MANAGING SOIL PH IN UTAH

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INTRODUCTION

PH is a measure of the acidity or alkalinity of a substance. The range of pH for most soils is from 4 to 10 (Figure 1). The pH scale is logarithmic, meaning that a change in one numerical pH unit equals a 10-fold change in acidity or alkalinity. For example, a soil with a pH of 8 is ten times more alkaline than a soil with a pH of 7.

THE IMPORTANCE OF SOIL PH

Soil pH is considered the single most important chemical property of soil because it affects the availability of essential plant nutrients (Figure 1). The availability of iron, for example, is severely reduced in high pH soils. Even though iron is present in relatively large quantities in most soils, its availability to plants is limited by reactions that form insoluble solids at high pH. This is the main reason iron deficiency (iron chlorosis) is such a widespread problem in the alkaline soils of Utah.

Most plants have a wide range of pH adaptation. For example, common crops like alfalfa, corn and small grains are well adapted to soil pH's ranging from 5.7 to 8.1. Beyond this range, increasing incidences of nutrient deficiency and growth reduction may occur. Other plants have a more limited range of pH adaptation. Cranberries, for example, are acid-loving and will not grow well in soils with a pH above 6.0.

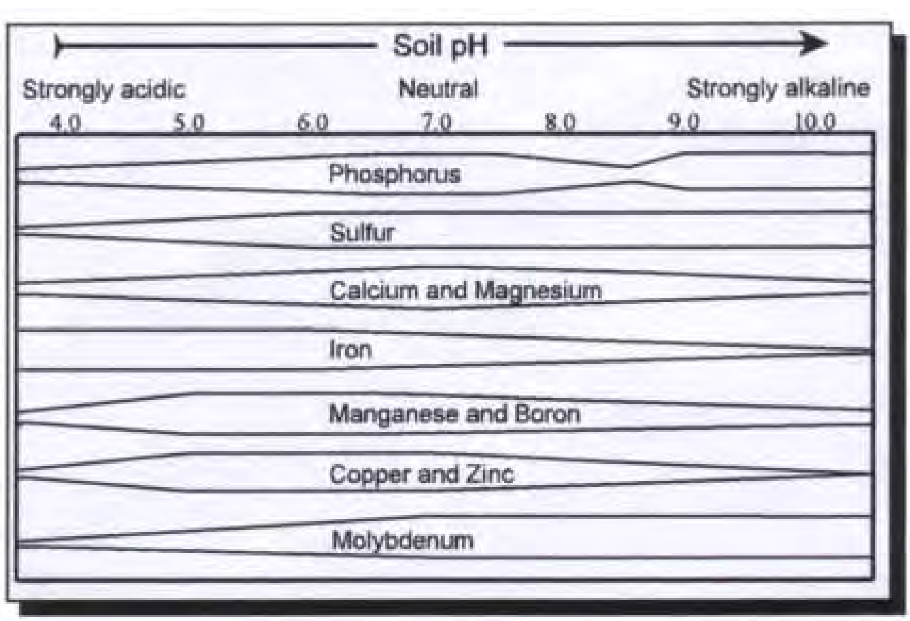

Figure 1. The effect of soil pH on nutrient availability. Wider bars indicate greater nutrient availability at that pH.

SOIL pH IN UTAH

In 1999, 92% of the soil samples submitted to the Analytical Laboratory at Utah State University had pH values above 7. The majority of these samples fell in a pH range between 7.8 and 8.2. The high pH of soils in Utah, as well as other western states, is primarily the result of thousands of years of soil development in a low rainfall environment. This lack of rainfall has allowed large amounts of calcium carbonate (lime) to accumulate in western U.S. soils.

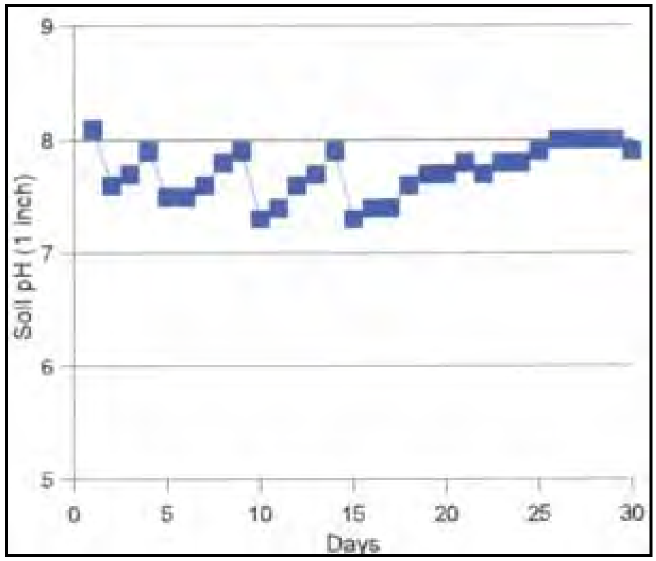

Figure 2. The effect of repeated liquid sulfuric acid applications on the pH of the surface inch of soil. Acid was applied four times (Day 1, 4, 9 and 14) at the rate of 1000 pounds of sulfur per acre per application. Soil pH was measured daily.

THE EFFECT OF LIME ON SOIL pH

In Utah, soil lime contents range from 0% to more than 50% by weight. Each percent of lime translates into approximately 20 tons of lime per acre-foot of soil. Lime acts as a buffer, maintaining soil pH in the alkaline range. Buffers like lime continue to resist a change to pH even when acids are added directly to the soil.

The buffering capacity of lime in Utah soils was recently demonstrated in a field experiment where sulfuric acid was repeatedly sprayed on the surface of a soil containing 38% lime. Soil pH was measured daily in the surface inch of soil (Figure 2). Each time acid was applied, soil pH dropped but rapidly rebounded due to the buffering capacity of the lime.

MEASURING SOIL pH

Soil pH is relatively easy and inexpensive to measure. Samples sent to university or commercial testing labs can be analyzed for pH for less than $5.00. Inexpensive pH meters are also available from horticulture outlets and scientific equipment suppliers starting at about $50.

IDENTIFYING AND MANAGING SOIL PH PROBLEMS

Table 1 provides guidelines for interpreting soil pH. Due to the buffering power of lime, changing soil pH can be extremely costly and difficult. Before investing in amendments to lower soil pH consider whether pH is a problem (Table 1) and the cost of materials to alter pH. Periodically adding small amounts of micronutrients such as zinc or iron to control nutrient deficiencies may be more cost effective than attempting to lower pH.

The remainder of this guide describes various methods and materials commonly used to alter soil pH.

Farm the soil. Cultivation, cropping, irrigation, and the return of crop residues (organic matter) to the soil can, over time, slightly lower pH . Native (uncultivated) desert soils commonly have pH values in the range 8.2 to 9.1. It is common to see soil pH's decline 0.2 to 0.5 units after several years of farming. Maximizing the amount of organic matter returned to the soil accelerates this process since decomposing organic matter contributes small amounts of acid to the soil.

Table 1. General guidelines for interpreting soil pH.

Soil pH	Interpretation	Recommended action
Less than 6.0	Acidic. Rare condition in Utah. May indicate the presence of reduced iron or sulfur compounds, or contaminants in soil.	Monitor pH every 3 to 5 years, or more frequently if problems develop. If pH continues to decline below 6.0 lime additions may be needed.
6.0 to 7.5	Near neutral. Ideal pH for most crop plants.	Monitor pH every 3 to 5 years as part of a regular soil testing program.
7.6 to 8.2	Moderately alkaline. Normal soil pH range for Utah. Should pose no significant problems for crop growth.	Monitor soil pH every 3 to 5 years as part of a regular soil testing program, or more frequently if problems develop.
Above 8.2	Highly alkaline. May be causing plant growth and water infiltration problems. Soil may be *sodic* (contain excess sodium).	Test soil for *sodium adsorption ratio* (SAR) and, if necessary, treat soil for an excess sodium problem. Treatment may include the application of gypsum. Other options are also available. Contact your local County Extension Agent for further assistance and information.

Soil additions of elemental sulfur and liquid acids. Elemental sulfur (90-99% sulfur) oxidizes slowly to form sulfuric acid in soil. Therefore, direct application of elemental sulfur, as well as liquid acids, has the potential to lower soil pH. However, the buffering capacity of lime limits the effect of sulfur and acid additions on soil pH (recall Figure 2). Studies conducted in 1996-1999 on the effect of solid elemental sulfur additions on soil pH showed that a soil with no lime could be acidified while pH was only slightly affected on a high lime soil (Figure 3). At both locations measurable changes in soil pH were not observed until 12 to 18 months after sulfur application. Some success may be achieved by banding elemental sulfur or liquid acids to influence pH in small volumes of soil rather than trying to change pH in the entire soil volume.

Elemental sulfur and liquid acids do have value in treating highly alkaline, sodium-dominated or *sodic* soils (Table 1). The main effect of sulfur in the treatment of a sodic soil is not through direct acidification, but rather by dissolving lime and releasing calcium which replaces sodium and allows it to be leached from the soil. Excess water must be applied to leach sodium, which is often difficult in poorly drained soils. Many Utah soils are high in sodium because water is in short supply and the soil does not have adequate drainage.

Soil additions of gypsum (calcium sulfate). Gypsum has no direct effect on soil pH. The main use of gypsum is in the reclamation of highly alkaline, *sodic* soils (Table 1). Gypsum dissolves to release calcium which replaces sodium and allows it to be leached from soil. Excess irrigation and drainage is required to effectively leach sodium from soils.

Irrigation water treatments. Many irrigation waters in Utah have high pH coupled with high levels of carbonate, bicarbonate, and sodium. When applied to soil these waters can increase soil pH and sodium levels, and reduce water infiltration and drainage rates by plugging pores with dispersed soil particles and lime. Direct injection of acids into irrigation water has the potential to improve irrigation water quality, aid in the reclamation of sodic soils, lower soil pH, and improve soil water infiltration and drainage characteristics. Acid injection does not lower calcium or sodium levels in irrigation waters; however, it can lower pH and remove carbonate and bicarbonate from these waters, which may reduce the plugging of pores by dispersed soil particles and lime.

Irrigation water can also be treated with an acid generating plant (sulfur burner). Sulfur burners oxidize elemental sulfur in a controlled combustion reaction to produce acid which lowers the pH of water passing through the unit.

The effect of a sulfur burner on irrigation water quality, soil properties and alfalfa yield and quality was recently evaluated in a level basin irrigation study in Millard County, Utah. Water was treated by diverting approximately 5% of a canal stream through a sulfur burner. The treated water was then reintroduced into the canal where it mixed with the main stream before entering the field. Over four irrigations the sulfur burner acidified the water and removed all bicarbonate. After mixing with the main stream and before entering the field, pH was the only property of the water still affected by the burner treatment (Table 2). Table 3 shows the results when treated and untreated waters were used to irrigate adjacent basins containing alfalfa. The sulfur burner treatment did not increase alfalfa yield or quality or alter soil pH and available nutrient levels.

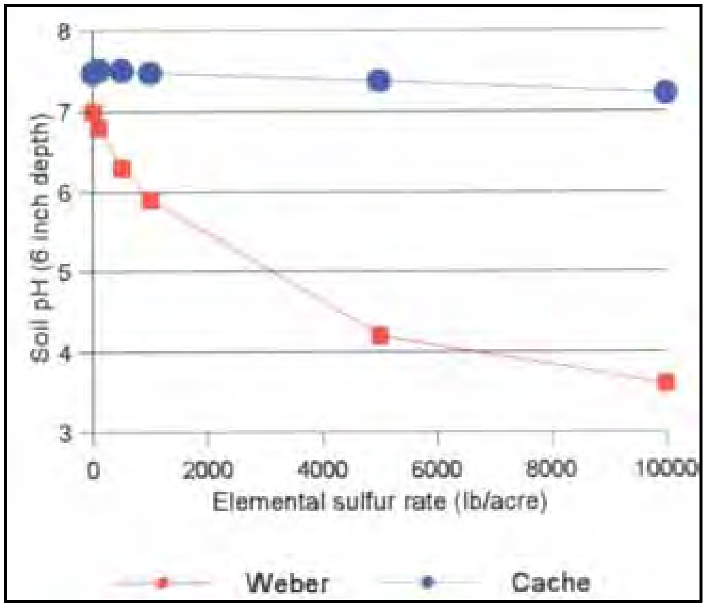

Figure 3. The effect of elemental sulfur on soil pH in the surface 6 inches. The Weber County (Huntsville) soil contained no lime while the Cache County (Logan) soil contained 38% lime. Both fields were in alfalfa and the alfalfa died at the Weber location with 5000 and 10000 lb sulfur/acre treatments.

Table 2. Irrigation water quality parameters *before* treatment (bulk canal water), *during* sulfur burner treatment, and 50 feet downstream *after* treated water mixed with the bulk canal stream.

	pH	Sodium	Calcium + Magnesium	Bicarbonate	Adjusted SAR
	---------------- milliequivalents per liter-----------------				
Before	8.0 (0.1)†	10.4 (0.5)	8.7 (0.4)	5.0 (0.3)	12.0 (0.6)
During	2.3 (0.2)	10.1 (0.7)	9.1 (0.7)	0.0 (–)	–
After	7.4 (0.2)	10.5 (0.5)	9.1 (0.5)	4.6 (0.1)	11.5 (0.5)

†Mean (standard error) of four samples collected from irrigations in April, May, June and August.

Table 3. The effect of untreated and sulfur burner-treated water on alfalfa yield, crude protein, and soil chemical properties at the end of the growing season.

	Irrigation water treatment	
Parameter	**Untreated (control)**	**Sulfur burner-treated**
Alfalfa yield (tons/acre)	6.6	6.5
Average crude protein (%)	20.2	20.9
Soil pH	8.0	7.9
Soil test phosphorus (ppm)	4.2	5.3
Soil test zinc (ppm)	0.7	0.7
Soil test iron (ppm)	6.8	6.8
Soil test copper (ppm)	1.1	1.1
Soil test manganese (ppm)	2.3	2.4

Both liquid acid injection and sulfur burner treatment of irrigation water have been used with apparent benefits in other situations. Greenhouses, golf courses, and orchards have successfully used direct acid injection and sulfur burners to treat irrigation water. This is apparently due to the smaller volume of water used by these operations and the ability to treat a larger proportion of this water with greater effect. Where a large proportion of irrigation water can be treated more beneficial effects of sulfur burners may be seen. Using much larger quantities of low pH water could affect soil pH, but the long term effects of using low pH irrigation water on established agronomic crops like alfalfa has not been studied. Use of either acid injection or sulfur burners should be preceded by a thorough evaluation of irrigation water quality and soil properties to determine if treatment is needed, whether acid injection or a sulfur burner can accomplish the required level of treatment considering the volume of water needed, and whether the method of treatment is economical.

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