



SOIL PH AND IMPLICATIONS FOR MANAGEMENT: AN INTRODUCTION

Soil Acidification Series

SOIL PH AND IMPLICATIONS FOR MANAGEMENT: AN INTRODUCTION

By

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Abstract

Decreasing soil pH, also called soil acidification, is a growing concern in eastern Washington and northern Idaho. Researchers and farmers have measured soil pH values below 5.0 throughout the Palouse region. Decreasing soil pH has serious implications for the cropping systems of the Palouse. This introduction is the first in a series of fact sheets on soil acidification and introduces the fundamentals of soil pH and acidification. Other fact sheets in the series will cover more specific information on topics such as the influence of pH on pathogens and microbes, herbicide activity, crop nutrition, liming, and [variety selection](#).

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Soil pH and Implications for Management: An Introduction

What is pH?

Acidic, neutral and alkaline/basic are terms commonly used to describe pH. A measure of the concentration of hydrogen ions (H^+) in a system, pH is described using a negative-logarithmic scale. This means that for each whole number step down on the pH scale there are ten times more hydrogen ions, or “acidity,” than the previous step. Neutral pH is 7, while the neutral pH range is generally thought to be between 6 and 8. Alkaline or high pH values are above 8, while acidic or low pH conditions are typically considered to be below 6. Figure 1 shows pH values for common substances from battery acid to lye.

14 - lye
13 - bleach
12 - common household cleaners
11- soapy water
10 - antacids
9 - baking soda, green tea, toothpaste
8- eggs, sea water
7- blood,
6 - potatoes, normal rain
5 - tomatoes, coffee
4 - orange juice, beer
3 - soda pop, vinegar
2 -stomach acid, lemon juice
1 - battery acid

Figure 1. The pH of common items. Each pH unit is a ten-fold increase or decrease of acidity (H^+).

pH in the Soil

In soil, pH is known as a *master variable* because it influences almost every process in the soil system. The health of crops and other soil life, the availability of nutrients, and the activity of pesticides are all affected by pH. Generally, soil pH below 5 is considered to be very low and extremely acidic for many agricultural crops.

A pH too far from neutral, either above (alkaline) or below (acidic), will make essential nutrients less available to plants. Figure 2 shows how pH affects nutrient availability in soil.

For many nutrients, optimum availability occurs near neutral pH (7.0) and availability decreases as pH values become more extreme. This can lead to nutrient deficiencies in crop plants. Figure 3 shows yellowing between the veins (*interveinal chlorosis*) of a corn plant due to iron deficiency in a field where the soil pH is too high.

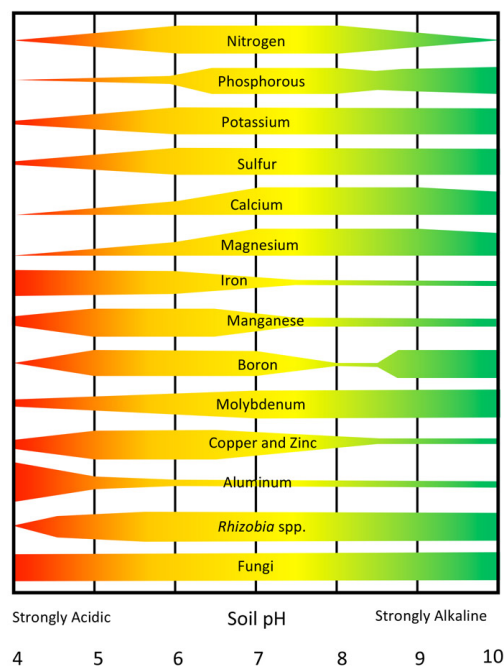


Figure 2: General pH effects on nutrient availability and soil biology. Wider parts of the bar indicate the element is relatively more available to plants, while narrow parts indicate decreased availability of the element at that pH. Deviation from neutral pH decreases availability of many essential plant nutrients as well as bacteria populations. (Adapted from Truog 1947).



Figure 3: Yellowing between veins in corn resulting from iron deficiency in high pH soil (from Koenig- used with permission).

In addition to decreasing nutrient availability, low pH can degrade clay minerals in the soil that contain aluminum. This process releases aluminum (Al), which is toxic to plants and can interfere with root growth and crop development. Absorption of aluminum and other toxic elements under low pH conditions results in yellowing, stunting, and general reduced vigor, especially in early growth stages. This is shown in Figure 4 by the sparse growth of winter wheat at the early stage of stem elongation under low pH conditions. As aluminum is released, it will preferentially bind to the cation exchange sites on soil organic matter and clays. Desirable plant nutrients, such as calcium and magnesium, are then released and become more susceptible to leaching out of the root zone. This also reduces the over-all nutrient holding capacity of the soil.



Figure 4: Reduced vigor, yellowing and patchiness in wheat resulting from low pH and Al toxicity.

The effects of low soil pH extend throughout the crop production system. Reduced availability of certain nutrients resulting from low pH affects the growth and development of crops and weeds. Pesticides, including herbicides may be less effective and/or persist longer in low pH soil. Low pH can negatively impact the soil microbial community, especially rhizobia symbionts of legumes, other important contributors to nitrogen cycling, and even earthworms.

Low pH can alter the soil environment to favor common fungal pathogens and certain weed species. The far-reaching effects of soil pH on the cropping system underscore its importance as a factor influencing crop production and soil quality.

Soil Acidification

Thirty percent of the earth's soils are acidic. Most of these soils have been naturally acidified over geologic time. Several factors contribute to natural acidification.

The material and history of a soil's formation affects the likelihood of acidification. Climate is also a main driver of natural acidification; atmospheric CO₂ slightly acidifies rainwater, and, over geologic time, contributes to soil acidification. Acidic conditions are also created by removal of *base cations* such as calcium (Ca²⁺) and magnesium (Mg²⁺) from the root zone, either by leaching through the soil profile or removal with harvested plant material.

Typical acidic soils, such as those found in the southeastern United States, developed over thousands of years under humid conditions and have been naturally acidified. These soils typically have lost most of their ability to hold nutrients. They have a unique texture and fewer base cations like calcium and magnesium in the root zone because the cations have been flushed deep into the soil through the process of leaching. The soils of the Palouse are relatively younger, wind-deposited silt loams in a drier climate and not typical of acidic soils.

The Palouse previously had native forest or grass prairie cover and, as recently as the 1950s, its soil pH was near neutral. Differences in native vegetation resulted in local soil properties developing differently. Prairie soils developed in the drier part of the Palouse and tend to be higher in organic matter and concentrations of calcium and magnesium, which help to stabilize soil pH. Alternatively, Palouse soils that were historically forested have lower calcium and magnesium contents, lower organic matter and higher aluminum levels. This leads to a reduced ability to buffer pH changes, thus, such soils can become acidic more quickly. Figure 5 is a general map of the Inland Pacific Northwest depicting the zones that were historically forested.

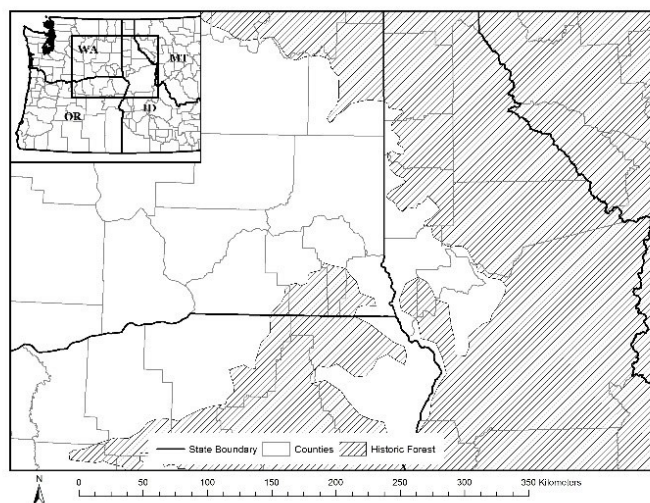


Figure 5: The shaded area of the map shows areas of the Inland Pacific Northwest that were historically forested. These soils may become acidic more easily (Koenig et al., 2011, used with permission).

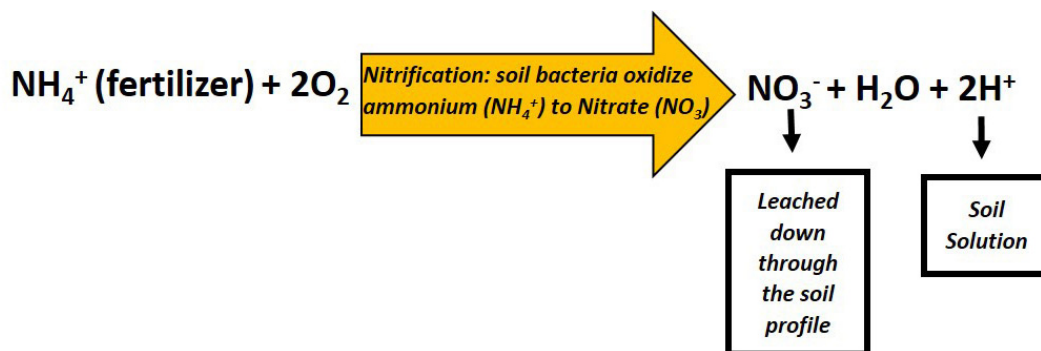


Figure 6: When ammonium-based fertilizers are applied to the soil, they quickly convert to nitrate. This nitrification process releases excess hydrogen ions (H^+) that make soil more acidic.

Use of nitrogen-based (ammonium/ NH_4^+) fertilizers has accelerated the rate of soil acidification on agricultural lands. Ammonium in anhydrous ammonia and other nitrogen fertilizers is converted to nitrate by soil microbes (Figure 6). This process produces acidity (H^+) in the soil. An acidic zone typically develops in reduced tillage systems where fertilizer is banded at a depth of 3 to 5 inches. This effect can be reduced through tillage in the short term, as the excess H^+ is mechanically mixed throughout the plow layer.

Acidification in the Palouse

Acidification is an increasing concern in the Palouse as production of high yielding wheat crops has required substantial nitrogen fertilizer inputs. Nitrogen fertilizer use in the entire US has been rapidly rising since the 1960s, as shown in Figure 7. In the early 1980s, University of Idaho researcher, Dr. Robert Mahler expressed concern after a survey of northern Idaho and eastern Washington soils showed a trend with over 65% acidification, to below pH 6, in several counties between 1972 and 1980 (Mahler et al, 1985). Today, farmers, researchers and extension personnel are finding many sites in the PNW with a surface soil pH below 5.0. In extreme cases, pH of the fertilizer zone has been measured at lower than 4.0. A growing trend of extremely low pH values in Palouse soils represents a serious threat to land quality and represents the degradation of a significant capital investment for farms throughout the region.

Low pH and Crops

Each crop has an optimum pH range for normal growth. If the soil pH drops below a critical threshold, the crop will not thrive. Another study led by Dr. Mahler looked at yield performance under low pH conditions for crops commonly grown on the Palouse. Figure 8 shows data adapted from this study and illustrates the trend that, as pH decreases, the maximum attainable yield decreases at different points and rates depending on the crop.

Tolerance to acid soil varies among plants and can be improved through crop breeding. Plants have many adaptations that can mitigate the impact of extreme pH and accompanying nutrient deficiencies or toxicities.

Developing aluminum-tolerant wheat varieties that grow better in low pH conditions is one current objective of the wheat breeding programs at WSU. These varieties can help reduce yield loss associated with acidic conditions. However, even using aluminum-tolerant varieties and crops, yield will still often be lower than if they were grown on soils with a pH closer to neutral.

Managing Low pH

Amending soils with agricultural lime is the most common and effective long- and short-term strategy to correct soil acidity. Other short-term strategies that can mitigate the impact of low soil pH on crop yield include planting aluminum-tolerant varieties of wheat or aluminum-tolerant crops such as triticale.

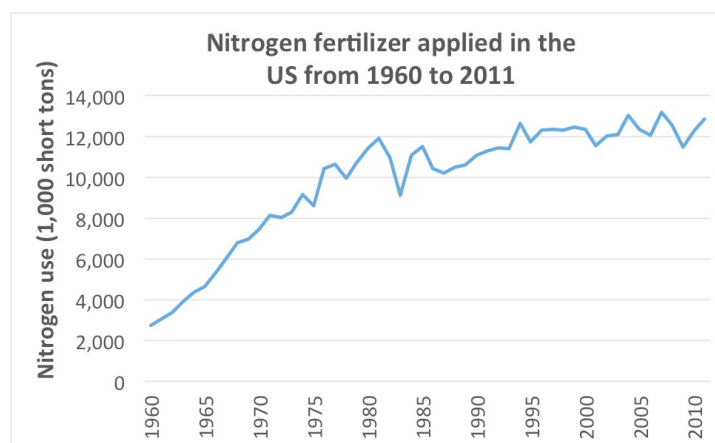


Figure 7: Nitrogen fertilizer use increased greatly since the 1960s and 1970s. Current U.S. nitrogen fertilizer use is near 12 million tons per year (Data from USDA-ERS).

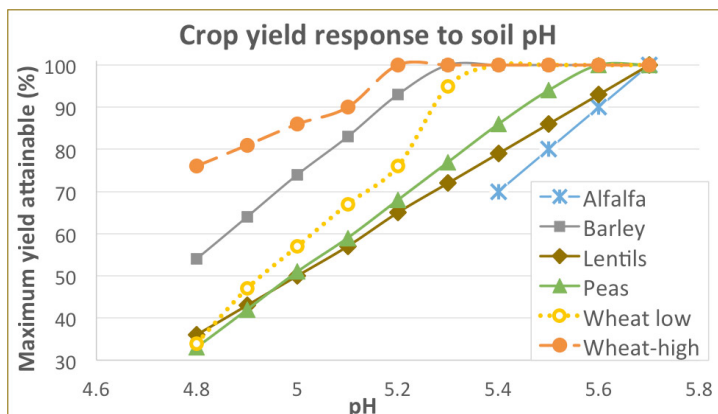


Figure 8: As soil pH decreases, the crop yield potential also decreases for common field crops. The “wheat-low” values show results for varieties with low tolerance to acidity and Al. The “wheat-high” values show results for varieties with higher tolerance to acidity and Al. (adapted from Mahler and McDole 1987).

Acidic conditions are even more detrimental to legumes such as pea, lentil, chickpea and alfalfa. These crops are less tolerant of acidic soils than non-legumes largely because of adverse effects on the unique nitrogen-fixing bacterial community on which they depend.

Strategies for *reducing the rate of soil acidification* and restoring the health of low pH soils include:

1. Leaving crop residues in the field to minimize the removal of base cations from the soil and to increase the soil organic matter content, which helps buffer pH changes;
2. Use crop rotations that incorporate legumes because, while legumes still produce some acidity with N fixation, they do not require supplemental nitrogen fertilizers that accelerate acidification.
3. Use alternative nitrogen fertilizers. Unfortunately, non-acidifying fertilizers, such as calcium nitrate, are not commonly used because they are not economically competitive, compared to commonly used ammonia-based fertilizers.
4. Applying lime that compensates for the acidification occurring from annual N fertilizer applications; and
5. Implementing practices that optimize nitrogen use efficiency in the cropping system.

Before taking management action, it is critical to measure and understand the extent of the soil pH problems within fields and across farms, as well as in the region.

Like many features of Palouse soils, soil pH can vary spatially in fields. Typical soil sampling is not providing all the necessary information needed to identify the severity of soil acidity. Appropriate soil sampling and analysis are important first steps to identifying a soil pH problem. Then, implementing strategies to stabilize and reverse acidification is essential to achieving optimal crop yields in the short term and critical for the long term maintenance of soil health and productivity.

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