Research Reports:

Lowering of Calcareous Soil pH in Field-Grow Containers[1]

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Abstract

Wettable sulfur (S) mixed with a Pineda fine sand (an Arenic Glossaqualf with 7.8 pH and 1.5% calcium carbonate equivalent) quickly acidified the soil, but the effect was lost within 8 weeks at low application rates and within 21 weeks at the highest rate (1 g S/kg soil or 1 lb S/1000 lb soil). Granular S mixed with the soil took one year to produce maximum pH reduction of 0.3, 0.4, and 0.9 pH units at 250, 500, and 1000 mg S/kg soil (1/4, 1/2, and 1 lb S/1000 lb soil), respectively. Wettable sulfur (S), surface-applied at 100 g/m^2 (0.036 oz/10 ft^2), lowered the pH of the upper 5 cm (2 in) of soil to the 5.6 to 5.8 range for one to two months before the pH returned to >7.0; granular S took about five months to lower the pH to 6.7 but the soil pH was 6.2 two years after application. Wettable S at 20 g/kg soil (0.32 oz S/lb soil) in a small cylindrical zone resulted in a temporary depression of pH within the treated zone but had no effect on pH in other areas of the container. Mixing up to 1.0 g iron sulfate/kg soil (0.016 oz/lb soil) failed to reduce soil pH. Live-oak trunk diameter and plant height were not affected by any of the soil treatments in the two-year experiment.

Index words: Sulfur, iron sulfate, *Quercus virginiana*

Significance to the Nursery Industry

Lowering the pH of calcareous soil with sulfur is temporary since the reserve soil carbonates reestablish the equilibrium as soon as the acid produced from the sulfur is neutralized. Wettable sulfur mixed with the soil lowers pH rapidly (within 2 weeks), but the effect is short-lived (back to near original pH within 8 weeks at low application rates and within 21 weeks at the high rate). Granular sulfur lowers pH more slowly than wettable sulfur, but its effects are longer-lasting (months rather than weeks).

Surface application of granular sulfur (0.2 lb/10 square feet) slowly lowered pH of the surface 2 in of soil over a period of two years. For long-term crops, this effect may be more beneficial than the more drastic but shorter-lived lowering of pH.

Iron sulfate applied at fertilization rates does not lower pH of calcareous soil. There is too much reserve soil carbonate for the small acidifying effect of the iron sulfate.

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Given the lack of response for the parameters measured, and the acceptable growth of the trees, it appears that live oak is not particularly sensitive to calcareous soil pH and resultant effects on plant nutrition.

Introduction

Plant production in soils containing free calcium carbonate frequently is hindered by nutrient deficiencies resulting from the relatively high soil pH (7.5 to 8.2). Reduced solubility of phosphorus (P), iron (Fe), manganese (Mn), and zinc (Zn) is a well-recognized effect of elevated soil pH (4, 6). For crops which are known to be particularly sensitive to high soil pH (so-called acid-loving plants), lowering soil pH by additions of acidifying materials such as elemental sulfur (S) or aluminum sulfate is a widely-recommended practice (1, 3, 9).

Most recommendations for lowering soil pH note that the effect will only be temporary when free carbonates are present. This point is poorly understood, and many fail to realize that growing acid-loving species in calcareous soil requires continuous effort to avoid high-pH-induced nutrient deficiencies.

Variations in soils and oxidation conditions make it difficult to predict the quantities of S or other acidifying materials required to accomplish the desired lowering of pH (2). Pratt and Bair (7) suggested a procedure for determining the S requirement, but it is not in general use. Instead, based on the assumed complete oxidation of S to sulfuric acid in soil, and the fact that the molecular weight of $CaCO_3$ is 3 times the molecular weight of S, one-third as much S is generally recommended to lower a soil's pH as lime is recommended to raise the pH an equivalent amount.

Lowering pH once plants are growing in a soil presents the problem of getting the acidifying agent into the soil where the pH change is needed. Surface-applied acidulents need to be sufficiently soluble to move through the soil in percolating water, or they need to be cultivated into the soil. If the acidulent could be mixed with the soil prior to planting, or if pre-selected parts of the root zone could be acidulated, plant roots would encounter amended soil as they developed. The well-delineated rooting zone of plants grown in Field-Grow Containers presents a situation for testing the feasibility of different systems of altering soil pH for production of nursery plants.

The purpose of this study was to test the effectiveness of sulfur, iron sulfate, and several application methods in lowering pH of calcareous soil. Rates of chemical were chosen to represent a range which exceeded those normally used by growers.

Materials and Methods

The experiment was conducted in a Sarasota County, Florida commercial nursery on a soil mapped as Pineda fine sand (Arenic Glossaqualf, loamy, siliceous, hyperthermic). The soil had an average calcium carbonate equivalent of 1.5%, a pH (1:2 soil:water) of 7.8, and Mehlich-1-extractable values for P, K, and Mg (8) of 40, 48, and 20 ppm soil, respectively. Mollusk-shell fragments were readily visible on the soil surface after rain or irrigation. The management was experiencing unsatisfactory growth of live oaks (*Quercus virginiana* Mill.) and hypothesized that high soil pH was causing nutritional disorders. To test the hypothesis, trees were planted in Field-Grow Containers[3] filled with soil amended as described below.

At initiation of the experiment on Feb 7, 1986, the top 30 to 40 cm (12 to 16 in) of soil from each tree-planting hole was thoroughly mixed in a rotary mixer and used to fill a Field-Grow Container into which a year-old live oak was transplanted. The trees had been growing in 1 gal containers (#1) of soil-less media. Treatment chemicals (Table 1) were pre-measured and mixed with soil in the mixer. Field-Grow Containers, about 0.5 m (18 in) in diameter and 0.3 m (12 in) to the fill line, were estimated to hold 80 kg (180 lb) of soil. A randomized complete block design with 13 treatments and 16 single-plant replications was used. Trees were planted about 2 m (6 ft) apart in a square pattern and, after installation of the experimental treatments, received the same cultural practices as other trees in the nursery.

The 20 g (0.04 lb) of S used for Treatments 11 and 12 was applied evenly over the soil surface inside each Field-Grow Container. That rate was equivalent to 100 g elemental S/m^2 or 1000 kg/ha (0.2 lb/10 ft^2 or 900 lbs/acre).

For installing Treatment 13, 20 g (0.04 lb) of wettable S were mixed with about 2.5 l (2.5 qt) of soil, and the mixture was poured into a 10 cm (4 in) diameter pipe which was held in position at the Field-Grow Container wall while the tree was planted. The pipe was then carefully removed, leaving a column of amended soil which extended from the surface to the bottom of the container.

Tree-trunk diameter 15 cm (6 in) above the soil surface, and tree height, were measured at initiation of the experiment and after the first and second growing seasons post-treatment. Soil samples for monitoring pH were taken from the same eight randomly-selected replications 2, 8, 21, 48, and 100 weeks after application of treatments. Samples were taken from the top 15 cm (6 in) of soil in Treatments 1 through 10. Samples from Treatments 11 and 12 were divided into the top (T) 0 to 5 cm (0 to 2 in) and the bottom (B) 5 to 15 cm (2 to 6 in) portions. Treatment 13 was sampled 0 to 15 cm (0 to 6 in) deep inside (Z) and outside (C) the treated zone, the latter on the opposite side of the tree from where the S was placed. Soil pH was measured with a glass electrode pH meter in a suspension consisting of one volume of soil to two volumes of water.

Results and Discussion

Soil pH changes. The effect of the treatments on soil pH is summarized in Table 2. Mixing wettable S with the soil (Treatments 2, 3, and 4) lowered the pH dramatically within two weeks of application. For example, 1000 mg S/kg soil (1 lb S/1000 lb soil) lowered the soil pH from 7.8 to 5.5. However, by week eight the pH had risen considerably, with the treatments receiving 250 and 500 mg wettable S/kg soil (1/4 and 1/2 lb/1000 lb) having pH values of 7.4 and 7.2, respectively. Even at the 1000 mg (1 lb) rate, the pH had risen to 7.3 within 21 weeks of treatment. Two years (100 weeks) after application, effects of S treatment were no longer evident.

Granular S mixed with soil (Treatments 5, 6, and 7) at the same rates as wettable S had a much slower effect on soil pH, but the effect was more long-lasting. This is a

[3]Manufactured by Root Control, Inc., Oklahoma City, OK.

Table 1. Description of soil treatments for Field-Grow Containers[z].

Trt. No.	Description	Rate Metric	Rate U.S.	Application Method
1	no chemical			
2	wettable sulfur	250 mg/kg	1/4 lb/1000 lb	mixed in thoroughly
3	wettable sulfur	500 mg/kg	1/2 lb/1000 lb	mixed in thoroughly
4	wettable sulfur	1000 mg/kg	1 lb/1000 lb	mixed in thoroughly
5	granular sulfur	250 mg/kg	1/4 lb/1000 lb	mixed in thoroughly
6	granular sulfur	500 mg/kg	1/2 lb/1000 lb	mixed in thoroughly
7	granular sulfur	1000 mg/kg	1 lb/1000 lb	mixed in thoroughly
8	iron sulfate	250 mg/kg	1/4 lb/1000 lb	mixed in thoroughly
9	iron sulfate	500 mg/kg	1/2 lb/1000 lb	mixed in thoroughly
10	iron sulfate	1000 mg/kg	1 lb/1000 lb	mixed in thoroughly
11	wettable sulfur	20g/container[y]	0.04 lb/cont.	on soil surface
12	granular sulfur	20g/container[y]	0.04 lb/cont.	on soil surface
13	wettable sulfur	20g/container[y]	0.04 lb/cont.	mixed in a 10 cm (4 in) diameter column (zone)

[z]Approximately 0.5 m (18 in) diameter and 0.3 m (12 in) high, containing 80 kg (180 lb) soil.
[y]Equivalent to 100 g/m^2 (0.2 lb/10 ft^2).

Table 2. Average soil[z] pH in Field-Grow Containers as influenced by treatments. Each value is the average of eight replications.

TREATMENT No.	Description	Rate & Placement	WEEK POST-TREATMENT 2	8	21	48	100
	- mg/kg soil -		soil pH				
1	None		7.8	7.5	7.8	7.6	7.4
2	Wettable sulfur	250, mixed	6.5	7.4	7.7	7.3	7.5
3	"	500, "	5.8	7.2	7.6	7.5	7.4
4	"	1000, "	5.5	6.5	7.3	7.2	7.4
5	Granular sulfur	250, mixed	7.6	7.7	7.7	7.3	7.3
6	"	500, "	7.7	7.7	7.2	7.2	7.0
7	"	1000, "	7.5	7.4	7.0	6.7	6.9
8	Iron sulfate	250, mixed	7.7	7.7	7.6	7.5	7.4
9	"	500, "	7.8	7.6	7.8	7.5	7.3
10	"	1000, "	7.7	7.8	7.8	7.5	7.4
	- g/bag -						
11T[y]	Wettable sulfur	20, on surface	5.6	5.8	7.1	7.3	6.8
11B[x]	" "	" "	7.7	6.8	7.1	7.3	7.3
12T	Granular sulfur	20, on surface	7.5	7.7	6.7	7.1	6.2
12B	" "	" "	7.4	7.5	7.6	7.4	7.2
13Z[w]	Wettable sulfur	20, mixed zone	5.3	5.5	7.3	7.4	7.5
13C[v]	" "	" "	7.9	7.7	7.8	7.6	7.5
	Dunnett's (5% level)		1.2	1.1	0.9	0.6	0.7

[z]Mapped as Pineda fine sand. Initial pH in early February 1986 was 7.8.
[y]T = 0 to 5 cm (0 to 2 in) depth.
[x]B = 5 to 15 cm (2 to 6 in) depth.
[w]Z = inside treated zone, sampled 0 to 15 cm (0 to 6 in) deep.
[v]C = outside treated zone, sampled 0 to 15 cm (0 to 6 in) deep.

function of particle size, since the granular S had a much smaller surface area for reaction than the wettable S. One year was required for maximum soil pH reduction, at which time the 250, 500, and 1000 mg granular S (1/4, 1/2, and 1 lb) rates had reduced the pH 0.3, 0.4, and 0.9 pH units, respectively. The effects were still noticeable two years after application, although pH of the 250 mg (1/4 lb) treatment was approaching that of the untreated soil.

Iron sulfate at rates of 250, 500, and 1000 mg/kg soil (1/4, 1/2, and 1 lb/1000 lb soil) failed to measurably lower soil pH. While iron sulfate has soil-acidifying properties, the rates used (appropriate for supplying iron as a nutrient) were too low to change the pH of the calcareous soil in this experiment.

To evaluate the effects of surface-applied S, the top 5 cm (2 in) of soil depth was sampled separately from the next 10 cm (4 in) of depth. Soil pH measurements for the surface-applied treatments exhibited considerable variation, which was probably a reflection of the difficulty in sampling to a consistent depth in a treatment where the S was applied at the surface only. In the case of surface-applied wettable S (Treatment 11), within two weeks of application the pH had dropped to 5.6 in the upper 5 cm (2 in) of soil, and within eight weeks the pH of the next 10 cm (4 in) of soil had dropped to 6.8. Such results indicate that the acidifying effect was moving downward through the soil at a fairly fast rate. At the termination of the study, the pH of the surface layer was about 0.5 pH unit lower than that of the untreated soil.

Surface-applied granular S (Treatment 12) took longer to lower soil pH than did other treatments but pH reduction lasted longest. No effect was detected for over two months in the 0 to 5 cm (0 to 2 in) layer of soil, but then a gradual drop in pH was found over time until average pH was 6.2 two years (100 weeks) after application. The treatment had negligible effect on the pH of the 5 to 15 cm (2 to 6 in) layer of soil, suggesting that the slower production of acidity from granular material resulted in more complete reaction with the carbonates of the surface layer, leaving little acidity to percolate into the soil. This longer-lasting effect and lower pH in a sizeable part of the rooting zone is probably a more desirable effect for the plant than the more drastic but decidedly short-term lowering experienced with the surface-applied wettable S.

Results from acidifying a cylindrical zone of soil inside the Field-Grow Container were similar to those from surface application of wettable S. There was rapid reduction in the pH of the treated zone to 5.3, but the effect lasted only a few weeks. Within 21 weeks, the pH of this zone was in the range 7.2 to 7.4, too high for proper solubility of several essential micronutrients (5). Soil outside the treated zone had the same pH as the untreated soil.

Tree-Growth Responses. Tree-growth measurements were analyzed using analysis of covariance for the 16 replicate trees (data not shown). The soil treatments had no significant effect on either the height or the trunk diameter of the trees. Average trunk diameters were 5, 17, and 34 mm (0.20, 0.67, and 1.33 in), and average tree heights were 59, 128, and 175 cm (23.2, 50.4, and 68.9 in) at the beginning of the experiment, one, and two years later, respectively. Although there was no long-lasting effect on soil pH of even the most effective amendments, the lowering of pH for several months may have enhanced uptake of nutrients such as iron, manganese, and zinc, and improved plant performance had the plants been particularly sensitive to supply of these nutrients.

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