LIME MANAGEMENT IN THE SEMI-ARID REGIONS OF THE US

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ABSTRACT

Soil acidity is increasing in the semi-arid regions of the US; however, questions exist about the efficacy of different liming products to raise soil pH and how long the lime benefits last. Therefore, we monitored the efficacy of three liming products: sugarbeet lime (tilled and non-tilled), prilled lime (seed-placed), and aglime (tilled) to improve soil pH and crop yields at two sites in Montana. Soil samples were collected from 0-3 in. and 3-6 in. for soil pH, nitrate-N, Olsen-P, and extractable Al analysis. Crop yield and plant tissue aluminum concentration were also determined to evaluate the crop response to different lime products. We also evaluated how different sugarbeet lime rates perform to mitigate soil acidity over a 5-year period at three on-farm sites. Soil samples were collected to determine pH at 0-2 in. and 2-4 in. soil depths. Crop yield data were obtained through yield combine monitors. Data indicated that tilling sugarbeet lime is the most effective strategy to increase soil pH and improve crop yields. We observed that if precipitation is high, not-tilling lime can also improve soil pH and yield within a year. Under a low annual precipitation zone, no pH improvement occurred at the 2-4 in. soil depth after 5 years. Soil pH data collected after the 5-year of lime application indicated that lime may need to be re-applied after 5 years under semi-arid environments to mitigate soil acidity. These findings are useful to growers to prepare a lime management plan in semi-arid regions.

INTRODUCTION

Soils in the semi-arid regions of the US are undergoing soil acidification due to current agronomic management practices (Tarkalson et al., 2006). Since 1985, nitrogen fertilizer application has increased threefold in Montana to obtain high-yielding high protein wheat (Jones et al., 2019). Specifically, nitrification of ammonium-based fertilizers releases hydrogen ions in soil, ultimately causing soil acidification. Furthermore, prevalence of continuous wheat cropping system is likely to worsen the acidification issue in the region due to high N needs of hard red wheat. According to a survey, 24 of 56 counties in MT have at least one field with pH less than 5.5 (Jones et al., 2019). Growers in the region are experiencing huge economic losses due to soil acidity but limited information is available to manage soil acidity in semi-arid regions of the U.S.

Liming is an effective means of raising soil pH. Factors such as particle size and purity of liming products, cost associated with application, and potential of a liming product to increase crop yield within a given time interval can affect a grower's decision to use one product over the other. Some liming products such as sugarbeet lime are available for free at sugarbeet plants, whereas products like prilled lime cost around $250-$300/ton in Montana, which could be cost prohibitive if more than about ½ ton/ac is applied. Despite

the cost, some growers may favor the use of prilled lime due to the ease of application with a seed-drill and to avoid tillage and the purchase of an expensive lime spreader. Studies from other states show that products like prilled lime may or may not provide yield benefits and soil pH improvement may not be uniform across the field (Brown et al., 2008; Lollato et al., 2013, Huggins et al. unpub). No Montana data are available to compare prilled lime and other lime products to help producers and their advisers make informed decisions. Therefore, it is important to test the ability of different liming products and mode of application to raise soil pH and increase crop yield to make soil management decisions in a sustainable and economical manner. Another question pertains to the frequency of lime application to maintain the soil pH in neutral zone. A study from Saskatchewan indicated that single application of lime improved soil pH and crop yields for 16 to 27 years (Malhi et al., 1995). However, the duration of lime impacts in somewhat warmer and drier environments is relatively unknown. Therefore, we conducted two lime-based studies in Montana to evaluate the performance of different lime products to increase soil pH. Our objective for the first study was to evaluate the efficacy of different liming products to raise soil pH and improve crop yield. The second study was designed to determine how long lime benefits last in the semi-arid regions.

MATERIALS AND METHODS

Efficacy of different liming products

A study was conducted at the Springhill Experimental Farm near Bozeman and at an on-farm site near Billings in MT in 2022-2023. Soil at the Bozeman site is a Blackdog silt loam with pH 5.1. The Billings site had Shaaky silt clay loam with pH 5.2. The study had six liming treatments: no lime or control (tilled and no-tilled), sugarbeet lime (tilled and not-tilled), prilled or pelletized lime (seed-placed), and aglime (tilled), replicated four times. In Fall 2022, sugarbeet lime and aglime were applied based on calcium carbonate equivalent and pH buffer test, targeting a pH of 6.2 (1–4-ton lime /acre). The prilled lime was seed-placed in Spring 2023 at the rate of 250 lb/ac. Lime was incorporated with a chisel plow (about 4 in. depth) at Bozeman and with a rotary tillage at Billings during Fall 2022. One of the controls was also tilled to account for any tillage impact on crop yields and soil properties. Durum wheat, which has no aluminum tolerance, was planted in Spring 2023 at both sites.

In Summer 2023, plant samples were collected from a 3.3 ft strip of two adjacent rows. Dried and ground plant samples were sent to a commercial laboratory for nitrogen, phosphorous and aluminum analysis. In Fall 2023, soil samples were collected from 0-3 in. and 3-6 in. All the soil samples were air-dried and ground to pass through a 2-mm sieve and sent to a commercial laboratory for soil pH, nitrate-N, Olsen-P, and 0.12M KCl extractable-Al using standard lab protocols. Crop yield data were collected using a plot-scale combine in Aug 2023.

How long do the lime benefits last?

The second experiment was conducted as a strip trial at three Montana on-farm sites near Ft. Benton, Big Sandy, and Geraldine. Ft. Benton and Geraldine soils are Bearpaw-Vida clay loams and Big Sandy is a Telstad loam. Each site had a control and a 4-ton lime/ac treatment, replicated three times. All three sites also had a 2-ton/ac lime strip. Big Sandy and Geraldine had a non-replicated 1-ton/ac strip, whereas Ft Benton had a 6-ton/ac lime strip. Lime was applied at these sites in Fall 2017. At Ft Benton and Geraldine, lime was tilled whereas at Big Sandy, lime was not tilled.

Over the 5-year period, soil samples were collected in the fall from 0-2 in. and 2-4 in. to monitor soil pH changes. Crops varied from year to year at each site and included winter wheat, spring wheat, lentils, and corn. Crop yield data was obtained from combine's yield monitors.

RESULTS AND DISCUSSION

Efficacy of different liming products

Liming products significantly affected the soil pH (Fig.1). At Billings, soil pH at 0-3 in. was highest in the tilled beet lime treatment. The tilled aglime and not-tilled beet lime also had higher soil pH than the control and prilled lime treatments. A similar pattern of soil pH change was observed at Bozeman with the lowest soil pH in the controls and prilled lime treatments. At Bozeman, tilled and not-tilled beet lime had the highest soil pH. Soil pH did not differ at 3-6 in. among treatments at any site.

The results indicated that incorporating sugarbeet lime is the most effective way of raising soil pH, but no-till beet lime also increased the pH levels above 6 in this study conducted in 2023. The results suggest that freely available lime products (e.g., sugarbeet lime) are as, or more, effective as costly lime products (e.g., aglime) to raise soil pH. Prilled lime, which was seed-drilled (250 lb/ac) to investigate as an option for no-till farmers, was not an effective strategy to raise pH. Liming did not affect nitrate-N or Olsen-P in soil. The concentration of aluminum in plant tissue was also similar among the treatments.

Liming treatment also affected the durum wheat yield at both sites. At Billings, the not-tilled control (64.3 bu/ac) produced 14 bu/ac less yield than tilled control (78.1 bu/ac) and aglime (78.5 bu/ac). The durum wheat yield was greater in the tilled beet lime (56.6 bu/ac) treatment than tilled aglime (41.0 bu/ac) and not-tilled control (39.2 bu/ac) treatments at Bozeman. It appears that yield was affected by a combination of improvement in soil pH and some artifact of tillage at both sites.

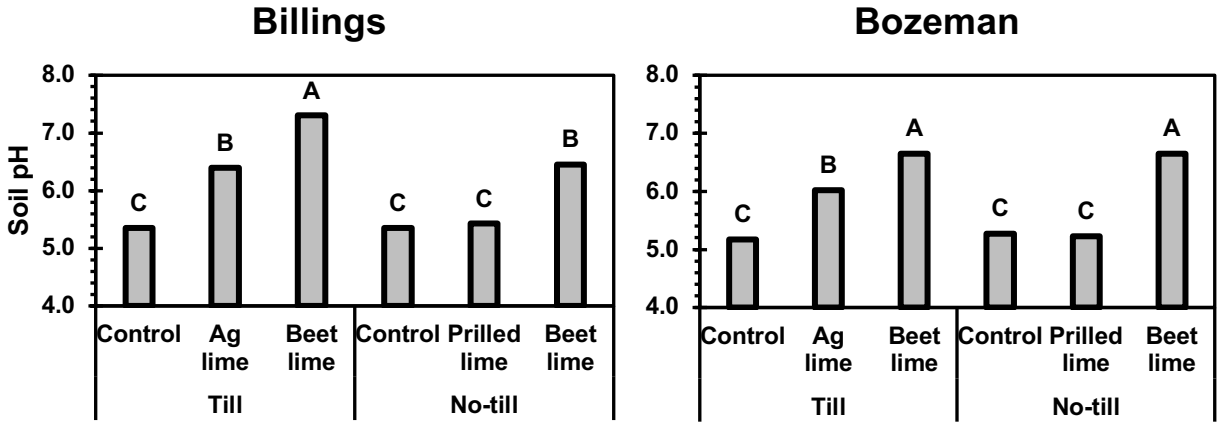

Fig. 1. Soil pH at 0-3 in. under different liming products and modes of application at two sites in MT in Fall 2023. Application of products and tillage occurred in fall 2022 except seed-drilling of prilled lime which was done in spring 2023.

How long do the lime benefits last?

The application of lime increased the soil pH at all sites at the 0-2 in. soil depth; however, by 2022, pH decreased from the 2019 peak at all sites except at not-tilled Big Sandy (Fig. 2). The drop in pH below 5.5 at Geraldine indicates that re-application of lime could be needed after 5 years to raise pH to the optimum pH zone at least in some soils. At the other two sites, even though surface pH was above 6, pH at 2-4 in. was below 5.5 which could negatively affect the crop growth. It is important to consider that 2-4 in. is in, or directly below, the seeding zone, therefore an optimum pH could be critical in that soil zone. The highest rate at each site (4-ton or 6-ton/ac) increased soil pH the most, whereas 1- and 2-ton/ac rates were not able to keep the soil pH in the optimum zone by 2022 at two of the sites, even in the upper 2 inches. At the Big Sandy site where lime was not tilled, no pH increase occurred at 2-4” over the 5-year period, demonstrating that there is not enough moisture to dissolve and move lime below 2 in. in a low annual precipitation zone (14”). This is a disappointing finding given the importance of no-till at reducing wind erosion losses and conserving moisture. This stresses the importance of catching low soil pH before it becomes a problem as liming is expensive and requires tillage to be effective in dry environments prone to wind erosion.

At the Ft Benton site, spring wheat yield was 4.5 bu/ac higher in the 4-ton/ac lime treatment than the 0-ton/ac treatment in 2022 (data not shown). The results indicate that applying 4-ton/ac lime produced yield benefits over no lime 5 years after lime application (lime was applied in 2017). In contrast, at the Big Sandy site, winter wheat showed no yield improvement with the 4-ton/ac lime application. As mentioned previously, lime was not incorporated into the soil at this site. We suspect that low pH at 2-4 in. negatively affected crops. Another reason for the lack of a lime benefit at Big Sandy in 2022 could be extreme drought which may have limited yield more than pH.

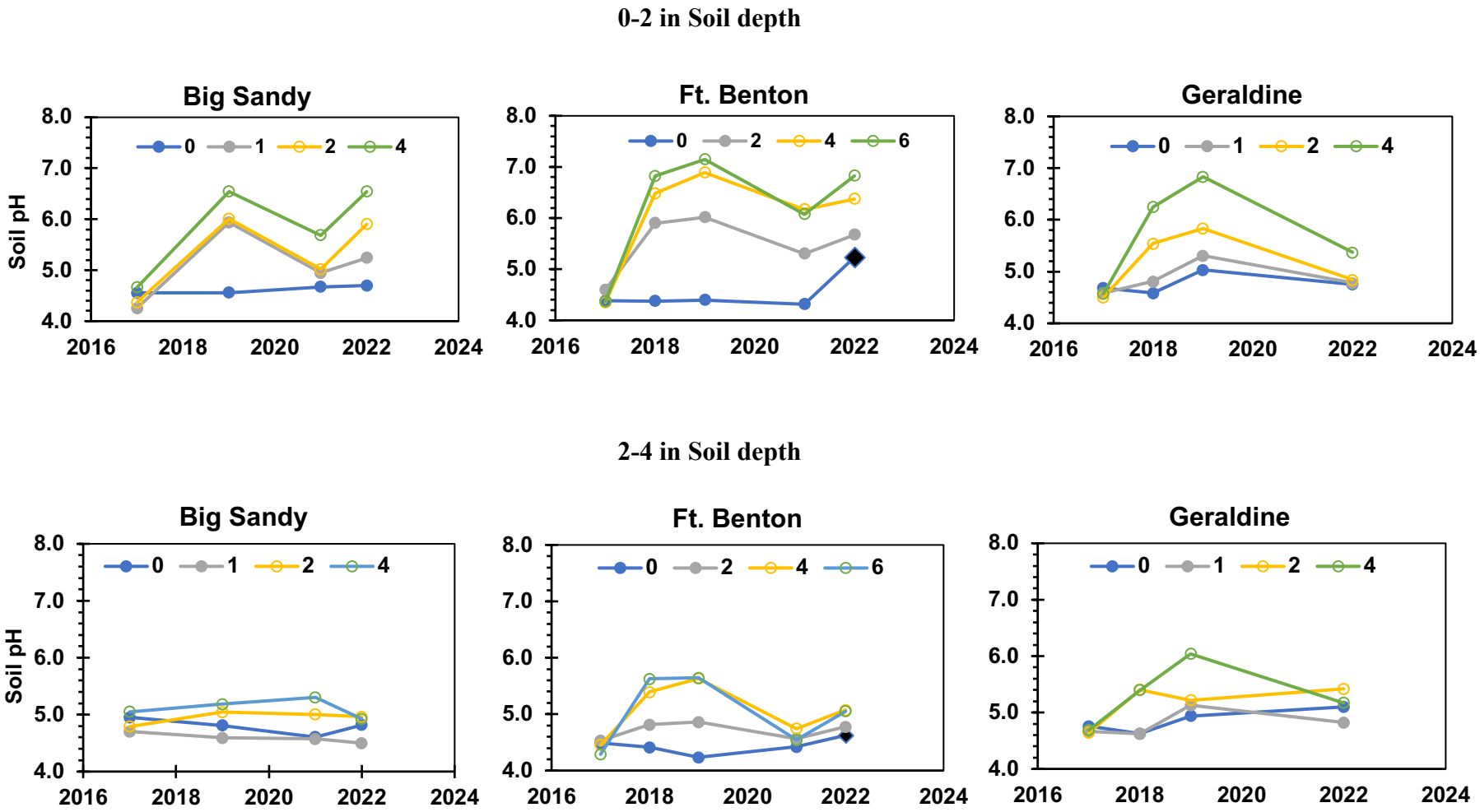

Fig. 2. Soil pH at 0-2 in. and 2-4 in. soil depth under four different lime rates over 5 years at three sites in MT. Lime was applied in fall 2017 without tilling at Big Sandy, with vertical tillage at Ft. Benton and with intensive tillage at Geraldine site. At Ft Benton, the 0 ton/acre treatment received 2-ton/acre lime after 2021 sampling which increased soil pH in 2022. Numbers in legend are beet lime rates in wet tons/ac

In conclusion, liming is an effective way of mitigating soil acidity. The efficacy of liming products and longevity of lime varies with management. The research findings indicated that beet lime can improve soil pH and crop yields better than tilling aglime and seed-placed prilled lime under MT conditions. Not-tilling beet lime can also improve soil pH under good soil moisture conditions. However, in low rainfall zones of Montana, not-tilling beet lime didn't show improvement in the 2-4 in. soil depth over 5-yr period. Based on strip-trial results, it appears that re-application of lime could be needed after 5-yrs of lime application to keep the soils in optimum pH range.

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