity than Ashton soils. The Barley Commission grant will add two on-farm dryland sites east of Ashton in the Squirrel-Driggs region. The Alfalfa Commission grant would allow us to collect 7 additional soils for the laboratory lime requirement study. In addition to our previously outlined research goals, we plan to increase the value from the study by evaluating if soil pH modifies germination vigor of five different weed species including wild oat, kochia, and lambsquarters. We will utilize the lime-amended incubation soils for this analysis.

In addition to the Idaho Wheat Commission, there is interest at a national level to re-evaluate lime recommendations. Dr. Jared Spackman is participating with the USDA funded Fertilizer Recommendations Support Tool team (FRST) on developing and conducting a national liming rate recommendation study. Information and progress about this study will be shared with the Idaho Wheat Commission as the FRST team develops the project study plan.

With today's fertilizer prices, we will be evaluating the cost-benefit of applying sugar beet lime as a soil amendment and nutrient source compared to the cost of lime transportation and application. This information will be shared at the 2022 Cereal School. As previously mentioned, sugar beet lime contains 420 lb P2O5 per ton of lime. Given that sugar beet lime has a pH of 8.5 and high calcium content, it is uncertain how plant available the phosphorus in the lime is. Future

research may evaluate how much sugar beet lime phosphorus is available to the crop and how its availability changes as the lime neutralizes acidic soil.

Publications:
This project will be described at the 2022 Winter Cereal School. We will potentially present information from the incubation study at the 2022 American Society of Agronomy-Crop Science Society of America-Soil Science Society of America annual conference.

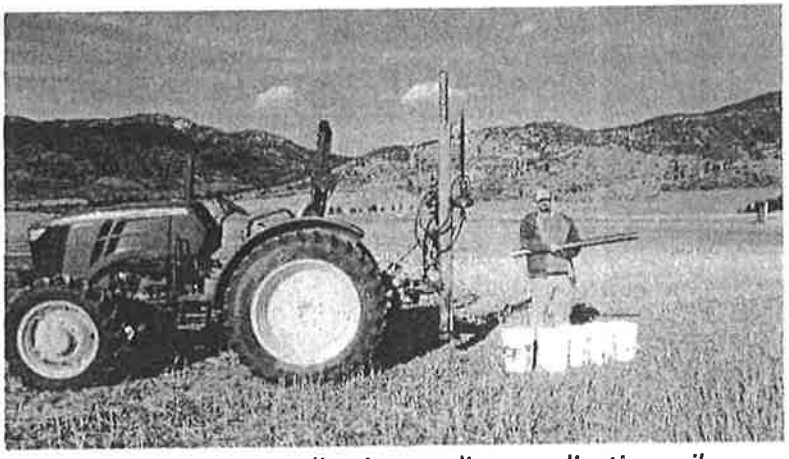

Image 3: Jacob Bevan collecting pre-lime application soil samples at Clark Hamilton's field site in Swan Valley.