WASHINGTON GRAIN COMMISSION
USDA ars Agricultural Research Service
www.ars.usda.gov

Remediation of stratified soil acidity through surface application of lime in no-till cropping systems

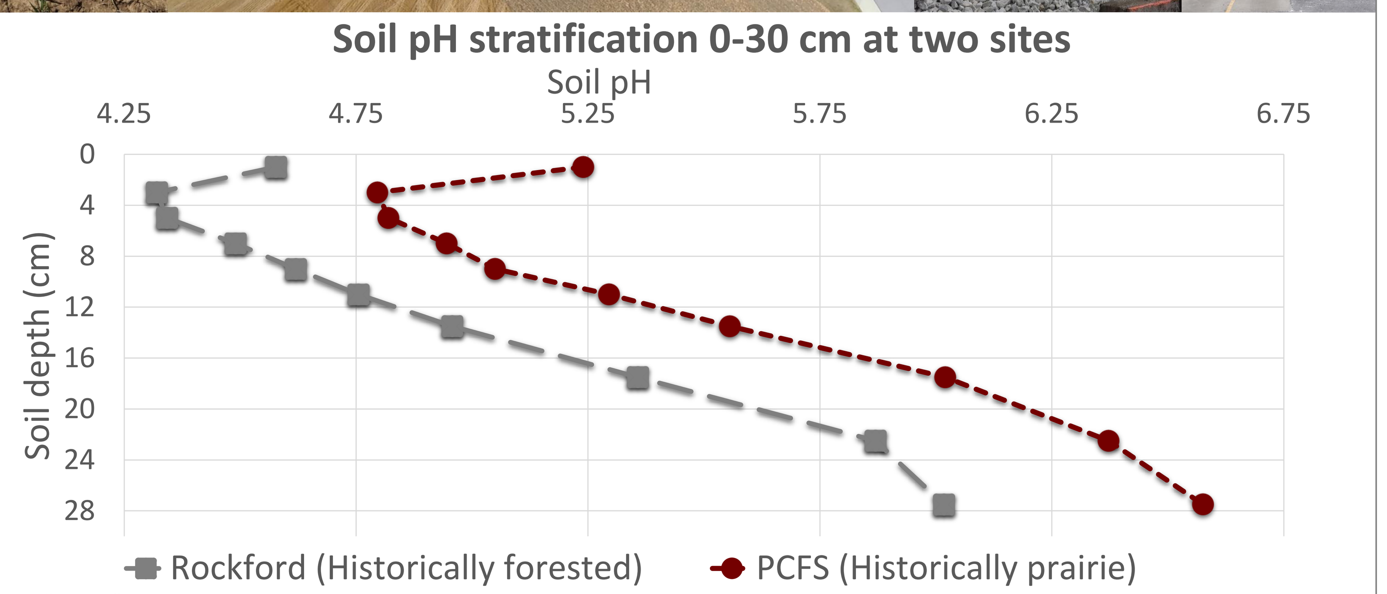
Carol McFarland, David R. Huggins, Kurt L. Schroeder, J. Joey Blackburn, L. Carpenter-Boggs, Rich Koenig, Timothy C. Paulitz

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.
University of Idaho

Introduction:

- Accelerated soil acidification resulting from application of ammonia-based fertilizers has been an issue of increasing concern in the Palouse region of Eastern Washington and Northern Idaho (Mahler et al., 1985)
- Low soil pH reduces crop yield as acidic conditions release phytotoxic levels of aluminum (Al) and manganese (Mn)
- Soils that developed under native prairie have greater base saturation, organic matter and increased buffering capacity to resist pH changes as compared to soils that developed under native forest
- In no-till systems acidification is often concentrated in a stratified band where fertilizer has been placed
- Traditional incorporation of liming materials is not possible for producers wanting to maintain no-till management systems
- Surface application of lime has been shown to remediate stratified acidic conditions (Caires, 2005)
- Recent availability of an ultra-fine (1-2 micron) fluid lime may help growers address stratified soil acidity issues

Objective: **Assess surface application of fluid lime and sugar lime on crop and soil properties in no-till cropping systems with stratified soil pH**

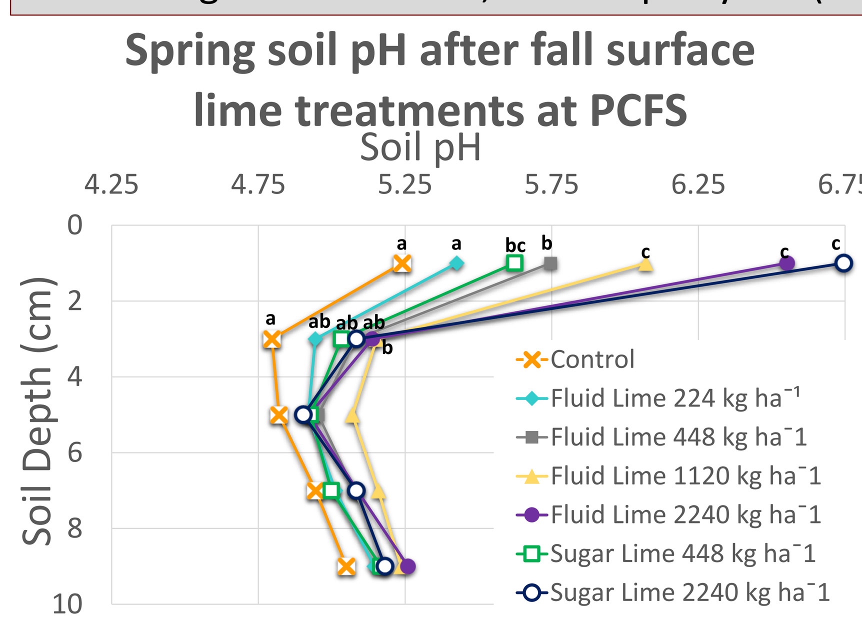


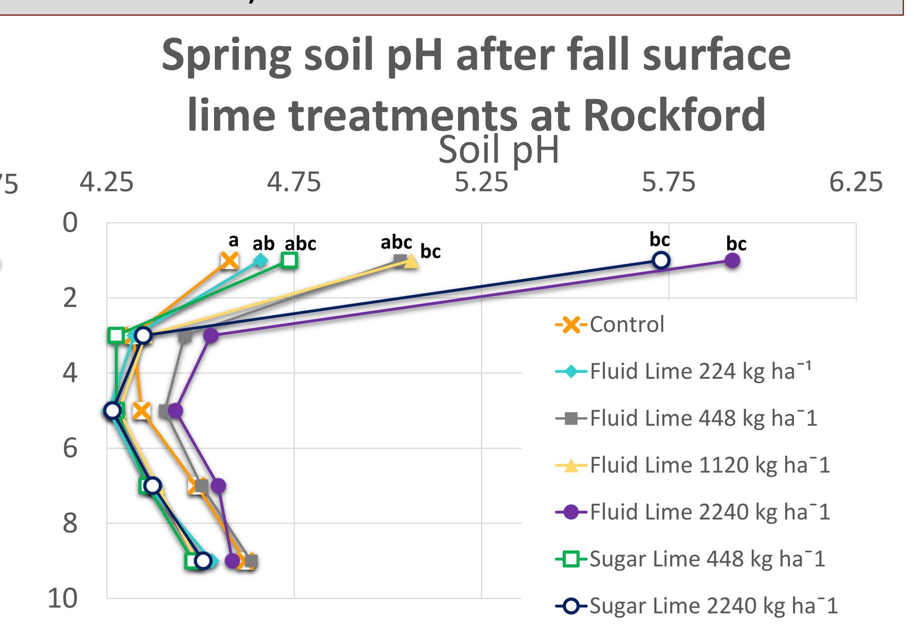
Methods:

- Two sites representative of soils that were historically forested (Rockford) or in native prairie (PCFS) prior to agricultural cultivation
- November 2013 application of two calcium carbonate sources to experimental field plots in a Complete Randomized Block Design
    - Ultra-fine (1-2 micron) particle size fluid lime (NuCal), applied with a sprayer at rates: 224 kg ha^{-1}, 448 kg ha^{-1}, 1120 kg ha^{-1} and 2240 kg ha^{-1} calcium carbonate equivalent
    - Sugar lime – byproduct of sugar beet processing, shaken onto the soil surface at rates: 448 kg ha^{-1} and 2240 kg ha^{-1} calcium carbonate equivalent
- Spring soil sampling from 0-10 cm divided into 2-cm strata
- Above-ground biomass was taken at anthesis stage from each plot by hand with a 1m^2 quadrat
- Chickpea yield was harvested using a plot combine in 1.52m x 9.14m strips
- Soil pH 1:1 water (vanLierop, 1990)
- KCl extractable Al
- DTPA extractable Mn (Gambrell, 1996)
- Plant biomass was dried and ground and sent to a certified laboratory for analysis of Al and Mn
- Statistical analysis was done using SAS 9.3 with Tukey LSD significance of 0.1

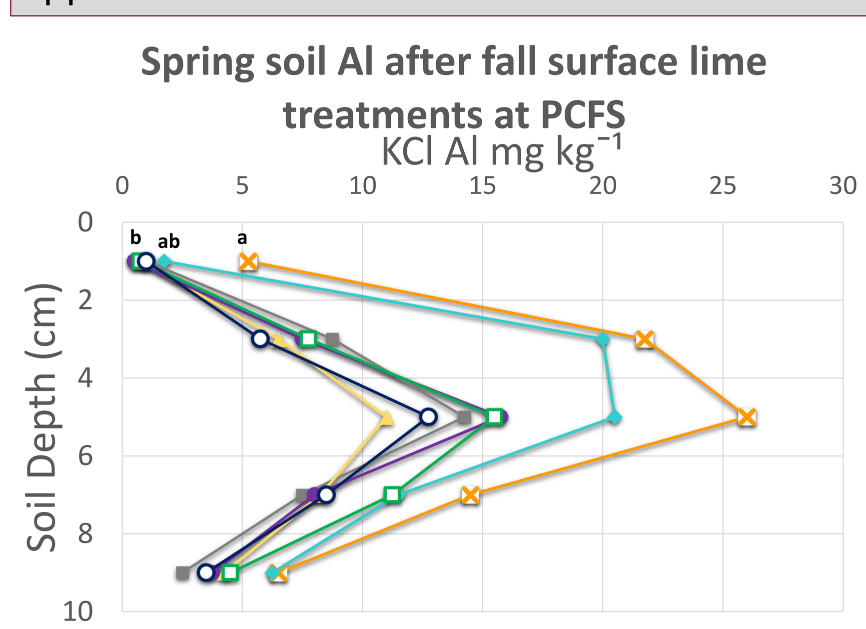
Results:

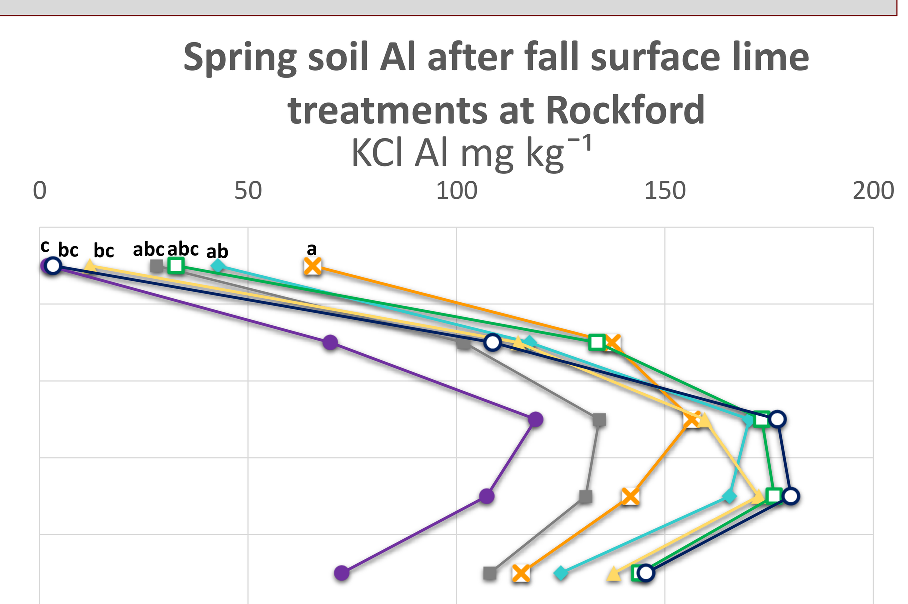
- There was no significant difference between the lime treatments with chickpea or canola above-ground biomass, or chickpea yield (data not shown)



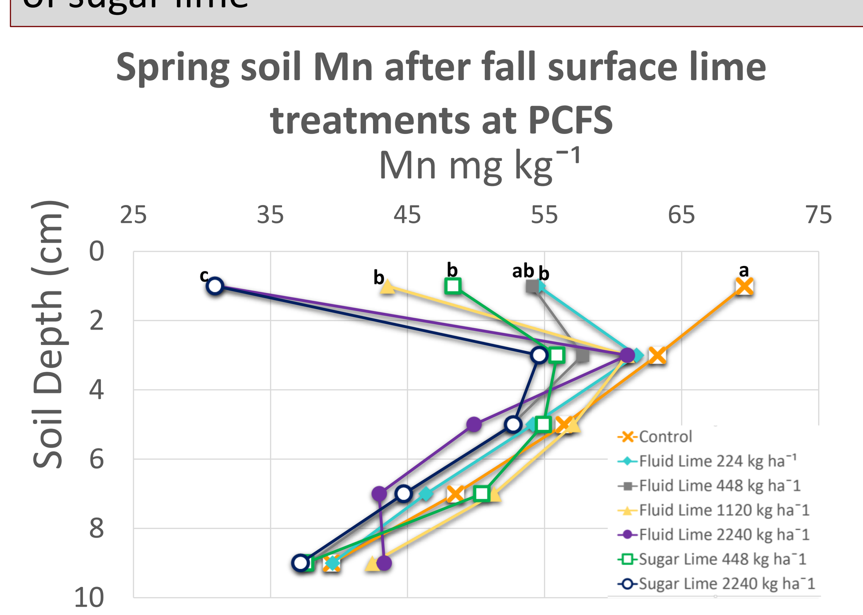


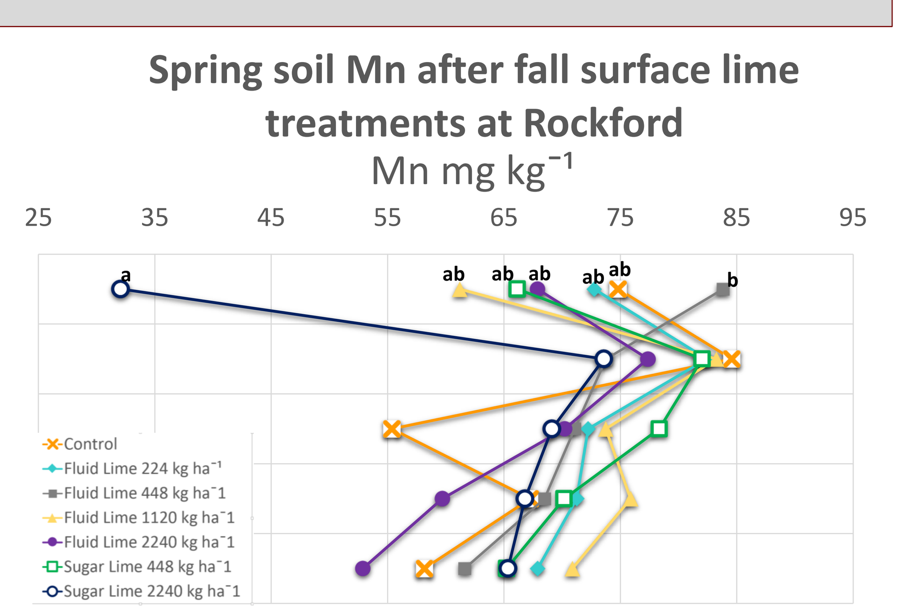
Soil pH at the surface depth of 0-2 cm, increased significantly between the 2240 kg ha^{-1} rate application of both lime sources and the controls





Concentration of soil exchangeable Al at the surface depth (0-2 cm) was reduced significantly between the highest (2240 kg ha^{-1}) and control treatments at both sites. At Rockford we saw a difference between the 224 kg ha^{-1} rate and the 2240 kg ha^{-1} of fluid lime but not the same rate of sugar lime





Concentration of Mn at the surface depth (0-2 cm) was reduced under the 2240 kg ha^{-1} rate of fluid lime at both sites as well as sugar lime at PCFS

References:

Brown, Tabitha T., Richard T. Koenig, David R. Huggins, James B. Harsh, and Richard E. Rossi. "Lime Effects on Soil Acidity, Crop Yield, and Aluminum Chemistry in Direct-Seeded Cropping Systems." *Soil Science Society of America Journal* 72, no. 3 (2008): 634. doi:10.2136/sssaj2007.0061.

Caires, Eduardo F., Luís R. F. Alleoni, Michel A. Cambri, and Gabriel Barth. "Surface Application of Lime for Crop Grain Production Under a No-Till System." *Agronomy Journal* 97, no. 3 (2005): 791. doi:10.2134/agronj2004.0207.

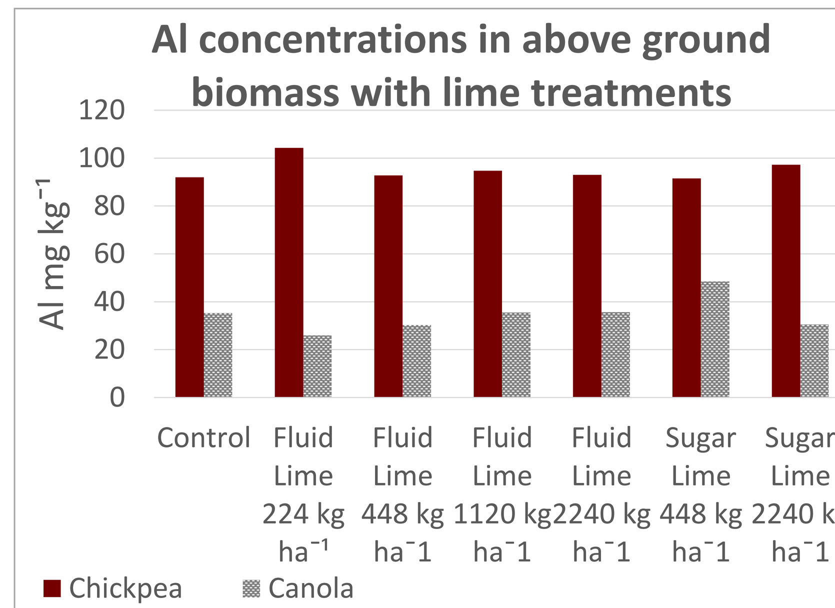
Mahler, R. L., A. R. Halvorson, and F. E. Koehler. "Long-Term Acidification of Farmland in Northern Idaho and Eastern Washington 1." *Communications in Soil Science & Plant Analysis* 16, no. 1 (1985): 83–95.

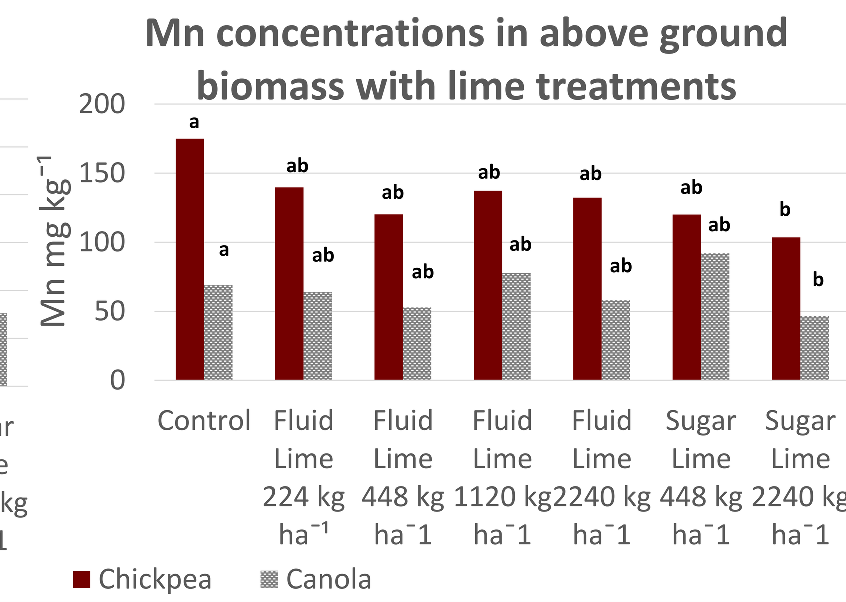
Marschner, Horst. *Marschner's Mineral Nutrition of Higher Plants, Third Edition*. 3 edition. London ; Waltham, MA: Academic Press, 2011.

McBride, Murray B. *Environmental Chemistry of Soils*. New York: Oxford University Press, 1994.

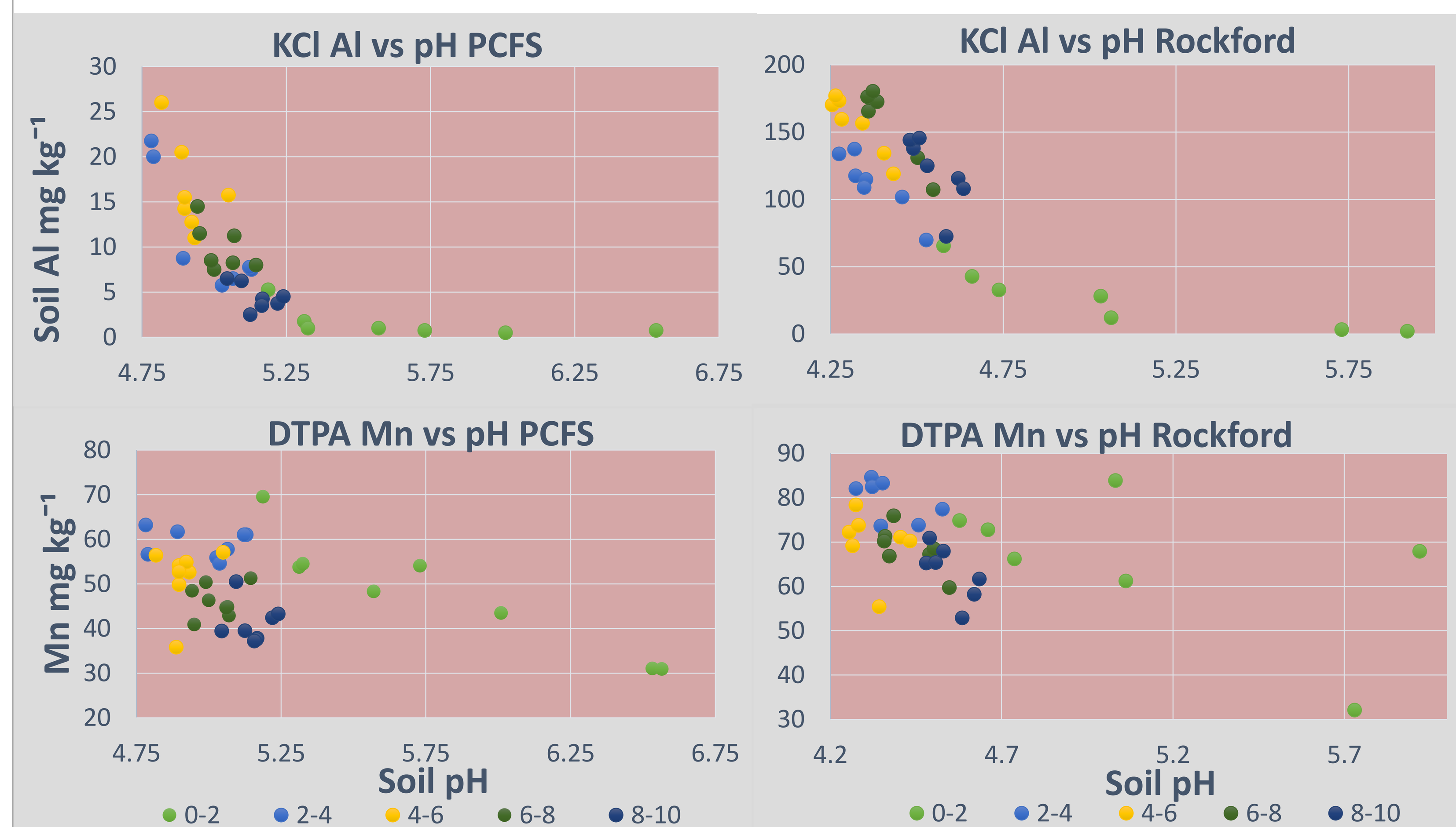
Sparks, Donald L. Soil Science Society of America, American Society of Agronomy, and G.W. Thomas. *Methods of Soil Analysis. Part 3, Chemical Methods*. Madison, Wis: Soil Science Society of America, 1996.

Van Lierop, W. "Chapter 5: Soil pH and Lime Requirement Determination." In *Soil Testing and Plant Analysis*, 73–120. SSSA 3. Madison, Wis: Soil Science Society of America, 1990.





- Plant tissue concentrations of Al showed no significant differences between the treatments
- Plant tissue concentrations of Mn were significantly different between the control and 2240 kg ha^{-1} rate of sugar lime



As pH decreased Mn increased at PCFS and at both sites Al increased exponentially

Discussion:

- Soil pH is an important parameter of soil quality, particularly for nutrient availability and toxicity
    - **Fall lime treatment increased pH in the 0-2 cm soil surface at both sites within six months**
- Availability of Al to the plant can result in phytotoxicity with symptoms such as root-stunting, which limits uptake of water and nutrients
- Aluminum phytotoxicity is dependent on the concentration, species, availability and activity of Al in soil (Brown et al., 2008) and the tolerance of plant species, and varieties which varies widely with a range of adaptive mechanisms
    - At soil pH values under five, Al concentration increased exponentially at both sites
    - **A significant reduction in soil Al was seen at the 0-2 cm depth with lime treatment both sites**
    - The surface applied lime treatments did not significantly decrease levels of Al in plant tissue and in chickpea, concentrations were within the toxic range of 50-200ppm (McBride, 1994)
- Mn is an important co-factor in many plant enzymes with a significant role in the TCA cycle, but in high concentrations it can compete with Ca and Mg and be toxic
- Concentration of Mn in the soil solution is critical to phytotoxicity (Marschner, 2011)
- Plant growth can be inhibited at dry tissue concentrations ranging from 200 mg kg^{-1} to 5300mg kg^{-1} (Marschner, 2011)
    - **Surface application of lime significantly reduced Mn concentrations in both the soil and the plant at both sites**
- Significant differences in crop biomass and yield were not seen during the 2014 season. This may be because of high variability of the data, or Al toxicity was not inhibiting plant growth. Al may not be present at sufficient levels or species to cause toxicity. Alternatively, it may be chelated by high levels of organic matter present in no-till systems (Brown et al., 2008). It is also likely that the effects of lime surface applications have not yet reached the critical root zone

Acknowledgements:

Funded by the Washington Grain Commission. Thanks to the Huggins lab crew for technical support!