SOIL AMENDMENTS....THEIR ROLE IN CROP PRODUCTION

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Soil amendments are used to improve both chemical and physical conditions of the soil for increased crop production. Amendments may be either organic or inorganic materials.

For the purpose of discussion, soil amendments can be divided into several groups. Some amendments are applied to make soils more acid (decrease soil pH) while others are added to make them more basic (increase soil pH). Amendments may be applied to replace excessive sodium ions from sodic soils or to improve soil tilth. Wherever soil amendments are required, a basic understanding of how they react in soils is essential in order to use these materials properly as an aid in crop production.

A simplified explanation of soil pH will aid in understanding the role of some soil amendments. pH is a measure of hydrogen ions (H^+) in solution. When there are equal numbers of hydrogen ions and hydroxide ions (OH^-), the solution is neutral and has a pH of 7. If a soil solution contains more hydrogen ions, it is acid and has a pH below 7. Conversely, if more hydroxide ions are present, the soil is alkaline (basic) and the pH is above 7. As increasing numbers of hydrogen ions accumulate, the pH decreases progressively below the neutral point. With increasing numbers of hydroxide ions, the pH increases progressively above 7. Soil pH generally ranges between a low of 4-4.5 and a high of 9.5 - 10.

Each change of one pH unit represents a 10 fold increase or decrease of hydrogen ions in solution. For example, there are 10 times as many hydrogen ions in solution at pH 6 as there are at pH 7, and 100 times as many at pH 5 compared to pH 7. Most crops grow well in the pH range of 6-8. The most ideal pH for crops, considering all growth factors is about pH 6.5. Extreme pH values on either side of the neutral point have adverse affects on crop production.

ACID SOILS

Soils of the southwestern desert area generally are calcareous and problems related to low pH do not exist. Acid soils result primarily from excessive leaching in areas of high rainfall. They may also result from continuous use of acid-producing fertilizers such as ammonium sulfate. Nitrification of ammonium ions in the soil produces hydrogen ions. The accumulation of hydrogen ions causes soil pH to decrease.

When soils become too acid for optimum crop growth, the condition can be corrected by adding limestone ($CaCO_3$) to the soil. Limestone reacts with acid soils to neutralize hydrogen ions and raise the soil pH.

The amount of limestone required varies with soil conditions. A general recommendation is given in the following table:

LIME REQUIRED TO RAISE SOIL pH to 6.5
(POUNDS PER ACRE)

SOIL pH	LIGHT SOIL	MEDIUM TO HEAVY SOIL
5.5	1,000 - 2,000	3,000 - 5,000
4.5	3,000 - 4,000	6,000 - 8,000
3.5	4,000 - 5,000	9,000 - 12,000

Several liming materials may be used to correct soil acidity, depending upon availability. Some of these materials are listed on the following page.

LIMING MATERIALS

NAME	CHEMICAL NAME AND FORMULA		$CaCO_3$ EQUIVALENT
Limestone	Calcium Carbonate	$CaCO_3$	100%
Hydrated Lime	Calcium Hydroxide	$Ca\ (OH)_2$	120%
Burned Lime	Calcium Oxide	CaO	150%
Dolomite	Calcium-Magnesium Carbonate	$CaMg(CO_3)_2$	110%

ALKALINE SOILS

Sulfur is the most widely used soil amendment for correcting high pH soils. When elemental sulfur is added to soil, it is oxidized by soil organisms to sulfuric acid.

$$2\ S + 3\ O_2 + 2\ H_2O \longrightarrow 2\ H_2\ SO_4$$

This reaction produces energy which is utilized by the sulfur oxidizers in their life processes.

Finely ground sulfur is oxidized more rapidly than coarse particles. The fine particles provide more surface area for microbial activity. Oxidation procedes more rapidly in warm soils than in cold soils.

Poor growth of crops at high pH values may be the result of reduced availability of plant nutrients. Some plant nutrients form highly insoluble compounds at high pH values. Poor growth may also be the result of a direct pH affect on root cells causing a reduction in permeability to water and to nutrient elements.

General recommendations for soil sulfur applications are shown in the following table:

SULFUR REQUIRED TO LOWER SOIL pH TO 6.5
(POUNDS PER ACRE - BROADCAST)

SOIL pH	LIGHT SOIL	MEDIUM TO HEAVY SOIL
7.5	400 - 600	800 - 1,000
8.0	1,000 - 1,500	1,500 - 2,000
8.5	1,500 - 2,000	2,000 - Up
9.0	2,000 - 3,000	

Many calcareous soils contain such large amounts of precipitated lime that it would be economically unfeasable to apply sufficient sulfur to cause any appreciable change in the overall soil pH. 100 lbs. of calcium carbonate will neutralize the acidity produced by 32 lbs. of sulfur. Imperial Valley soils contain as much as 200,000 lbs. or more, of precipitated lime per acre 6" of soil.

The oxidation of sulfur particles from an application of 500 - 1,000 lbs. per acre can produce small zones of decreased pH around the particles of sulfur. Roots growing into these zones could benefit from increased solubility of phosphorus and/or micro-nutrients. It may well be possible to utilize soil sulfur as a means of increasing the efficiency of soil phosphorus, especially during this period of phosphate shortage.

Several acidifying materials are available for use on high pH soils Some of the more useful materials are shown on the following page:

ACIDIFYING MATERIALS

MATERIAL	% SULFUR	POUNDS REQUIRED TO EQUAL 1 POUND OF SULFUR
Soil Sulfur	99+	1
Sulfuric Acid	31	3.2
Calcium Polysulfide	22	4.54
Ammonium Polysulfide	40-45	2.2 - 2.5
Ferric Sulfate	17	5.9
Ammonium Sulfate	25	4

SODIC SOILS

Sodic soils, by definition, contain 15% or more of their exchangeable ions as sodium ions (Na^+). High sodium soils are dispersed and cause problems with water infiltration and free exchange of gases between the root zone and the atmosphere. Reclamation of sodic soils requires two basic steps. First, sodium ions must be replaced from clay surfaces and second, these ions must be leached from the root zone. Calcium ions are used to replace sodium from the clay surfaces.

In non-calcareous soils, gypsum ($CaSO_4$ $2H_2O$) is the material used to supply calcium ions for reclamation of sodic soils As a rule of thumb, one ton of gypsum will dissolve in an acre-foot of water.

Gypsum is a neutral salt and has no affect on soil acidity. A common misunderstanding among agricultural people is that the sulfur in gypsum causes a lowering of soil pH. The sulfur in gypsum is already completely oxidized to the sulfate form. Therefore, it has no affect on soil pH. If a soil has a pH in excess of 8.5, as a result of adsorbed sodium, the addition of gypsum will cause the pH to be lowered somewhat as the sodium ions are replaced by calcium and leached from the soil. This is not the result of the sulfate from gypsum, however.

In calcareous soils, (soils containing precipitated lime) there is generally sufficient calcium present for reclamation of sodic conditions. Sulfur can be added to these soils to aid in reclamation. Sulfuric acid produced by the oxidation of sulfur, reacts with lime to release calcium ions. These in turn replace sodium ions from the exchange sites on clay particles. Subsequent leaching moves the sodium ions downward below the root zone.

Gypsum can also be used on calcareous soils as a source of calcium ions. A decision as to which amendment to use must be made on the basis of availability and economics. Economics should include not only the cost of product, but also transportation and application costs as well as any side benefits which may be beneficial to crop production.

One ton of pure sulfur is equivalent to 5.4 tons of pure gypsum. Most soil sulfur is 99% pure, while gypsum ranges from about 55% to about 85%. Ten tons of 55% gypsum would be required to equal one ton of sulfur. The sulfur application could provide side benefits from decreasing soil pH.

SOIL CRUSTING AND COMPACTION

Soils may be impermeable due to fine soil texture or compaction caused by traffic in the field. Chemical amendments such as gypsum and sulfur are not beneficial to these soils. A grower would be wise to determine the cause of water infiltration problems before spending money on a soil amendment that cannot correct his particular problem.

The addition of organic matter to problem soils of this type may aid in opening them up. Decomposing organic matter binds soil particles together forming larger soil pores. Root growth from crops can also aid in opening up compacted soils.

It may be necessary to chisel or rip these soils first in order for roots to grow into the compacted layer. Above all, in these soils, every effort must be made to minimize compaction by good management of crops, water and equipment.

CONCLUSION

The use of soil amendments is a tool to aid in crop production on problem soils. Tools must be selected to match particular needs. A carpenter would not select a saw to drive nails. Neither should a grower apply amendments to a problem soil without first determining the cause of the problem and then selecting the proper amendment to do the job.