AMENDING ACIDIC SOILS FOR SUSTAINABLE WHEAT PRODUCTION

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ABSTRACT

Soils in the Inland Pacific Northwest region have been gradually declining in quality as the result of applications of nitrogen fertilizers, regardless of the nitrogen form. Soil test reports evaluated in the 1980's and 90's indicated this decline. Recent surveys have provided more extensive data that the pH decline is continuing. Soil test reports indicate that nearly 90% of soils have declined to below 5.2 pH (strong to very strongly acid) in the surface layer of the soil profile. As a result of the recent survey, research plots (minimum tillage) were established with lime ($CaCO_3$) treatments to raise the soil pH. Lab reports indicated nutrient deficiencies of Copper (Cu), Zinc (Zn), and Boron (B) which were supplemented. Farmer fields in the region, where micro-nutrients are normally applied, have shown rapid response to liming; soils lacking micro-nutrients were less responsive. Lime was applied in the spring (Plot "T") and fall (Plot "P") of 2014 with micro-nutrients applied in the fall of 2015. Plot P was seeded with soft white winter wheat in fall 2015 and Plot T was seeded with soft white spring wheat in spring 2016. Plots were harvested August 23, 2016. Plot P and T both recorded yield increases, 6.8 and 11.98 bu/ac respectively, for strips treated with lime and nutrients compared to un-treated strips.

INTRODUCTION

Soils in the Inland Pacific Northwest are rich, forgiving, and young having been farmed only in the recent 150 years, approximately. Most soils were near neutral pH and bountiful in nutrients with a few exceptions. This region has some of the steepest terrain for cropped soils in the world often exceeding 40-50% slopes, Figure 1, and result in difficult conditions to do ordinary cropping practices. Due to the steepness, erosion has taken its toll over the years of plowing and summer fallow leaving the soil exposed to rain and wind much of the time.

Nitrogen (N) fertilizers were introduced in the 1940's to increase wheat production. Only small amounts of N were applied in the beginning, 5 to 10 pounds/acre. As producers learned how to increase production, more N was applied to where current rates may exceed 50-150 pounds per acre.

Nitrogen, being one of the primary factors acidifying the soil, started to reduce the soil pH and over time has created an acidic layer in the surface of the soil approximately equal to the plow layer. Dr. Mahler (1985) captured soil test reports in an effort to understand the effect on soil pH by the N over the years. He observed that many of the soils had become strongly acidic as a result. Continuing to look at the effects, Mahler (1994) followed with additional studies in the 1990's finding that the pH was continuing to decline and looked at different liming materials to be used for correcting the problem.

While liming is a standard practice in many parts of the world, it is a relatively new idea for the Inland Pacific Northwest. There are some specific areas where liming is practiced but for most of the dryland wheat producing areas it is not considered as part of the nutrient management and cropping systems strategy. Some of the lack of acceptance relates back to an available ready supply of lime that is economical to apply while an additional component is the lack of industry and scientific community support for a balance nutrient management plan. An additional barrier has been the steep terrain and the capability of equipment.

Figure 1. Farmed areas in and around the Inland Pacific Northwest Palouse region with long and steep slopes sometimes exceeding 50%.

Recent investigations in Columbia County Washington provided additional confirmation of continued soil pH decline. Paul Carter, WSU Extension Specialist, conducted a survey sponsored by the Columbia Conservation District in an effort to determine the county soil health status. The survey included two years of soil sampling data collection, 2013 and 2014, on farm fields. The resulting data showed that farm fields had reached strongly acidic levels (90% <5.2 pH in the plow layer).

A research team was identified and a plan was developed to study the soil acidity problem. A grant proposal to the USA Dry Pea and Lentil Council was to study the application of ultra-micronized liquid lime ($CaCO_3$) provided by Columbia River Carbonates and observe the soil pH changes combined and yield responses. The grant was planned for up to three years. The plot would have ten varieties of both spring dry pea and spring chickpea to see if there would be a lime by variety response. Plots would be soil sampled to observe changes in pH values during the experimental time frame. Unfortunately, the grant was not renewed after the initial year. Without the grant funding the research plan changed, other funds were secured from various sources, and observations continued on a reduced level.

MATERIALS AND METHODS

Three farmer fields were identified for the project, two in Columbia County (direct seeded or conservation tillage cropping systems) and one in Walla Walla County (basically no-till system). Soils were all silt loam with rainfall ranging from 14 to 18 inches/year. Soil samples were collected in layers (0-3, 3-6, 6-9, 9-12, and 12-24 inches) in an effort to identify stratified acidic conditions, Figure 2.

Figure 2. Soil sample probe soil cores are divided into sample layers for analysis.

Research funded by the USA Dry Pea and Lentil Council included three farm field plots locations in Columbia and Walla Walla Counties. A plot map of the project plan (Figure 3) showed the included strips of 2,000 pounds/acre of ultra-micronized liquid $CaCO_3$ treatments (10 feet wide x 100 feet long) randomized with control plots in an area of 200 feet by 100 feet. Application was completed with the use of an ultra terrain vehicle (UTV) configured with a small holding tank, portable centrifugal pump, and one spray nozzle, Figure 4. No tillage was conducted immediately following the lime application.

Figure 3. Map of the lime treatment plot strips and micro-nutrients application area.

no added nutrients	Border	1B-	2W-	3W-	4B-	5W-	6B-	7B-	8W-	Border	Border	9W-	10B-	11W-	12B-	13W-	14B-	15W-	16B-	Border
Cu, Zn, and B nutrients added	Border	1B+	2W+	3W+	4B+	5W+	6B+	7B+	8W+	Border	Border	9W+	10B+	11W+	12B+	13W+	14B+	15W+	16B+	Border
		1 no lime	2 lime	3 lime	4 no lime	5 lime	6 no lime	7 no lime	8 lime			9 lime	10 no lime	11 lime	12 no lime	13 lime	14 no lime	15 lime	16 no lime	

Figure 4. Lime application vehicle (ultra terrain vehicle) configured with a small holding tank, portable centrifugal pump, and one spray nozzle (Boom Buster nozzle 375).

Without the support of the original grant, continued support funding was needed and secured through companies and groups including Columbia River Carbonates, ProGene Plant Research, Columbia County Wheat Growers Association, and Best Test Analytics Service; companies that had participated in the original grant or showed interest in continuing observations. The supporting funds provided for continued soil sampling data and harvest results. Following the 2015 harvest year, additional treatments of trace nutrients (included Copper (Cu), Zinc (Zn), and Boron (B)) were added based on soil test results. The recommended nutrients and rates (Table 1) were applied as a liquid on the surface in September 2015 prior to seeding winter wheat (Plot P) and before spring wheat seeding (Plot T). No tillage was conducted following the nutrient application. Soil samples were collected and analyzed in the spring following the fall nutrient applications.

Table 1. Micro-nutrients applied to lime treatment strips in September 2015 before seeding. Soil samples were collected in the spring following nutrient application.

Micro-nutrients Applied

- Nutrients were evaluated using the soil test reports to determine the rate needed
- Date Applied: September 15, 2015
- Nutrients Applied:
    - Zinc 1.13 #/acre
    - Copper 0.788 #/acre
    - Boron 1.1 #/acre
    - Potassium 21.5 #/acre
    - Chloride 16 #/acre
    - Nitrogen 1.2 #/acre
- Potassium Chloride (KCL) was used as the carrier for the other nutrients

Normal farmer field activities were conducted throughout the cropping cycle. The farmers conducted tillage, fertilizer and chemical applications, and seeded the plots at the same time as the rest of the field with seed rows running perpendicular to the treatment strips. Harvest was completed after farmers had harvested the area around the plots. The harvest plan included using a plot combine (five foot cut header) harvesting a five-foot strip from the middle of the 10-foot wide lime and control treatment strips. Sample areas were 5 feet wide by 50 feet long (Figure 5). Plot strips were flagged all season for identification of treatments and management. Bags of grain were weighed on-site with a digital platform scale. Samples for grain tissue and quality analysis were collected from plot numbers 3 & 4, 9 & 10, and 14 & 15 (data not included).

Figure 5. Image of the plot harvest for the spring wheat Plot T where the harvest was from the middle of the lime application and control strips. Treatment strips were marked with colored wire flags for identification and management.

RESULTS AND DISCUSSION

Soil sample results were consistently low in all sample areas with the 0-3 and 3-6 inch layers being the lowest pH values. This is typically the area where nitrogen fertilizers are injected prior to seeding.

The result of the soil samples project indicated severe stratified soil acidity layers (90% of fields < 5.2 pH) in the plow layer of the soil profile. It has been often assumed that the more severe soil pH areas are the result of higher rainfall, previously forested soils (less buffering capacity), and no-till cropping systems. However, the resulting data collected did not correlate with any of previous assumptions. Low rainfall areas were the same values as the higher rainfall. No-till cropping systems were no lower than minimum or conservation tillage systems. The zone of acidity was most likely linked to the depth of N injection over the years combined erosion.

Plot T was established first and the lime was applied in April 2014 prior to seeding or spring dry pea and chickpea varieties. Results from both crop years (2014 spring pea and chickpea and 2015 winter wheat) did not produce any significant lime treatment benefits. The summers were very dry both years and the deer and voles enjoyed the green plants and seed-pods. It was noticed that the deer showed a preference for certain varieties of chickpeas, probably related to the plan tannins.

Plot P was not established until the fall of 2014 and the lime was applied at that time. This plot included fall seeded dry pea varieties, spring dry pea, and spring chickpea varieties. Some varieties of the fall-seeded peas did not winter well and had significant winter damage. These plot harvest results did not produce any significant yield differences.

Plots were soil sampled in the spring of 2015. The soil pH results, Table 2, showed the changes that occurred between the treated and un-treated strips. The major observed changes occurred in the 0-3 inch layer with treated strips ranging from 6.00 to 6.76 and the untreated checks ranging from 4.81 to 5.90.

The soil pH variability across and within all the plots for the 3-6 inch layer ranged from 4.40 to 4.90. Separating the treated versus the un-treated showed treated strips ranged from 4.40 to 4.90 while the untreated layer ranged from 4.40 to 4.80 (Table 2).

Table 2. Soil sample pH test results from samples collected after treatments were applied to the plots. The "B" strips were untreated while the "W" strips were treated with 2000 lbs./acre of NuCal ultra-micronized liquid lime.

Plot "T"	Soil Sample pH Values 11 Months After Lime Treatment															
sample layer	1B	2W	3W	4B	5W	6B	7B	8W	9W	10B	11W	12B	13W	14B	15W	16B
`0-3	4.81	6.62	6.38	4.97	6.29	5.33	5.40	6.76	6.76	5.11	6.00	5.08	6.46	5.04	6.41	4.95
`3-6	4.52	4.79	4.72	4.67	4.71	4.66	4.71	4.81	4.65	4.51	4.48	4.65	4.45	4.45	4.54	4.63
`6-12	5.77	5.94	5.95	5.81	5.69	5.80	5.86	5.80	5.62	5.56	5.53	5.75	5.46	5.44	5.55	5.56
Plot "P"	Soil Sample pH Values 8 Months After Lime Treatment															
Sample Layers	1B	2W	3W	4B	5W	6B	7B	8W	9W	10B	11W	12B	13W	14B	15W	16B
`0-3	4.90	6.10	6.70	5.20	6.70	5.00	5.90	6.40	6.50	5.30	6.20	5.40	6.70	5.30	6.60	5.10
`3-6	4.40	4.40	4.70	4.50	4.60	4.50	4.60	4.80	4.70	4.70	4.80	4.80	4.90	4.70	4.80	4.70
`6-12	5.70	5.60	5.50	5.40	5.50	5.60	5.60	5.60	5.80	5.90	5.70	5.70	5.80	5.60	5.70	5.70

The inconclusive harvest results created a lot of questions. As the results were pondered, it had been observed that applications of lime for some farmers were seeing yield results while others were not, just as our plots had provided. Why did some farmer lime treatments produce increased yields while the others did not? A common theme developed; the ones with positive yield increases applied micro-nutrients based on soil test results and the others did not.

Based on this insight it was decided to review the soil sample results see what micro-nutrients needed to be applied to balance the needs of the plants. Table 1 provides the resulting application decision. Soil samples collected from the plots the following spring provided solid evidence (data not shown) that the nutrients that had been applied would be available for plant uptake. There were no observational differences of the plants during the growing season.

The Plots T and P were harvested on August 23 2016 and the results produced significant yield increases of 15 and 7%, respectively, on the two locations (Table 3). Grain samples have been submitted for tissue and quality analysis.

Table 3. Plot T soft white spring wheat and Plot P soft white winter wheat yield results. Harvest results produced significant yield increases of 7 and 15% on the two locations of Plot T and Plot P respectively.

Plot "T"				Plot "P"			
2016 Lime/Micro-nutrients Trial - Spring Wheat				2016 Lime/Micro-nutrients Trial - Winter Wheat			
no lime no nutrients	no lime with nutrients	lime w/o nutrients	lime with nutrients	no lime no nutrients	no lime with nutrients	lime w/o nutrients	lime with nutrients
64.7 bu/ac	75.5 bu/ac	68.0 bu/ac	76.6 bu/ac	94.0 bu/ac	99.1 bu/ac	94.1 bu/ac	100.2 bu/ac

SUMMARY

Based on the results from this study, the conclusion could be drawn that it takes some time for the lime to react and release nutrients that are bound, soil nutrients need to be in adequate supply and balanced to produce increased crop yields, and wildlife can cause research plots severe damage minimizing the value of any results.

The spring wheat produced the largest yield response. This could be because spring wheat roots shallower and might benefit more from the added nutrients where as the winter wheat roots somewhat deeper and may have accessed available nutrients from deeper in the soil profile. Continued studies are needed to see if this was an anomaly or if it might be consistent.

Soil pH is considered the "Master Variable" and should be considered when performing any plot studies. The acidity of the soil can impact plant diseases (Murray and Walter, 1991; Paulitz and Schroeder, 2016), herbicide effectiveness and carryover (Raeder et al., 2016), soil properties, water infiltration, and shifts in weeds due to an acidity preference (Gazey and Andrew, 2010).

There is a great need to be researching the impact of soil acidity in the Inland Pacific Northwest Palouse region, considering liming application methods and supplies, and educating producers and industry on the need for additional nutrients for proper plant growth and development. Lime plot research needs to be considered long term compared to traditional research plot studies.

The lime industry needs to develop application methods that will work well on steep terrain fields where winds can often carry light dry fine lime particles long distances. The liquid lime and pelleted lime both have benefits in windy conditions. Economical liming supplies are needed along with the infrastructure to service the industry.

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