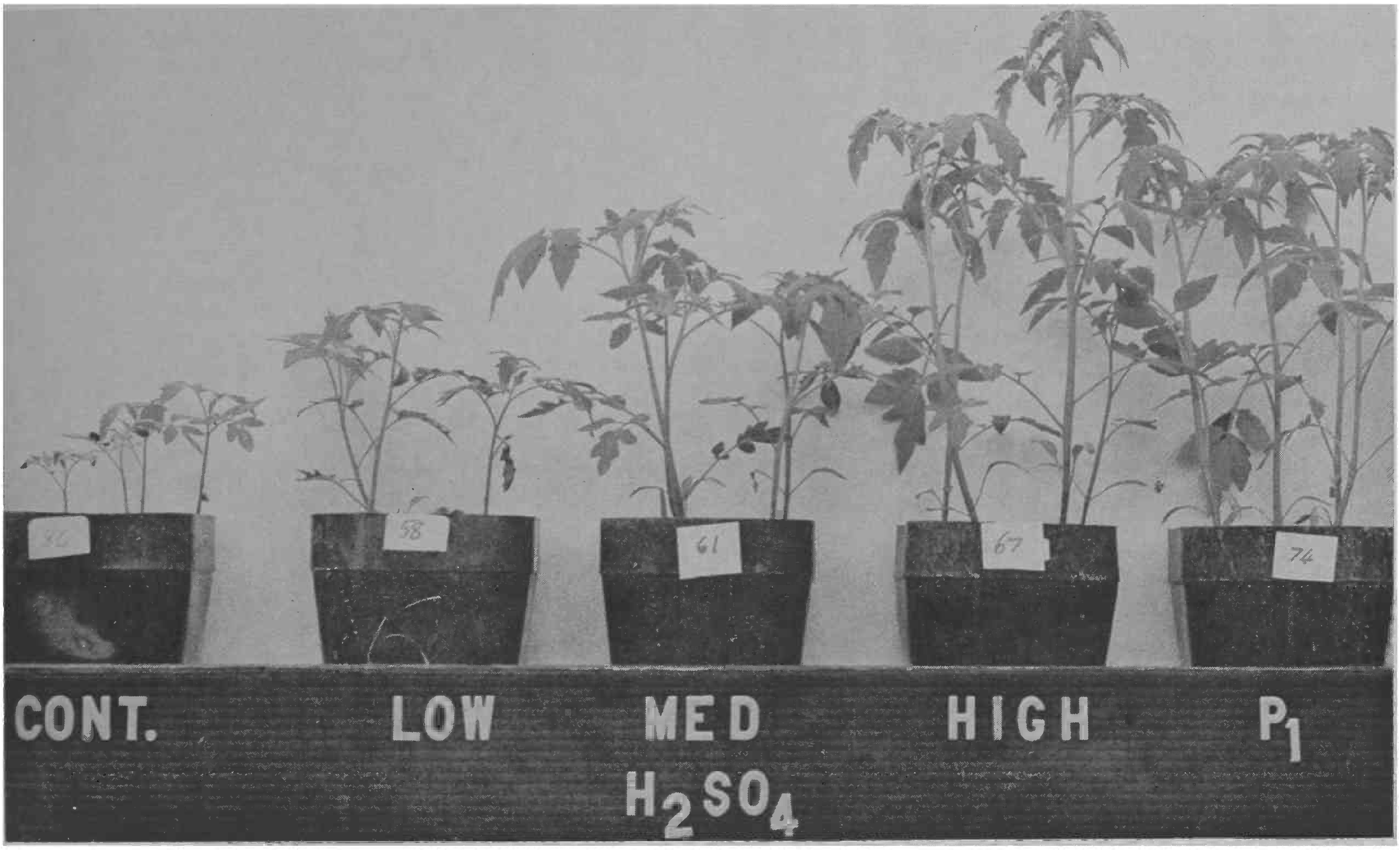

Figure 1. Effect of spot treatment with sulfuric acid on growth of tomatoes grown on the Comoro soil. (Low = 300 Med. = 600; High = 1200 P_1 = 300 lbs./acre.)

Use of Sulfuric Acid on Phorphorus Deficient Arizona Soils

*by John Ryan and J. L. Stroehlein**

The amount of native or naturally occurring soil phosphorus (P) and residual fertilizer in calcareous Arizona soils is adequate for many agricultural crops even though P which is chemically available to the plant is only a fraction of the total amount of the element in the soil. While some Arizona soils are known to be deficient in available P, it is likely that in marginally deficient soils, P will become more deficient under more intensive cropping systems, particularly for short season crops. In the study reported herein it was found that sulfuric acid applied at low rates was effective in increasing both vegetative yield and P uptake of tomato plants grown on a calcareous soil low in available P in the greenhouse.

In acid and neutral soils P is mainly associated with iron and aluminum compounds while in calcareous soils of high pH, calcium is the principal element involved. The rate at which calcium phosphate compounds release P to growing plants depends on the chemical nature of these compounds as well as the texture and surface area of the soil. Available data suggest the P occurs in calcareous soils in Arizona principally as hydroxyapatite which is relatively insoluble but potentially available. (See Arizona Agricultural Experiment Station Bulletin A-42).

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A relatively minor portion has been shown to occur as stable and insoluble compounds such as carbonatoapatite and fluroapatite. Calcium phosphate compounds become more soluble by reducing the pH of the soil. The form of phosphate ion most readily taken up by plants occurs in the slightly acid to neutral range. The type of crop as well as environmental factors such as temperature are important. Cool season crops such as small grains and lettuce are more likely to respond than most warm season crops. Alfalfa is probably the warm season crop which responds best to P applications.

Several acid producing materials such as elemental sulfur, sulfuric acid, calcium and ammonium in polysulfides, and sulfates of iron and aluminum have been used in the past on calcareous soils. Responses in terms of increased micronutrient availability and improved water penetration have been frequently observed. Most studies involved the use of elemental sulfur which gradually oxidizes in the soil to form sulfuric acid. Its mode of

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action is thus different from that of sulfuric acid which reacts immediately with the soil. Whether a response to P occurs or not depends upon the relative amounts of calcium and P dissolved by the acid treatment as large amounts of soluble calcium tend to depress phosphate solubility. In most studies of soil acidification the effect on P in relation to plant growth has received only incidental consideration. Consequently, soils selected were not primarily deficient in P which would tend to invalidate conclusions in this regard.

Sulfuric acid has been used as band treatment in soils and in irrigation water under field conditions. However, no direct comparison between various methods of application have been made at equivalent rates of acid. In this greenhouse experiment four methods were compared: 1) applying acid in the irrigation water, 2) uniformly mixing the acid with the soil, 3) acid application as a layer and 4) as a spot treatment. Treatments were compared at a rate equivalent to 1200 lbs/acre. In the case of the spot treatment rates of 300 and 600 lbs/acre were also used. A higher level of acid, equivalent to 1% of the soil weight, was used as a layer or band treatment. As a comparision two rates of P were included, 300 and 600 lbs/acre. While no direct comparison can be made between field and greenhouse studies there rates were such as to alleviate any P deficiency.

Sulfuric acid was added in sufficient water to bring the soil to field capacity and poured on the surface of the potted soil in the case of treatment 1. Two hundred gram lots of soil were treated with acid and water, dried and mixed with the remaining 1800 g for treatment 2 and as a 2 cm layer in the pot at a depth of 6 cm for treatment 4. For the spot treatment appropriate amounts of acid were injected into the center of the pot at a depth of 10 cm using a pipette and rubber bulb. Untreated control pots were also included and all treatments were replicated five times. Adequate and equal amounts of N were supplied as NH_4NO_3 in solution.

The soils used in the study were a Comoro sandy loam which was P deficient and a Lateen sandy loam which had previously shown a response to added P when greenhouse tomatoes were grown under cooler temperatures during late winter. Both soils had a pH of 8.2. The $CaCO_3$ equivalents were 6.0% and 12.5% and the P available contents as extracted by CO_2 and water were 1.7 and 6.9 ppm, respectively.

The randomized pots were seeded with tomatoes (*Lycopersicum esculentum*) at a depth of 1 cm in March. After establishment, the seedlings were thinned to four plants per pot. The plants were harvested after nine weeks, dried, weighed, and analyzed for total P. The cropped soil was subsequently sampled from the zones of acid treatment. The pH was determined using a 1:2.5 soil water ratio and soluble P in the extract was determined.

Marked differences were observed in behavior between the two soils. On the Lateen soil, deficiency symptoms were apparent in the early stages of growth in March but disappeared with the onset of higher temperatures. The irrigation treatment and high level of acid applied as a layer produced slightly higher yields than the controls, but they were not significant. A comparison of the various treatments is shown in Figure 4. Yields from the Lateen soil were greater than from the Comoro soil. The absence of any significant response indicates that from the Lateen soil contained an adequate level of available P under the conditions of this study. This is further evidenced by the higher levels of P in the plant tissue from the Lateen soil as well as by the amounts of available P as shown by the soil tests.

Significant responses occurred in growth and P uptake on the P deficient Comoro soil. Figure 2 shows the effect on plant growth from the four methods of application. The patterns of P uptake were similar to those of dry matter yield and are depicted in Figure 3. The low uptake of the acid treated pots relative to the applied P may be partly due to positional unavailability in the early stages of growth. As the plant roots permeate the soil, the P solubilized in the acid treated zones would be available for uptake. The acid applied at 1200 lbs./acre both as a band and a spot treatment produced yields almost as high as the P fertilizer at 300 lbs./acre. High yields were also shown where the acid was applied to the soil surface in the irrigation water. Mixing of the acid with the bulk of the soil was the least effective of the four methods. The slope of the response curve for the spot treatment suggests that maximum growth could be obtained by increasing the rate of acid (Fig. 1). When the acid was applied at 1% of the soil weight as a band treatment, a depression in yield resulted. This was probably due to growth inhibition as a result of soil acidity as the pH of the layer was 3.9 No such effect was observed with the Lateen soil which had a pH of 6.5 after cropping, reflecting the higher lime content of this soil. Plants growing on the untreated Comoro soil showed symptoms of P deficiency which also occurred with the low rate of acid as a spot treatment and when the acid was thoroughly mixed with the soil. In the former case it is prob-

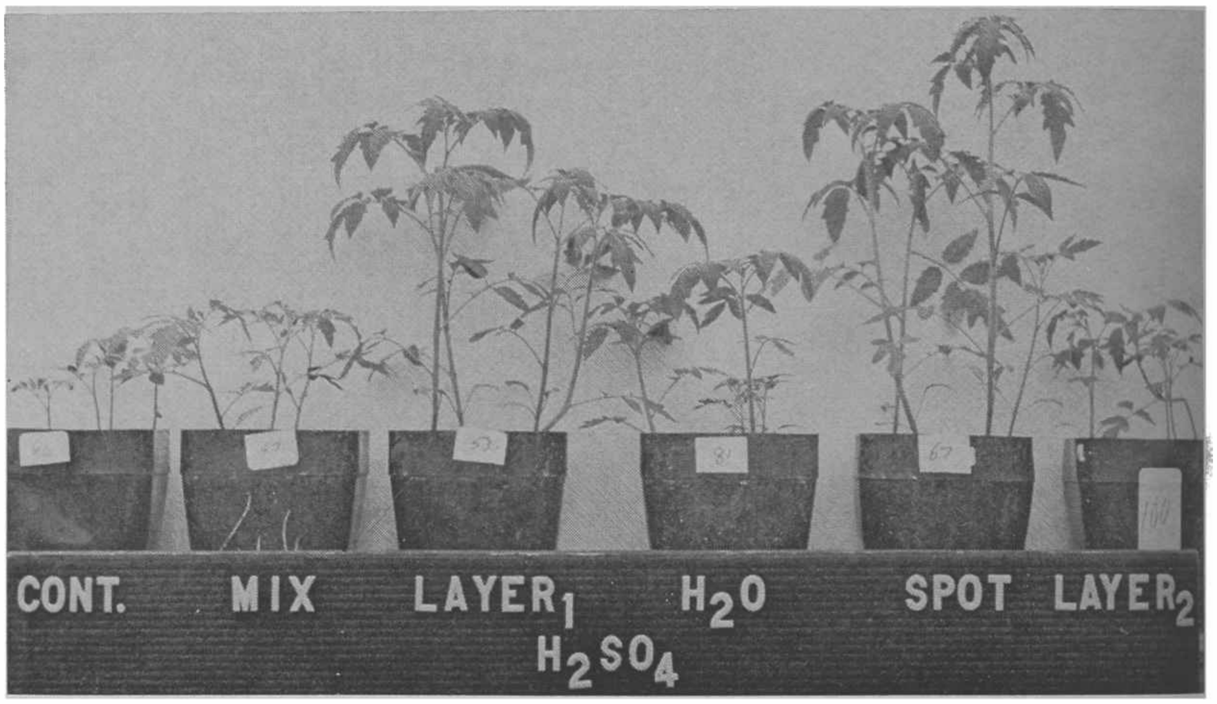

Figure 2. Comparison of sulfuric acid application methods on growth of tomatoes on calcareous Comoro soil. (H_2SO_4 at 1200 lbs/acre applied as spot treatment, mixed with soil, as a 2 cm.-layer, in water on pot surface and as a layer at 1% of the soil weight.)

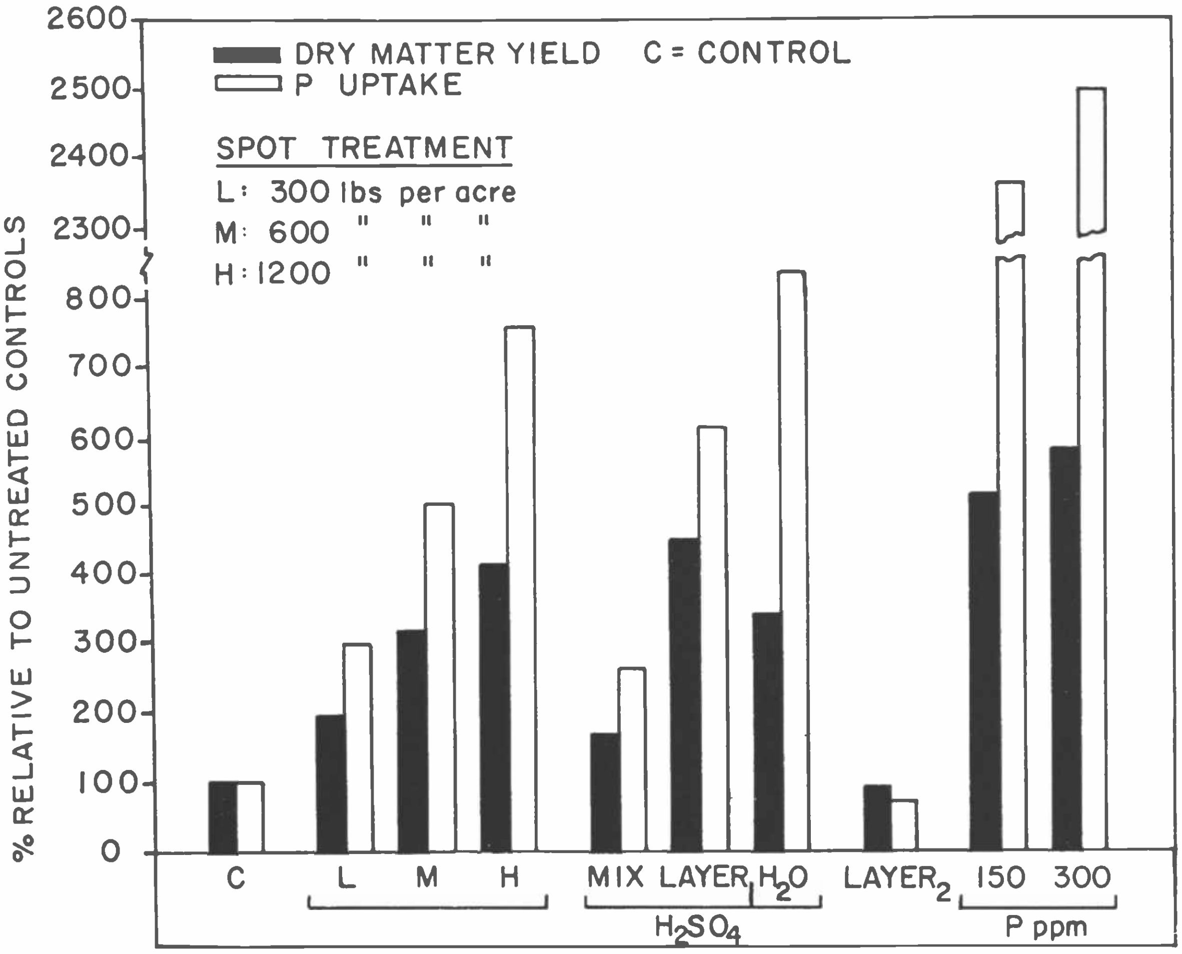

Figure 3. Effect of sulfuric acid application on relative dry matter yield and P uptake of tomatoes grown on Comoro soil.

able that sufficient P was not released while in the latter it is likely that the initially dissolved P was reprecipitated when mixed with the untreated soil, since insufficient acid was applied to change the pH of the entire soil volume.

Measurements of soil pH and water soluble P served to explain the results observed. Only a small fraction of the soil was influenced by the spot treatment. The pH of the treated zone in the Comoro soil decreased from 8.2 to 6.4 while the water soluble P increased from 1 to 8 ppm. The effect of the acid was limited to the treated zone. The increased supply of P from the zone was effective in promoting plant growth. The treatment effect was less pronounced in the Lateen soil with pH decreasing from 8.2 to 7.0 and P increasing from 0.7 to 1.8 ppm. In neither soil had the mixing of acid with the bulk soil any effect on P solubility. The acid treatment in the irrigation water reduced the pH of the surface centimeter of the Comoro soil to 7.8 and increased P solubility to 3.8 ppm accounting for the improved growth and uptake of P. With layer treatment at the high rate of acid there was no increase in soluble P. This may be due to fixation of the initially dissolved P by iron and aluminum which were dissolved by the acid treatment.

The results indicated the potential use of sulfuric acid for increasing P availability and hence plant growth on P deficient soils. The rates of application were such to suggest that sulfuric acid might be economically used on a field scale. While banding was shown to be the most effective method, this situation may not be easily simulated in the field. Injecting behind a plow moldboard is a possibility. This may also help to destroy existing plow soles. However, no information is available as to the possible effect of such a practice. Injection of acid into the soil has been practiced in the field, followed by tillage which results in complete incorporation into the soil, possibly decreasing the effectiveness of the application. In contrast, the effectiveness of elemental sulfur would be enhanced by soil incorporation. Cultivation would influence the residual or long term effect of the acid treatment which can only be reliably measured in the field. The advantages of using sulfuric acid for improving P availability are further enhanced when trace element deficiencies occur in these soils. The latter effect has been shown in the March-April issue of this journal. With increasing costs and a projected decrease in the supply of P fertilizers, sulfuric acid may prove to be an economic and effective substitute.

As yet, no economic analysis has been made of sulfuric acid in Arizona agriculture. While the agronomic advantages are obvious at this stage we can only speculate as to the dollar returns to the farmer from using sulfuric acid. It is important to realize that like most farm chemicals, sulfuric acid requires careful handling. It should only be used as an amendment for specific purposes based on soil and water analysis and professional advice.

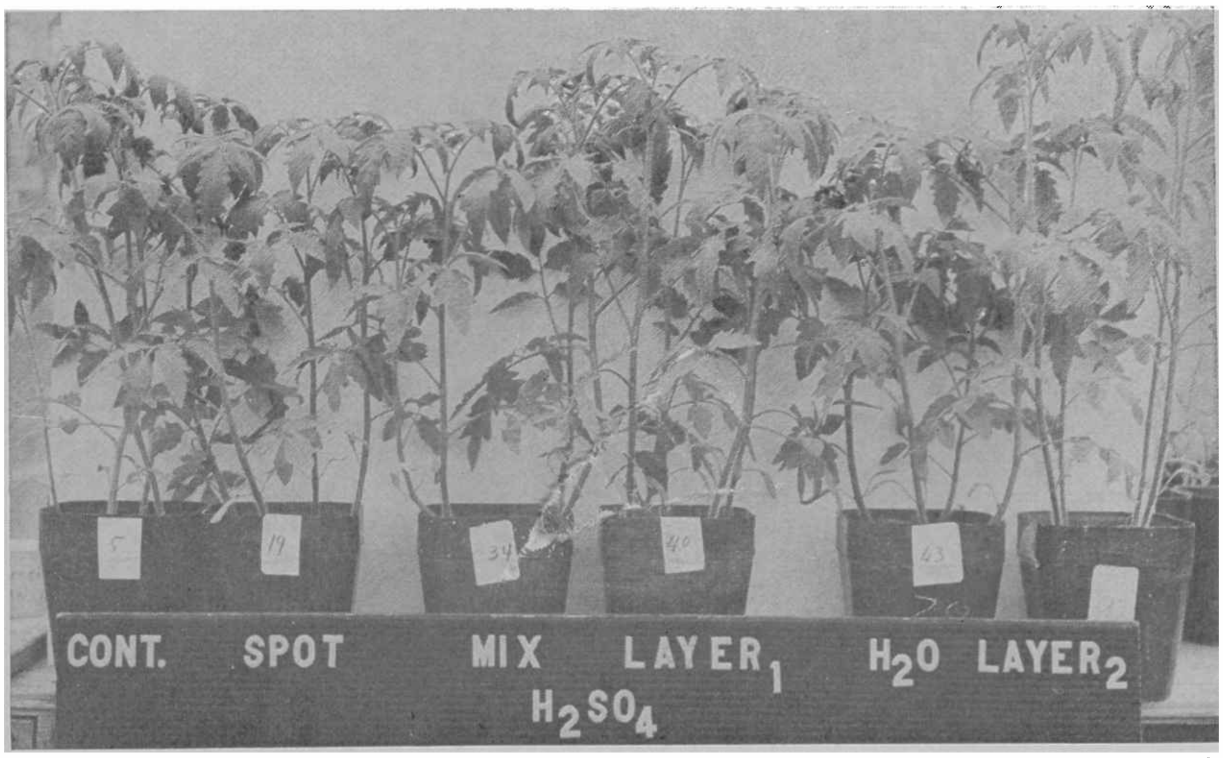

Figure 4. Comparison of sulfuric acid application methods on growth of tomatoes on calcareous Lateen soil. (H_2SO_4 at 1200 lbs/acre applied as a spot treatment, mixed with the soil, as a 2 cm-layer, in water on pot surface and as a layer at 1% of the soil weight.)