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Implications of Acidification Of Farmland in Northern Idaho

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Soil acidity has long been recognized as a primary factor affecting crop yields throughout the world. Yield reductions because of excess soil acidity occur primarily in the midwestern, southern and eastern regions of the U.S. Agricultural soils west of the Cascades in Washington and Oregon are also acid.

An acid soil has a pH below 7.0. For agricultural purposes, a soil with a pH below 6.6 is considered acid. The term acid is usually applied to the plow layer (upper 8 to 10 inches of the soil profile) and does not imply anything about the pH of the subsoil (soil below the plow layer).

Soil acidity occurs when levels of exchangeable aluminum (Al^{+++}) and hydrogen (H^{+}) on clay particles (cation exchange sites) in the soil are high compared to levels of calcium (Ca^{++}), magnesium (Mg^{++}) and potassium (K^{+}). Excessive levels of H^{+} and Al^{+++} on clay particles in the soil have been shown to reduce wheat, alfalfa and pea yields by more than 80 percent in parts of the U.S. (Fig. 1). Application of lime to soils corrects acidity problems.

Specific Plant Growth Problems

Aluminum and hydrogen in large quantities inhibit plant growth in acid soils. In soils which have pHs between 4.5 and 6.0, Al^{+++} is usually the major ion interfering with plant growth. Conversely, H^{+} is the major growth suppressant in soils with pHs less than 4.5.

Aluminum is not required for plant growth; however, most plants can take up Al^{+++} without consequences. Aluminum restricts a plant's uptake of calcium (Ca) and phosphorus (P). Calcium is required by the plant for cell division and cell elongation. Legumes (alfalfa, lentils, beans, chick-peas, peas) require large amounts of calcium for nodulation. Thus when aluminum is present in large amounts, nodulation and nitrogen fixation are reduced.

Aluminum also interferes with P uptake by plants. Excess aluminum can precipitate (make unavailable) P in the soil solution. Without adequate P, plants lack vigor and often have a reduced yield.

Hydrogen adversely affects plant growth when soil pH falls below 4.5. Hydrogen ions irreversibly destroy areas on roots where plant nutrients are taken up.

Fig. 1. Alfalfa growing in the same soil series. The soil on the left has been limed; the soil on the right has not.

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How Soils Become Acid

Soils become acid because of several factors including high precipitation, acid rainfall, removal of basic plant nutrients by crops and the application of ammonium-based fertilizers.

• **Removal of Ca^{++} and Mg^{++}.** Leaching is the major way Ca and Mg are removed from the soil profile in regions which have high precipitation (in contrast to northern Idaho which is temperate and relatively dry). Under conditions of high precipitation, negatively charged ions (anions) such as sulfate (SO_4^{--}) and chloride (Cl^-) leach; however, positively charged ions (cations) such as calcium, magnesium and/or potassium must accompany the anions to neutralize the negative charge.

The principal mechanism of Ca^{++} and Mg^{++} loss from the soil profile in Idaho is by removal of the cations by the growing crop. Wheat is capable of removing from 20 to 50 pounds each of Ca and Mg from the soil per acre per year. Every year, Ca and Mg are literally mined from soils in northern Idaho; they are continuously removed from the soil and not replaced.

• **Addition of H^+ to the Soil System.** Hydrogen is added to the soil system in several ways. Organic matter decomposition yields H^+ ions, and roots of certain plant species also release H^+. Peas, lentils, chickpeas, alfalfa and other legumes emit H^+ ions into the soil system and acidify the soil.

Acid rainfall also can acidify soils significantly. Acid rains primarily occur in the eastern U.S. At present, it is not a significant threat in northern Idaho.

In northern Idaho, the addition of ammonium-based fertilizers is by far the most important factor causing soils to become acid rapidly. Every two ions of ammonium fertilizer added to the soil will produce four ions of H^+ when conversion to nitrate (NO_3^-) occurs as shown in the following formula:

$$2\,NH_4^+ + 3O_2 \rightarrow 2NO_2^- + \underbrace{4H^+}_{} + 2HOH$$

Generates

For every pound of ammonium nitrogen added to the soil, 1.9 to 3.6 pounds of lime is required to neutralize the acidity generated. The ranking of commonly used nitrogen fertilizers in northern Idaho on the basis of potential soil acidity generation from greatest to least on a pound for pound basis of total material would be:

anhydrous ammonia > **ammonium sulfate** >

urea > **ammonium nitrate**

On a pound for pound nitrogen basis, acidity ranking from greatest to least would be:

ammonium sulfate > **anhydrous ammonia** =

urea > **ammonium nitrate**

Growers in northern Idaho have been adding acid in the form of ammonium fertilizers to their soils in large quantities for more than 30 years. Conversely, most growers have not added a liming material to neutralize the generated acidity.

Acidity Trends in Northern Idaho

Most agricultural soils in northern Idaho were slightly acid to slightly alkaline (pH 6.6 to 7.4) in their virgin state. Farmers used N fertilizers sparingly on their soils until after World War II when higher yielding wheat varieties and cheap N became available. Nitrogen fertilizer use rapidly increased in the 1950s and has continued to increase as improved wheat varieties have been introduced.

In 1960, less than 15 percent of the soils in most counties in northern Idaho had soil pHs less than 6.0 (Fig. 2). Only Adams, Idaho, Kootenai, Lewis, Nez Perce and Valley counties reported more than 15 percent of their soils to have a soil pH below 6.0. By 1980, several counties in northern Idaho reported that a majority of their soils had pHs less than 6.0. Benewah, Idaho, Latah, Lewis, Nez Perce and Valley counties reported more than 65 percent of their soils to be below pH 6.0 (Fig. 2).

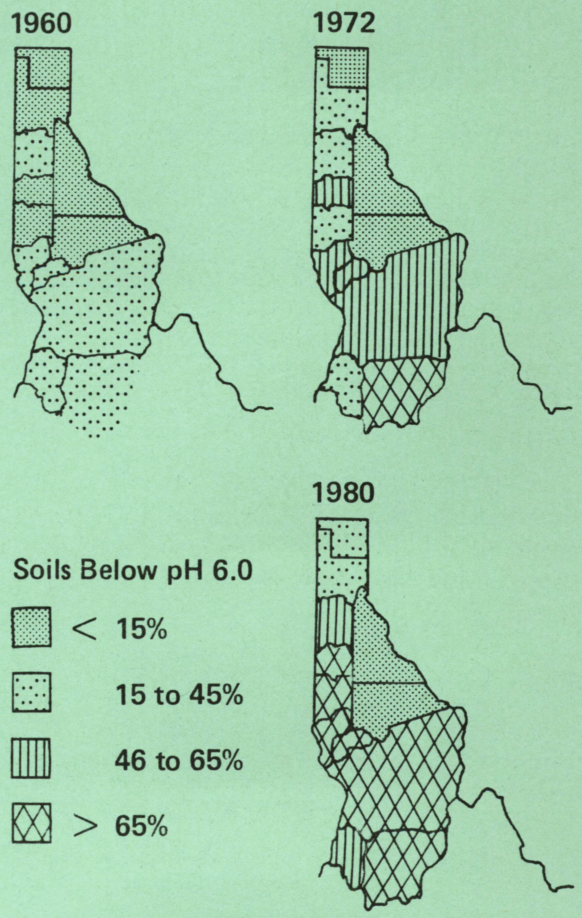

Fig. 2. Change in soil pH experienced by soils in northern Idaho.

Table 1. Acidity of commonly used nitrogen fertilizers.

Material	$CaCO_3$ equiv. per ton*	$CaCO_3$ equiv. per 100 lb N
Anhydrous ammonia	2,960	181
Ammonium sulfate	2,200	523
Urea	1,680	181
Ammonium nitrate	1,180	89

*Amount of lime needed per ton of material to neutralize the acidity generated.

As long as large quantities of nitrogen are required for high crop yields, soil pHs in northern Idaho will continue to decline. Once plant roots get through the plow layer, they can escape the problem of poor growth. However, during the time most of the roots are in the plow layer, crop performance may be affected adversely. Seed germination, seedling establishment and young plant vigor can be retarded.

Acidification Mechanism

Soils have differing abilities to resist changes in pH when acidifying agents are added. Eventually, though, the pH does change when enough material is added to overcome the soil's capacity to resist change. A soil's ability to resist pH change is called its buffering capacity.

Buffering curves conducted on soils in northern Idaho show that approximately 4 milliequivalents of acid per 100 grams have been produced in soils through the addition of ammonium-based fertilizers during the last 50 years. Approximately 4,000 pounds of lime per acre would be required to bring the soils back to their original pH.

Applying 120 pounds of N per acre as anhydrous ammonia each year (146 lb total material) will cause a pH drop from 7.2 to 5.4 in just 10 years (Fig. 3). Although the values shown in Fig. 3 are unrealistic (120 lb of N are not added to soils each year because of crop rotation), they do explain why soils in northern Idaho are rapidly becoming acid.

A grower who uses anhydrous ammonia and has added 1,000 pounds of N in the last 25 years has probably reduced his soil pH approximately one pH unit. The decline in pH would take less time if the N source were ammonium sulfate, more time if ammonium nitrate and approximately the same amount of time if urea.

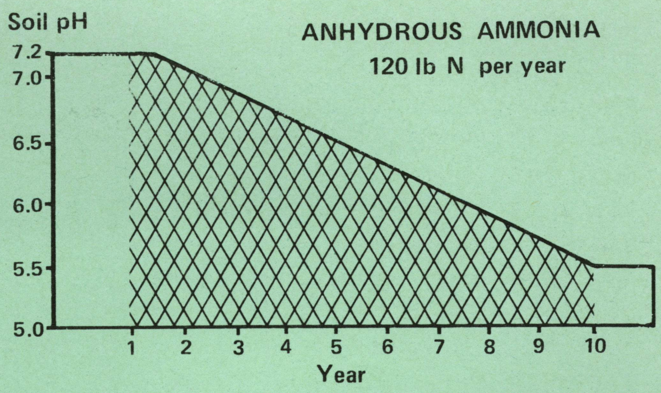

Fig. 3. Simulated influence of anhydrous ammonia on the pH change of a Palouse silt loam soil over time under laboratory conditions.

Consequences

In northern Idaho, the question is not if we will need to add lime in the future but rather when will we need to add it to prevent soil acidity from reducing yields significantly. Furthermore, varieties of wheat commonly grown in northern Idaho are extremely intolerant to acidity when compared to wheat varieties grown in acid soils of the midwestern and southeastern U.S. As a rule, legumes are less tolerant of acid conditions than cereals. The acidic conditions prevent optimum levels of nitrogen fixation and good root growth.

Soil acidity may complicate matters even more by favoring certain weeds and diseases. Weeds which were not problems in the past may become more competitive at lower pHs and become major pests. As soil pH decreases, the soil environment becomes more favorable for certain pathogenic fungi. Low soil pHs would also decrease molybdenum availability.

Lime may be mandatory for wheat, pea and alfalfa production in isolated areas of northern Idaho in the future if not today. Some 80 percent of crop acreage in northern Idaho may someday require lime. Someday may be much sooner than we think!

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