Prevent Chlorosis in Plants with use of Sulfuric Acid

*by John Ryan, Seiichi Miyamoto and Hinrich L. Bohn**

Concentrated sulfuric acid, when properly injected into the soil, can increase plant growth on calcareous and alkaline soils, according to a recent study at The University of Arizona.

Problems associated with calcareous soils containing high amounts of lime have long been recognized. These soils are widespread in the West especially in Arizona which also has alkaline soils resulting from excessive amounts of sodium. Soil pH is a major factor governing the solubility and availability of plant nutrients. Trace elements such as iron, manganese and zinc may be deficient and limit plant growth under conditions of high pH Diagnosis of such disorders through soil and plant analysis is difficult and time consuming. Correction of plant micronutrient deficiencies may involve expensive soil applications of chelated forms of these elements and/or repeated foliar treatments during the growing season.

The incidence of iron deficiency in Arizona soils is more common than that of manganese or zinc. Plants deficient in iron fail to develop chlorophyll and become chlorotic or pale green to white in color. The term "lime induced" chlorosis is often used to denote iron deficiencies on naturaly calcareous soils. This is misleading in view of the marked differences that exist between plant growth on naturally calcareous soils and on acid soils made calcareous through liming. Chlorosis may also be caused by deficiencies of other elements such as nitrogen, as well as pool soil aeration.

Plant species vary in their susecptibility to trace element deficiency. Iron deficiency has been observed in several Arizona crops such as sorghum, cotton, peas, peanuts, citrus and in many ornamental plants.

Iron nutrition is influenced by many factors such as soil moisture, the quality of the irrigation water, the nature of the crop grown and by interactions with other trace elements and with phosphorus. However, the most important factor is the supply of available iron in the soil.

Early research in Arizona and Utah showed that acidification or lowering of the pH of calcareous soils using elemental sulfur increased plant growth by increasing the solubility of soil nutrients. Sulfur has to be oxidized by micro-organisms to form sulfuric acid before it can become effective. The reaction rate varies with soil and environmental conditions. In recent years, interest has developed in using sulfuric acid directly. The production of surplus amounts of sulfuric acid from copper smelting in Arizona emphasizes the desirability of providing feasible outlets for the material.

The possibility of increasing plant yields by injecting small amounts of concentrated sulfuric acid into soil was studied in the greenhouse. The Anthony and Cave soils are calcareous while the Stewart and Cogswell have high levels of exchangeable sodium. Soil characteristics are shown in Table 1.

Table 1. Properties of experimental soils.

Soil	*Mechanical Analysis* Sand (%)	Silt & Clay (%)	Titratable Basicity mole/kg	*Saturation Extract* Na (ppm)	Ca (ppm)	Mg (ppm)	pH
Anthony	69.1	30.8	0.36	13.1	290.0	23.0	7.3
Cave	44.5	45.5	0.96	13.3	48.0	13.5	7.7
Stewart	50.8	49.2	1.08	1500.0	5.6	0.3	9.9
Cogswell	28.5	71.5	1.80	260.0	12.0	16.8	8.9

Two kilogram lots of soil were placed in pots. Concentrated sulfuric acid was injected into the soil to a depth of 8 cm using a glass pipette and rubber bulb. In this way only the soil at the site of the injection was affected. The amounts of acid applied ranged from 0.05 to 1 percent of the total soil weight. Each treatment was duplicated. The purpose of the treatment was to create an acidified zone which would supply sufficient quantities of iron and other metals for maximum plant growth. This approach is analogous to banding of solid fertilizer in the soil.

Table 2. Effect of sulfuric acid application on the growth of peas and sorghum.

Sulfuric acid % Soil wt.	*Anthony* Sorghum	Peas	*Cave* Sorghum	Peas	*Cogswell* Sorghum	Peas	*Stewart** Sorghum	Peas
0	100%	100%	100%	100%	100%	—	100%	100%
0.05	164	100	206	132	250	—	126	153
0.10	174	103	230	145	300	—	137	159
0.20	180	104	264	165	550	—	137	159
0.50	190	109	276	165	600	—	142	165
1.0	190	120	251	186	350	—	140	165
Control yields g/pot	4.7	4.5	3.3	2.9	0.2	—	1.9	1.7

* *Peas did not grow except at the highest rate of sulfuric acid.*

**Post-Doctoral Research Associates, from Ireland and Japan, and Associate Professor, respectively, Department of Soils, Water and Engineering, University of Arizona.* *This work was supported by a grant from the Arizona Mining Association.*

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The soils were cropped with sorghum and peas for two months. Throughout the growth period, the pots were surface irrigated with distiled water. Dry matter yields are presented in Table 2 and expressed as a relative percentage of the yields from the untreated soils. The plant tissue was analyzed for iron, manganese, zinc, sodium and phosphorus.

The sulfuric acid treatment increased the yields of peas and sorghum on the soils tested with the exception of peas on the Stewart soil. As peas are a sodium-sensitive crop, it is probable that growth suppression was due to the high levels of exchangeable sodium in this soil. That only measurable amounts of growth occurred at the highest level of acid application may have been due to a reduction in levels of exchangeable sodium and an improvement in soil physical conditions. On the Stewart soil, also, sorghum showed large relative increases due to the acid treatment. The amounts harvested were, however, less than in the case of the other three soils. In general, the greatest proportionate increase occurred with the first increment of sulfuric acid. Greater responses occurred with sorghum than peas on the calcareous Anthony and Cave soils.

Figure 1. Effect of sulfuric acid on growth of peas on Cogswell soil.

Plants grown on the untreated soils showed symptoms of iron chlorosis which was more evident in the case of sorghum. New leaves were chlorotic with symptoms becoming more accentuated as the growing season progressed. For both species the lowest level of sulfuric acid was sufficient to prevent the occurrence of symptoms. Figure 1 illustrates the effect of the acid treatment on peas grown on the Cogswell soil while the effect on sorghum on the Cave soil is depicted in Figure 2. The results of the plant tissue analysis indicate that iron was a limiting factor to growth. Iron uptake in general increased with increasing levels of acid while uptake of manganese, zinc, sodium and phosphorus showed no such trend.

Figure 2. Effect of sulfuric acid on growth of sorghum on Cave soil.

Interpretation of iron analysis data is complicated by the fact that total iron in the plant is not always related to growth. This is due to the inactivation of iron in the plant tissue reducing the metabolically active fraction. In some cases chlorotic plants may contain higher amounts of iron than non-chlorotic plants.

This experiment demonstrates the effectiveness of partial acidification of calcareous soils to increase nutrient availability and confirms similar studies conducted elsewhere. Due to the large buffering capacity of most Arizona soils, bulk treatment of the soil would be impractical due to the quantities of acid required. It would also cause excessive amounts of soluble salts in the soil adversely affecting plant germination. Increasing the salt concentration of groundwater would be a possible undesirable outcome of such treatment. A recent study by Mathers (Agron. J. 62:444, 1970) showed that banding of sulfuric acid increased yields of sorghum. Untreated plants responded to spraying with ferrous sulfate indicating that iron was the limiting factor. Favorable results were also reported from Colorado where sulfuric acid increased yields of lettuce, sugar beets and barley (Sulphur Institute J. 6:2-7, 1970). Band application of sulfuric acid has been introduced on a pilot scale in Cochise County where increased yields of sorghum were attributed to improved water penetration and increased availability of micronutrients. However, no reliable field data are available to support these contentions.

This experiment highlights the interesting possibility of solving an indigenous soil problem with an easily available economic material. General recommendations for widespread use of sulfuric acid as a soil ammendent must be based on more extensive field studies to identify the component effects of treatment on soil and plant properties.