The Influence of Ammonium Sulfate Fertilization on the pH of Sugarcane Soils

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INTRODUCTION

Sugarcane growers use high levels of nitrogen application. Most of the nitrogen applied is in the form of ammonium sulfate. There is a disturbing feature about this use of ammonium sulfate, because this nitrogenous material has a marked acidulating effect on the soil. This applies to anhydrous and aqua ammonia and urea as well as to ammonium sulfate, but ammonium sulfate has the greatest acidulating effect per pound of nitrogen fertilizer applied.

The acidulating action is an insidious one that creeps up on the soil and becomes a little more troublesome every year. A survey of the soil pH's of Puerto Rico revealed that many sugarcane soils were acid with about 18 percent below pH 5.0 and 1 percent with values below pH 4.0 (*13*)[2]. Soil samples from cane fields in both the Fajardo and San Sebastián area revealed cases of soils with a pH 3.7. All of these soils have been fertilized for more than 25 years with ammonium sulfate. In the well-drained river flood plains San Antón series on the southern coast of Puerto Rico, the soils are neutral in pH. Many of these San Antón sugarcane soils, however, have been heavily fertilized with ammonium sulfate for over 50 years, and after many years of application this residually acid fertilizer has lowered the pH on the lighter texture San Antón loams to pH 5 (*13*).

Inasmuch as many of our sugarcane soils are being heavily fertilized with ammonium sulfate, it is necessary that we know to what extent this acidification has taken place, and what changes it has caused in our sugarcane soils. The Agronomy and Horticulture Department of the Agricultural Experiment Station utilized several sugarcane-fertilizer experiments already in progress for this study. This paper reports the results of this study to determine the influence of ammonium sulfate fertilization on the pH and availability of certain nutrients in sugarcane soils.

PROCEDURE

Two long-range fertilizer experiments and a foliar-diagnosis fertilizer experiment were used for this study. The long-range experiments[3] involved

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[2] Italic numbers in parentheses refer to Literature Cited pp. 305–6.

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four nitrogen, two phosphorus, and three potassium levels. The experiment at Río Piedras was planted on a Vega Alta clay loam in 1943 (*14*) and has been fertilized and harvested every year to date. The experiment at Guánica on a Vayas clay under irrigation was begun in 1942 (*14*).

The foliar-diagnosis fertilizer experiment was planted in 1957 at Río Piedras on a Vega Alta clay loam. The experimental nitrogen and potash treatments were carried on at three levels and phosphorus at two.

All experiments were sampled after the cane was harvested. The soil was sampled from 0 to 6, 6 to 12, and 12 to 18 inches at each sampling site. Two replication plots from each treatment were used. The soil sample was taken at the center of the plot in the cane row except where otherwise indicated.

The soil samples were air-dried and then passed through a 20-mesh screen and mixed. Soil reaction was measured with a glass-electrode pH-meter using a 1:2 soil:water suspension.

Calcium and magnesium were determined by the versene procedure using an extraction of 10 gm. of soil with 50 ml. of sodium acetate solution, following the method of Peech and English (*11*). Iron, manganese, and aluminium were determined from the extraction solution using Peech's procedure.

RESULTS

The influence of ammonium sulfate fertilization of sugarcane for 18 years on soil pH and available nutrients of a Vega Alta clay loam is given in table 1.

Soil pH decreased with the increasing applications of ammonium sulfate. The decrease in pH or increase in acidity was evident at all three soil depths. At the surface level, 0 to 6 inches, all levels of ammonium sulfate used caused considerable increases in soil acidity. Although no pH values are available for this soil when the experiment was begun in 1943, the average pH value for the Vega Alta clay loam in the immediate area is about 5.8. The use of 500 pounds of ammonium sulfate with 100 pounds of nitrogen per year was sufficient to lower the soil pH from about 5.8 to 4.6 for the 0 to 6 inches. The 6-to-12-inch soil depth was also affected with its soil pH dropping to 5.0, but the 12-to-18-inch layer was not apparently touched, as its pH 5.6 was about normal for this soil.

With increasing rates of ammonium sulfate application the soil pH was reduced for not only the surface 0-to-6-inch horizon, but also the lower depths increased in acidity. The use of the highest ammonium sulfate application of 1,475 pounds, 295 pounds of nitrogen, per acre gave an extreme soil acidity of pH 4.0 for both the 0-to-6 and 6-to-12-inch horizons and pH 4.2 for the 12-to-18-inch horizon.

The pH is a measure of the hydrogen-ion concentration. A lowering of the pH means an increase in the hydrogen-ion concentration in the soil with an accompanying decrease in the presence of such basic ions as calcium and magnesium. With the increase in acidity or hydrogen-ion concentration

TABLE 1.—*The influence of ammonium sulfate fertilization of sugarcane for 18 years on soil pH and available nutrients, Vega Alta clay loam, Río Piedras, 1943–61*

Ammonium sulfate added per acre per year (pounds)[1]	Soil depth	pH	Available mineral nutrients in the soil on a dry-weight basis				
			Calcium	Magnesium	Iron	Manganese	Aluminum
	Inches		*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
500	0–6	4.6	371	172	18	268	85
825		4.5	529	122	18	255	128
1,150		4.3	225	169	42	409	150
1,475		4.0	207	111	40	306	156
Average		4.4	333	144	30	310	130
500	6–12	5.0	790	98	8	151	59
825		4.8	663	162	13	193	66
1,150		4.6	498	138	18	247	125
1,475		4.0	161	86	18	208	225
Average		4.6	528	121	14	175	119
500	12–18	5.6	1,000	170	1	78	68
825		5.5	1,265	162	2	60	60
1,150		5.2	948	159	2	97	90
1,475		4.2	438	128	27	173	85
Average		5.1	922	155	8	102	76
Heavily limed	0–6	7.0	2,231	221	3	49	9
	6–12	7.2	1,781	155	4	66	19
	12–18	7.1	1,386	162	[2]	44	55
Average		7.1	1,799	179	2	53	28

[1] All treatments received 20 lb. of P_2O_5 and 90 lb. of K_2O per acre.
[2] Trace.

increases in such ions as manganese, iron, and aluminum are normally found.

The decreases in basic ions and increases in soluble manganese, iron, and aluminum are shown in table 1.

The calcium content of the soil decreased with increasing use of ammonium sulfate and its accompanying increase in acidity. The 0-to-6-inch horizon where the fertilizer was actually applied had an average concentration of available calcium of but 333 p.p.m. as compared with 528 p.p.m. for the 6-to-12-inch, and 922 p.p.m. for the 12-to-18-inch horizon.

In any one of the three soil horizons, the use of increasing amounts of ammonium sulfate decreased the amount of available calcium. The lowest values obtained were 161 and 207 p.p.m. of calcium for the heaviest ammonium sulfate application in the 6-to-12- and 0-to-6-inch horizons, respectively (table 1). Ayres for Hawaii (*2*) gave a value of above a 100-p.p.m. available soil calcium as critical for responses to calcium.

A portion at the edge of the field which had been the dumping site of a pile of limestone, showed values of 2,231, 1,781, and 1,386 p.p.m. of calcium, respectively, for the three horizons (see table 1).

The losses of magnesium were slight as compared with calcium. The amounts of available magnesium present all averaged above the critical level of 100 p.p.m. However, the calcium-magnesium ratio is being continuously narrowed by the more rapid loss of calcium than magnesium. If we convert the average parts per million of the calcium and magnesium to their equivalents per million, and then find the calcium-magnesium ratio, we obtain values of 1.4:1 for the 0-to-6-inch horizon, 2.6:1 for the 6-to-12-inch horizon, and 3.6:1 for the 12-to-18-inch horizon. The 0-to-6-inch horizon is approaching the critical 1:1 ratio of calcium to magnesium and we may expect that a calcium deficiency may soon become a limiting factor.

In the correction of soil pH by liming, there is the danger that a pure calcium limestone may raise the available calcium in the soil to such a degree that the calcium:magnesium ratio would be too wide. If this should happen then a magnesium deficiency will result. An example of the widening of this calcium:magnesium ratio can be seen from table 1 where the heavily limed 0-to-6-inch soil horizon had very high available calcium with little change in its magnesium content. On an equivalent parts-per-million basis, the calcium:magnesium-ratio in this case has widened to 6.2:1.

The danger of highly acid soils to plant growth arises not only from an expected deficiency of such bases as calcium and magnesium, but also from a toxicity of such elements as iron, manganese, and aluminum. It can be seen in table 1 that, with increasing acidity, lowering of the soil pH, there were decreases in available calcium and magnesium and increases in available iron, manganese, and aluminum. This can also be seen graphically in figure 1.

The quantity of soluble manganese was much higher than that of iron, giving iron-to-manganese ratios all less than 1. Such ratios are not normally considered conducive to a good uptake of iron by the plant. Although the authors have seen iron deficiencies on young sugarcane in acid Catalina clay at pH 4.0, no such iron deficiencies were apparent on the cane growing in the Vega Alta clay loam experiments. Fujimoto and Sherman (*4*) reported no apparent injury to sugarcane growing on soils in Hawaii high in soluble manganese and low in soluble iron.

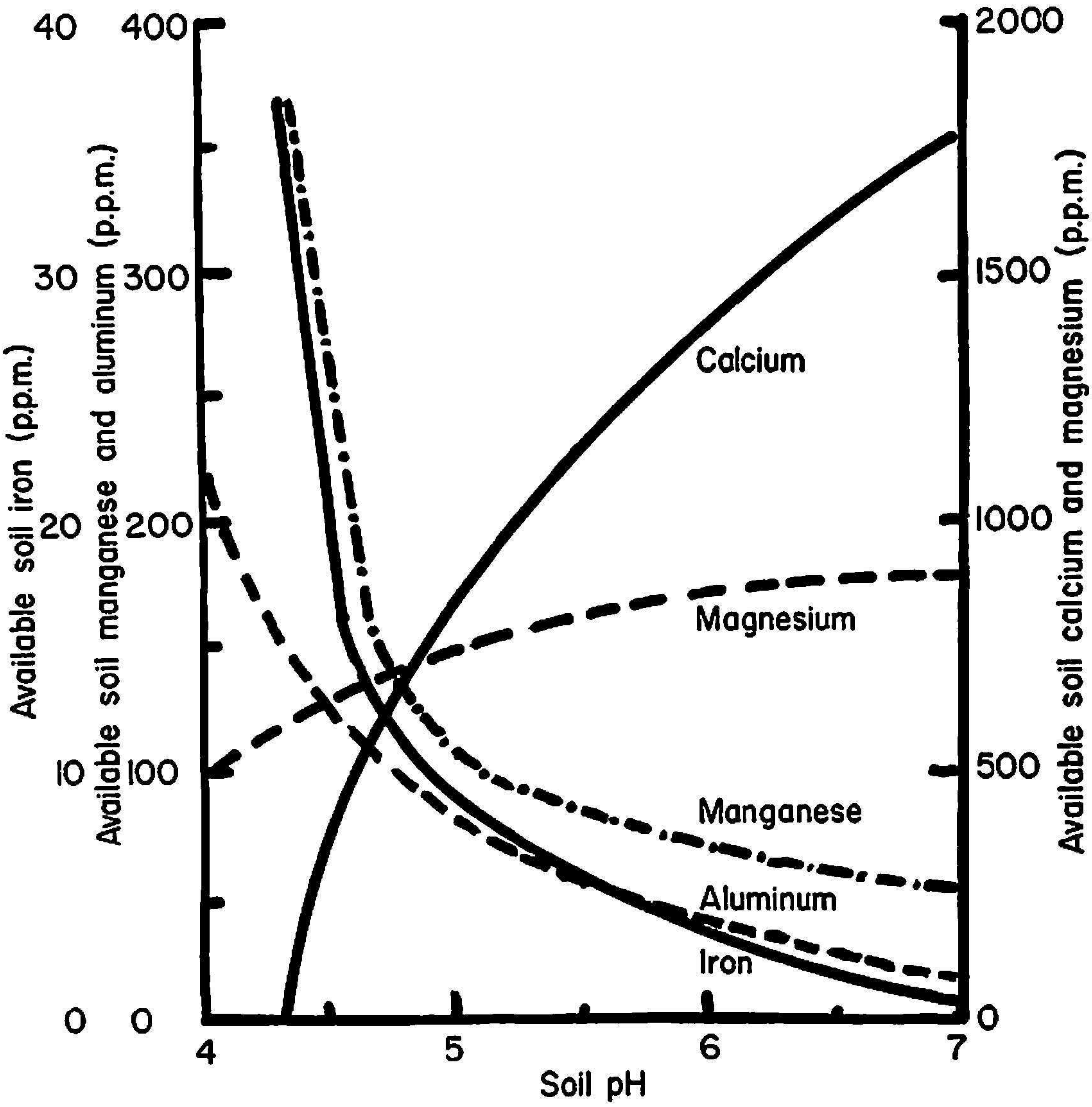

FIG. 1.—The influence of soil pH on the availability of iron, manganese, aluminum, calcium, and magnesium in a Vega Alta clay loam.

Manganese and aluminum toxicities to plant growth have been widely reported in the literature. Tobacco (*3*), soybeans (*15*), lespedeza (*9*), beans (*6*), pineapples (*7*), and potatoes (*5*) all have grown poorly when available manganese rose to toxic levels because of increased soil acidity and were corrected in most cases by liming to raise the soil pH and decrease the amount of available manganese. Similar results have been reported for aluminum (*8*, *12*).

The decrease in the amount of soluble manganese, iron, and aluminum caused by liming can be seen by comparing the values for these elements in the heavily limed soil (table 1) with those for the unlimed soil.

The continued annual application of ammonium sulfate for almost 18 years greatly increased soil acidity in a Vega Alta clay loam, but it is not necessary to wait this long for the acidifying influence of the ammonium sulfate. The foliar-diagnosis fertilizer experiment on the same Vega Alta clay loam lasted but 3½ years, and was fertilized three times, yet pH levels were lowered with increasing rates of ammonium sulfate. The application of the 750 pounds of ammonium sulfate per acre with 150 pounds of N per year reduced the 0-to-6-inch horizon from pH 5.0 to 4.6 with the 6-to-12- and 12-to-18-inch horizons barely affected (table 2). However, 1,500 pounds of ammonium sulfate per acre and 300 pounds N, lowered the surface soil from pH 5.0 to 4.1, the 6-to-12-inch horizon from pH 5.2 to 4.7, and the 12-to-18-inch horizon from pH 5.4 to 5.1.

TABLE 2.—*The influence of ammonium sulfate fertilization for 3½ years on soil pH and available nutrients of Vega Alta clay loam, Río Piedras, 1957–61*

Ammonium sulfate added per acre per year (pounds)[1]	Soil depth	pH	Available mineral nutrients in the soil on a dry weight basis				
			Calcium	Magnesium	Iron	Manganese	Aluminum
	Inches		*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*	*P.p.m.*
0	0–6	5.0	1,044	481	27	241	44
	6–12	5.2	1,010	948	13	101	61
	12–18	5.4	1,044	815	7	35	98
Average		5.3	1,033	748	16	126	68
750	0–6	4.6	782	458	48	290	86
	6–12	5.1	1,020	790	13	108	84
	12–18	5.3	794	858	8	108	64
Average		5.0	865	702	23	169	78
1,500	0–6	4.1	618	325	74	318	98
	6–12	4.7	994	664	18	151	124
	12–18	5.1	1,019	912	7	40	105
Average		4.6	877	634	33	170	109

[1] All treatments received 300 lb. per acre each of P_2O_5 and K_2O, respectively.

The reduction in pH attributable to the acidifying effect of the ammonium sulfate was accompanied by losses in available calcium and increases in available iron, manganese, and aluminum. The loss in available magnesium was not as marked as for calcium.

Pearson, Abruña, and Vicente-Chandler (*10*) found a severe reduction in pH of the 0-to-6-inch horizon and losses of calcium plus magnesium for a Fajardo-clay pasture receiving 4,000 pounds of ammonium sulfate, 800 pounds N, per acre annually for 3½ years. The same authors obtained a lowering of pH for the 0-to-18-inch horizon and subsequent losses of calcium and magnesium for a Catalina-clay pasture fertilizer at 800 pounds N

TABLE 3.—*The influence of ammonium sulfate fertilization of sugarcane for 19 years on soil pH, Vayas clay, Guánica, 1942–61*

Ammonium sulfate added per year per acre (pounds)[1]	Soil depth (inches)	pH
500	0–6	7.96
825		7.94
1,150		7.85
1,475		7.75
Average		7.88
500	6–12	8.09
825		8.13
1,150		7.94
1,475		7.92
Average		8.02

[1] All treatments received 20 lb. P_2O_5 and 90 lb. K_2O per acre.

per acre for 2 years (*10*), and for a Los Guineos clay in coffee for the 0-to-6-inch horizon in 2½ years (*1*).

The continuous use of ammonium sulfate for 19 years on the Vayas clay at Guánica did not cause any appreciable lowering of the soil pH (table 3). There was a slight lowering of soil pH in the surface 0 to 6 inches when rates of ammonium sulfate were increased; the decrease was about 0.2 of a pH unit from pH 7.96 to pH 7.75 from an application of about 18,500 pounds of ammonium sulfate per acre during 19 years, comparing the 500 pounds with the 1,475 pounds of the ammonium sulfate treatment per acre. The Vayas clay with its high soil pH and clay content appears to resist a lowering of its pH despite large applications of residually acid ammonium sulfate.

The foliar-diagnosis fertilizer experiment on the Vega Alta clay loam was used to show the influence of the place of fertilizer application on the soil pH. Soil samples taken for pH in the cane row had lower pH values than did corresponding soil samples taken between the cane rows in the furrow (table 4). The lower pH for the soils in the cane row occurred because fertilizer is normally applied by hand, mostly at the base of the cane stool in the row. This heavy deposit of fertilizer is comparable to banding the fertilizer in the cane row, whereas little fertilizer is applied between the cane rows.

TABLE 4.—*A comparison of soil pH in and between the sugarcane row as influenced by applications of ammonium sulfate, Vega Alta clay loam, Río Piedras, 1957–61*

Soil depth (inches)	Ammonium sulfate added per acre (pounds)	pH	
		In the cane row	Between the cane rows
0–6	0	5.1	5.1
	750	4.5	5.1
	1,500	4.1	5.0
6–12	0	5.1	5.4
	750	5.0	5.5
	1,500	4.6	5.3
12–18	0	5.4	5.8
	750	5.3	5.7
	1,500	5.0	5.7

SUMMARY

The continuous use of ammonium sulfate as a nitrogen source for sugarcane has caused a lowering of soil pH and changes in available nutrients on a Vega Alta clay loam as follows:

1. Increasing rates of ammonium sulfate fertilizers lowered soil pH values for all soil horizons from 0 to 6 to 12 to 18 inches.
2. Available calcium decreased with increasing amounts of ammonium sulfate in all soil horizons from 0 to 18 inches.
3. The loss of available magnesium in the soil was slight when compared to calcium, giving rise to narrow calcium:magnesium ratios in the surface 0 to 6 inches of soil.
4. With increasing acidity there were large increases in soluble manganese, iron, and aluminum in all soil horizons.
5. The quantity of soluble manganese was much higher than that of iron giving rise to iron:manganese ratios of less than 1.
6. The rapid decrease in soil pH with increasing rates of ammonium

sulfate application was evident not only in an 18-year experiment but also in a 3½-year experiment on the same soil.

7. A Vayas clay with a pH of about 8 failed to have its soil pH lowered to any marked degree by use of ammonium sulfate for 19 years.

8. The application of the ammonium sulfate in the cane row instead of between the cane rows has caused soil pH values to be lower in the cane row than between the rows.

RESUMEN

El uso contínuo del sulfato amónico como fuente de nitrógeno para el abonamiento de la caña de azúcar ha causado un descenso del valor pH del suelo y cambios en los nutrientes disponibles en el tipo de suelo Vega Alta arcilloso lómico, como sigue:

1. Al aumentar las proporciones de sulfato amónico en los abonos, bajaron los valores pH en todos los horizontes del suelo, desde 0–6 hasta 12–18 pulgadas.

2. El calcio disponible se redujo al aumentar las cantidades de sulfato amónico en todos los horizontes del suelo, desde 0 hasta 18 pulgadas.

3. Fue leve la pérdida del magnesio disponible en el suelo cuando se comparó con el calcio, lo cual dio lugar a que se estrecharan las razones calciomagnesio en la superficie (0–6 pulgadas) del suelo.

4. Con el aumento en acidez hubo grandes aumentos del magnesio, hierro y aluminio solubles en todos los horizontes del suelo.

5. La cantidad de magnesio soluble fue mucho mayor que la de hierro, lo cual dio lugar a razones de hierro a manganeso de menos de 1.

6. El rápido descenso del valor pH del suelo debido a los aumentos de las cantidades aplicadas de sulfato amónico se evidenció no sólo en el experimento de 18 años, si que también en el que solamente tiene 3½ años de instalado en el mismo campo.

7. En un suelo del tipo Vayas arcilloso con un pH de 8 no bajó marcadamente, en grado alguno, el valor pH en 19 años por el uso contínuo de sulfato amónico.

8. La aplicación del sulfato amónico a la hilera de caña en vez de a los espacios entre hileras causó que fueran más bajos los valores pH en el suelo de las hileras que en el de entre hileras.

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