Importance of Liming in Dry Land Palouse Cropping Systems

Fluid lime (NuCal) shows benefits in Palouse studies.

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***Summary:** Results of the 2016 fluidized calcium carbonate studies on spring wheat (club wheat) in Washington suggest that a limited but precise application of micronized calcium carbonate lime into the low pH soil strata can positively affect root development to overcome low soil pH stratification in no-till systems.*

In the North West of the United States, mainly Washington, Oregon, Idaho, Montana, but also the Canadian Provinces of Alberta and Saskatchewan (Figure 1), drought tolerant crops generate a substantial economic impact (Table 1). One major production area of that region is the dryland Palouse (WA, OR, ID) and is the focus of our current liming studies. Many of the soils here are young, developed from widespread loess deposits from windblown glacial dust some 10,000 years ago.

The soil pH in the inland Northwest (Figure 2) has declined in direct proportion to the cumulative amount of applied fertilizer ammonium N. Nitrification of ammonium N from any source, commercial fertilizers, legumes, manure, gradually make soils more acid. Wheat can generally tolerate pH down to about 5.4, but legumes such as peas, lentils, or clover need a pH greater than 5.6 (Figure 3). Liming in this region still is not considered economical using conventional liming materials and application methods, but the subtle side effects of a lower pH, such as increased disease, soil aggregation and weed problems, may already cost more than is now realized. Native soil pH in much of the Inland Northwest, including the Palouse, is pH 7 (neutral).

At such high pH aluminum is tightly bound to soil clay particles. However, at pH below 5.5 (more acidic), some aluminum (and possibly manganese and iron) becomes plant available (exchangeable) and may be toxic to plant roots, reducing uptake of water and nutrients. This is a well studied effect. During the past many decades, farm management strategies of the inland Northwest included increased fertilizer use and new acid tolerant wheat varieties as a result of lower soil pH.

While the use of lime to counteract acidity in high-input agriculture over the past 50 to 100 years has led to spectacular increase in yields (Rengel Handbook of Soil Acidity, 2003), dry-land farmers of the inland NW have never or very rarely considered the concept of liming fields. The Palouse cropping systems instead relied on wheat varieties and emerging breeding lines that are tolerant to aluminum toxicity (Kurt Schroeder, Mike Pumphrey 2013). This unfortunately is only a short term solution.

Liming studies on aluminum tolerant varieties resulted in increased yields (up to 46 percent) compared to acid sensitive varieties. However, the high quantity of regularly available standard lime that was required in these initial pilot studies was deemed not economically feasible.

The role of lime. There are several options to overcome soil acidity in the dry land regions. As an alternative to broadcast applications of large amounts of standard agricultural lime, pilot studies were initiated in 2011 examining in-furrow applications of prilled lime ($CaCO_3$) with seed at planting at a rate of 150 lbs/A. An average gain of 3.3 bu/A was seen across all varieties (Wheat Life, January 2013). Lime applications, however, remain a rare event and growers are skeptical about effectiveness, experience application difficulties, incur problems in lime sourcing, and, of course, expect to see an additional work load, time, and equipment need, which all can lead to an unknown return on investment.

Sound agronomy practices focus first on pH. The pH management is one of the most important factors for crop production. While it always seems to be overshadowed by the management of the macro-nutrients N, P, and K, the reality is that an improper pH has a major impact on soils and crops.

Low pH is one of the more difficult soil conditions to fix within a short time frame. Growers are conditioned to fast results such as response to efficient N fertilizer application (Figure 4) Results from standard liming are unpredictable and low in performance. Micronized fluid and pelleted limes can work within a short time frame compared to standard lime sources. Agronomic practices (no-till, direct seed), topography of the region (steep slopes), and large quantities of standard lime required (adding cost of freight and material handling) limit growers' acceptance of regular liming practices.

The ideal solution for managing soil

acidity and associated aluminum toxicity may be to plant a tolerant crop or wheat variety but also integrate an effective liming program in regular farming practices (see also Kurt Schroeder and Mike Pumphrey 2013). Liming benefits include:

- Increased soil pH and reduction of available toxic cations: Mn++, Al+++, Fe+++
- Increase in exchangeable Ca++ and Mg++
- Binding of heavy metals
- Improved soil structure
- Improved nutrient availability
- Decrease of susceptibility of moisture stress
- Higher soil biological activity
- More effective herbicide action

Our goal. Soil surface liming using highly reactive lime sources such as fluid and palletized micronized limes at sufficient rates to overcome soil acidity are the most effective method. However, the recommended rates as identified through standard soil analytical laboratories are not economical in inland Northwest farming systems where the return on investment (adding additional cost) can be negative (especially in the current grain market of 2017),

The greatest effectiveness, affordability and acceptance, we believe, will be found in alternative lime application methods. This includes precision placement of micronized fluid lime with the seed in the soil in direct seed, no-till operations, concentrated actions in soil microenvironments to neutralize the acidity produced by annual fertilizer applications and overcoming acid soils stratification (Figure 5).

It is our intent to introduce and establish such farming techniques to incorporate lime every year as a preventive measure and as a strategic system to gradually overcome acidity while improving soil health and crop yields in the dry land regions.

Sampling of specific soil strata may identify where acidity problems and lime needs are concentrated (0 to 3 inch, 3 to 6 inch and 6 to 12 inch).

Soil pH below 5.5 (particularly in the seed zone) impacts all of the associated limiting factors as well as aluminum toxicity. Examining the plant for short stubby and twisted roots further verifies aluminum toxicity. The toxicity of exchangeable aluminum varies greatly between soil types, organic matter content cationic exchange capacity and other factors. Plant tissue Al concentration greater than 200 ppm likely indicates a problem. Soil concentrations over 60 ppm clearly indicate Al toxicity.

The study. The goal for the study of precision application of NuCal fluid lime was:

- Determine if chosen equipment setup for fluid lime application in the seed row is an effective delivery method
- Determine if application of micronized fluid lime injected in the seed germination layer supports plant development to better push through the acidified soil strata
- Determine if this effort has any yield impact.

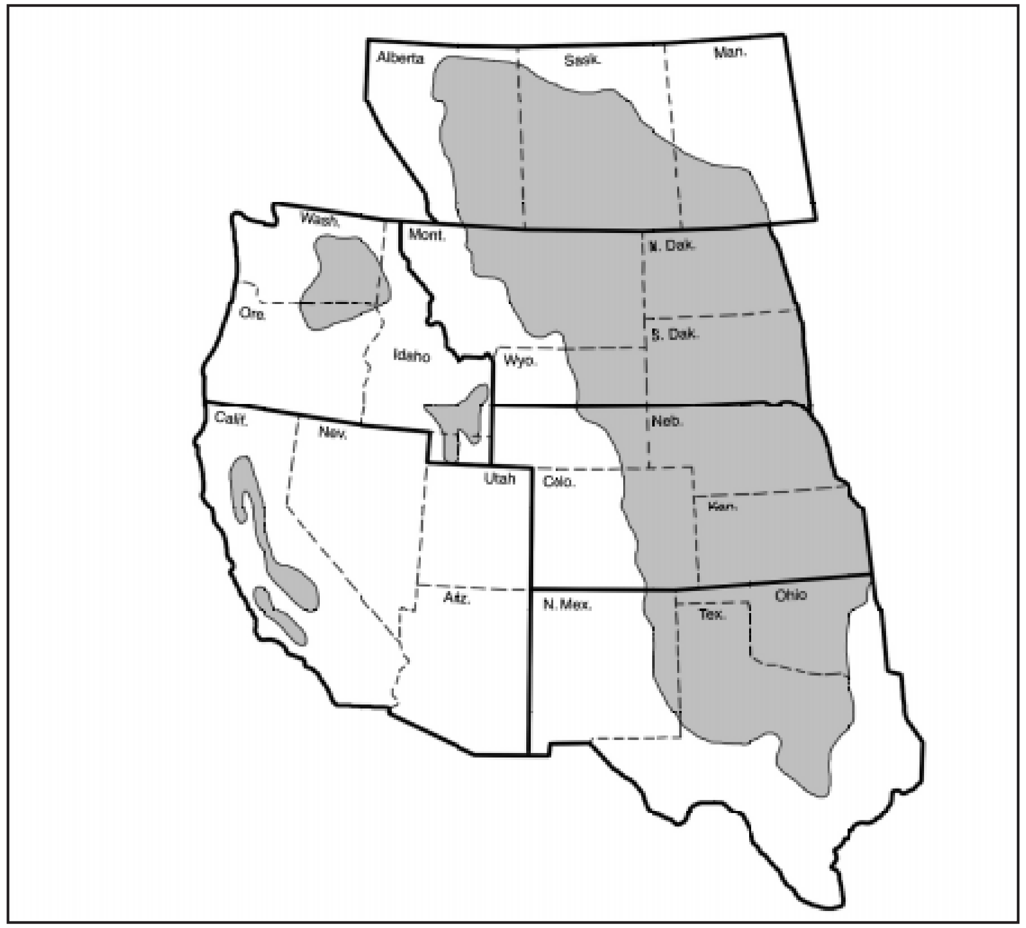

Figure 1. Major dryland farming areas of the United States and Canada. Source: Dregne and Willis, 1983.

Table 1. Wheat Acreage and Average Yields in the Northwest, 1987-1989. Includes irrigated Acreage.

State	Planted Area (1000 ac)	Average Yield (bu/ac)
Montana	5322	25.2
Washington	2457	55.3
Idaho	1297	69.1
Oregon	865	64.1
Wyoming	268	25.4
Utah	195	38.9

Source: USDA, 1990

Methodology

Design. Chuck Schmidt, owner of Schmidt Farms LLC, Rosalia, Washington, is one of the first adaptors using micronized fluid lime NuCal in broadcast spray and precision application--directly with the drill--in the inland Northwest. An experiment was conducted in Spring Wheat, club wheat variety, (Figure 6).

Application. NuCal fluid lime, a micronized fluid calcium carbonate manufactured by Columbia River Carbonates and branded, marketed, and sold by Helena Chemical Company was sourced from Helena's Pullman, WA agronomy location.

Application rate was calculated at 10 gallons/acre banded (equals 70 gallons broadcast) directly into the seed row using a HORSCH--Anderson No-Till precision drill. The Anderson Industries RAZOR point was used with NuCal fluid lime application system designed by Chuck Schmidt. The metering pump selected was a diaphragm 12V (Table 2).

Each drill shank of the 50 foot drill was equipped with separate tubing for fertilizer and a portion of the drill was equipped to deliver fluid lime:

- Two lines for starter fertilizer P and K
- Two lines for NuCal fluid lime, very close to the seed
- One line for N fertilizer
- Two large openings per row for seeds

Note: NuCal fluid lime is a reactive, effective fluid liming material with high impact on cropping systems. t is safe for direct seed contact, but will not mix with most fertilizers. Jar-tests will confirm compatibility. Fluid lime flow was controlled through orifices seated directly at the manifold connection. Product flow of fluid lime suspension was assured by eliminating air space in lines and water flushing after every use and refill to prevent drying an plugging. P and K starter fertilizer was applied in two tubes for each opener, two tubes of lime per opener and one separate tube for N fertilizer. Application tubing was air brake tubing normally used for highway trucks. These allowed for increasing flow using up to 40 psi and flow was then regulated by the size of the orifices. More pressure equals more volume. Also, the small tube diameter is helpful in reducing air space in the lines, which can cause NuCal to dry and potentially create particles that can plug the system. Cleaning with water is improved using small lines, which are quickly purged.

Calculation of NuCal fluid lime material needed per banded row is shown in Table 3.

Harvest. A Wintersteiger plot combine and Harvest Master weighting system was contracted from Kootenai Valley Farm and Research LLC, Hubbard Ag Science, Bonners Ferry, ID (Scott Cook). Three passes in the middle of each control (untreated) and treated plot were harvested and yields calculated (Figure 7). Field yield increase ranged from 3 to 14 bu/acre and averaged 7 bu/acre on

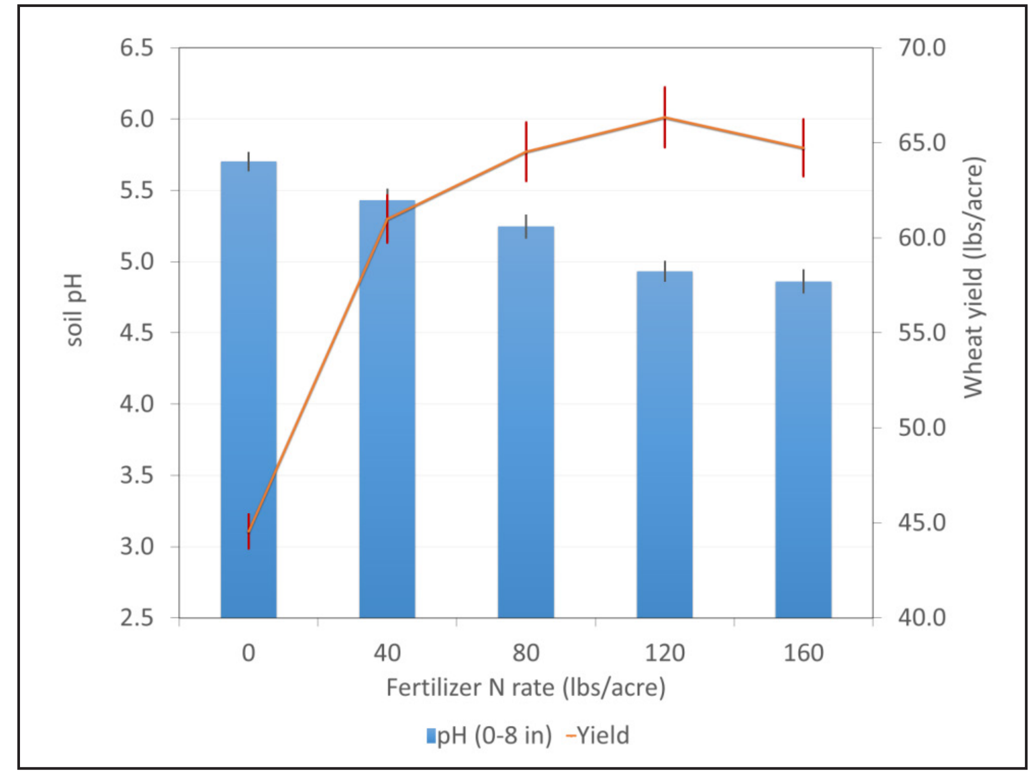

Figure 2. Effect of low soil pH on wheat grain yield in a winter wheat-summer fallow long-term experiment at the Columbia Basin Agricultural Research Center (1940-2010), (from Research Proposal for the Agricultural Research Foundation Oregon Wheat Commission). Title: Effect of Liming Acid Soils on Fertilizer-Use-Efficiency, Wheat Productivity, and Profitability, 2016.

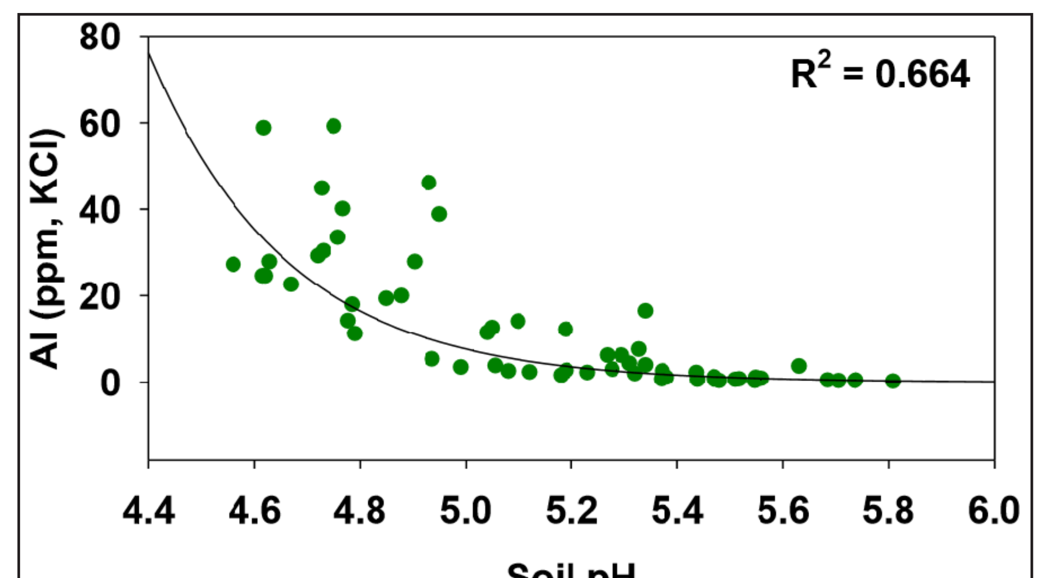

Figure 3. Liming the Inland Pacific Northwest, Kurtis L. Schroeder, University of Idaho, 2016.

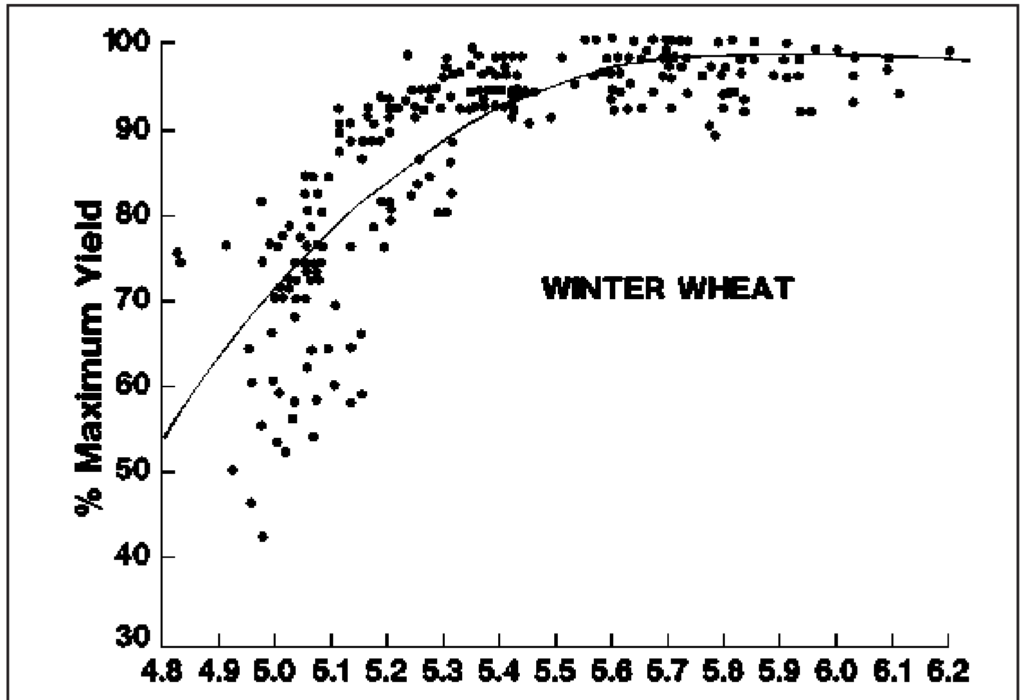

Figure 4. **Soil pH**

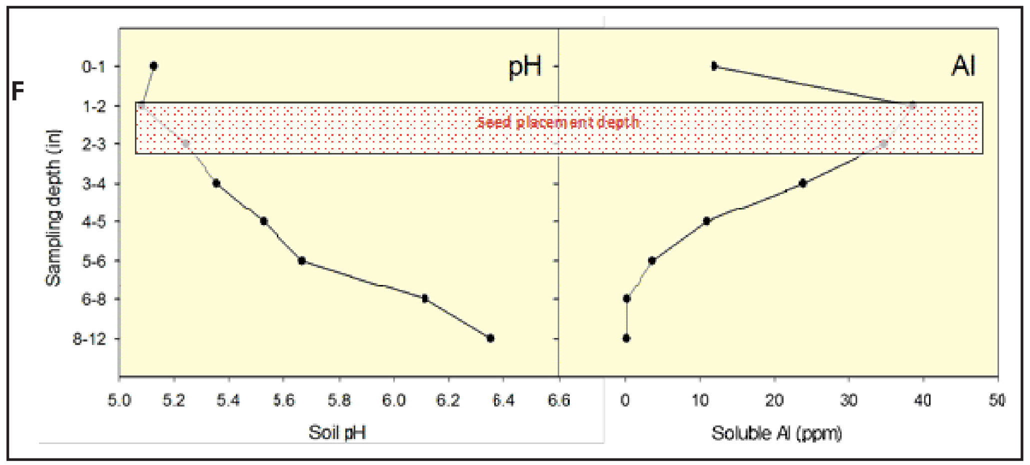

Figure 5. Soil pH stratification after long term surface nitrogen application. Aluminum concentration in solution increases with a decrease in soil pH. Ruiz Diaz 2016.

Figure 6.

Table 2. NuCal liquid lime flow is controlled through orifices seated directly at the manifold connection. Product flow of liquid lime suspension is assured by eliminating air space and water flushing after every use and refill to prevent plugging and drying.

Drill Set-up	US
Opener spacing	7"
Tubing OD	1/8" (3.2 mm)
Tubing ID / bore	2 mm
Tubing type	Air brake tubes
Tubing length	6 feet and longer
Pressure	22 - 30 psi (< 40psi)
Dilution	no water added
Agitation	by-pass
Pump Type	Diaphragm, 12 V
Shut down	water purge
Gal/acre	10 gal/acre
Speed	5 miles/hr

these large plots.

Observations

Most soils contain aluminum in a variety of forms. Fortunately, most of the aluminum is bound and found in non-toxic forms such as aluminosilicates. However, as solubility of aluminum is enhanced by low soil pH, exchangeable aluminum increase and aluminum toxicity becomes a major factor restraining plant growth and root development. Effects vary with crop species and varieties. Seed layer soil stratification of acidity in no-till systems can and does limit root development and growth. Seed placement of lime as used in this study is an effective means of addressing that problem. However, evidence demonstrates that traditional coarse particle dry lime surface applied at recommended rates is not effective or profitable in inland Northwest dry land systems. Dry lime is slow to react and application is cumbersome and inefficient. Much of what you pay for is "gone with the wind"!

The traditional broadcast application of liming material may be necessary to remedy pH overall, however the economics are challenging.Traditional dry lime methods require an investment of both time and money but the payback is often in the distant future. Nonetheless, lime application is a capital investment with longer term benefits in crop yields.

The collaboration and efforts of equipment expert and grower Chuck

S - Spacing between openers	7	"
T - Application width (treated)	1	"
U - Untreated area	6	"
A - Acres	1	acre
M - Material broad cast per acre	70	gallon/acre
B – Material per acre banded	10	gallon
T ÷ (T + U) x A x M = B		**Table 3**

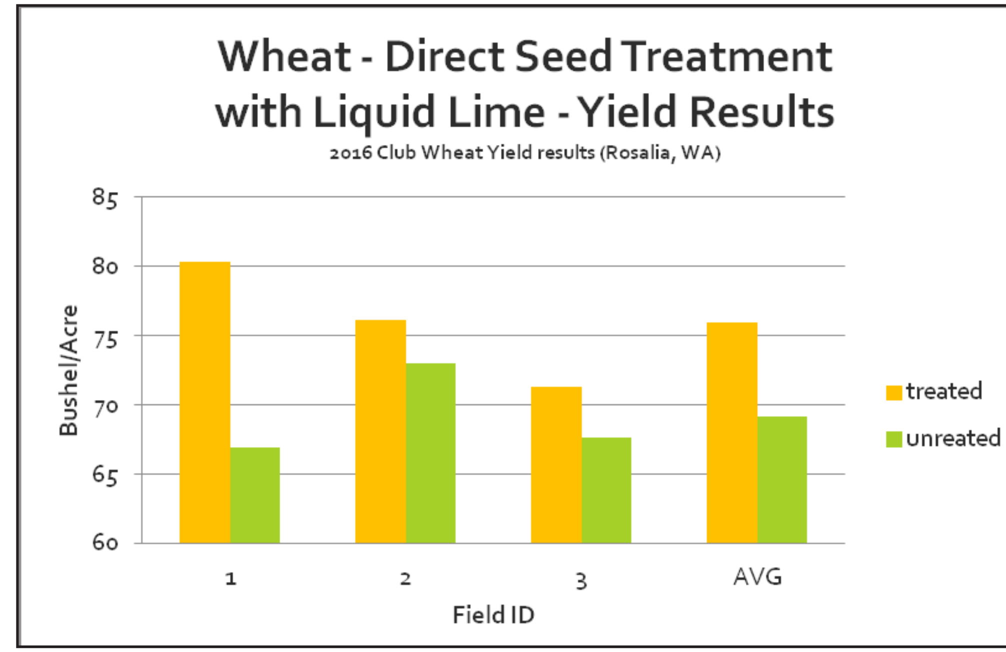

Figure 7.

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Schmidt, the field staff of Helena Chemical and the producer of NuCal micronized lime demonstrated an agronomically sound way to increase financial gains using the precise application of fluid lime. This was achieved at significantly reduced application rates in wheat production compared to standard liming practices. In fact, through extensive field testing of micronized fluid lime, when properly and strategically applied to inland Northwest wheat soils, has proven to be a very economical and effective method of long term pH management. The result is a positive and annual return on investment. The best part is that the application process is easy, efficient and virtually waste free. In fact, all of the lime that you pay for goes exactly where you want it: into the soil that will feed plants and maximize your crop yield now, not in the unknown future.

The ability to integrate precision application methods using NuCal micronized fluid lime in the described manner allows a level of control most of us never thought possible. We challenge wheat growers to take steps now that will enhance pH immediately and increase profits by using NuCal.

Summing up

The final results of the test suggest that a precise application rate of micronized calcium carbonate lime into the low pH soil strata can also positively affect yield. A positive ROI was possible, even in an otherwise very soft wheat market.

At a club wheat price of $5 per bushel x a 6.8 bushel crop increase per acre and a treatment cost of $25 per acre, the return on investment was 36 percent.