Crop Response to Soil Acidity Factors in Ultisols and Oxisols in Puerto Rico. VIII. Yams[1, 2]

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ABSTRACT

The effect of various soil acidity factors on yield and foliar composition of yams (*Dioscorea alata* L) were determined in two Ultisols and an Oxisol. The yam cultivar Smooth Statia responded strongly to variations in soil acidity in the two Ultisols. Yields decreased sharply as % Al saturation of the effective cation exchange capacity of the soil increased. Relative yields dropped to about 60% of maximum when Al saturation was only about 10%, and to 20% of maximum when Al saturation was 50%, a level common among Ultisols of Puerto Rico. The high sensitivity of this crop to soil acidity is shown by the fact that yields were sharply reduced when pH dropped from 5.6 to 5.1, a level at which most crops show little or no response to liming. Foliar composition was not affected by soil acidity, except that Ca content decreased with decreasing soil pH and increasing Al saturation. Yields of cultivar of the same species as Smooth Statia and known locally as Ñame de Palo were not affected by soil acidity levels in an Oxisol.

INTRODUCTION

Yams are an important source of carbohydrates for millions of people throughout the humid tropics. They produce high yields. An average crop yielding 12 t/ha has about 22 million calories compared with 9 million produced by an average crop of corn yielding 2,500 kg/ha in the tropics (8).

Despite the importance of yams as a food crop only limited research information is available on yam production and most of that is concerned with cultivars and planting systems (4,7,12). Information on the effects of soil acidity on yam production is largely limited to tropical Africa under shifting cultivation. Under these conditions, Nye and Greenland (10) in East Africa found a small response by yams to liming after 8 years of continuous farming of an Oxisol with a pH of around 6.0 in the savanna zone.

The present study was undertaken to determine the effect of soil acidity factors on yields and foliar composition of yams grown on two Ultisols and an Oxisol in Puerto Rico.

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[2] This paper covers work carried out cooperatively between the Agricultural Research Service, USDA and the Agricultural Experiment Station, College of Agricultural Sciences, Mayagüez Campus, University of Puerto Rico.

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MATERIALS AND METHODS

The study was conducted on plots with widely varying levels of soil acidity resulting from differential applications of limestone over a period of years.

One site was on Corozal clay (Aquic Tropudults), another on a Corozal clay subsoil (top soil removed 15 years ago), and one on Coto sandy clay (Tropeptic Haplorthox).

TABLE 1.—*Effect of soil acidity factors on yield and foliar composition of yams grown on two Ultisols and one Oxisol of Puerto Rico*

Soil acidity factor				Yield	Leaf Contents					
pH	Exchangeable Al	Exchangeable Ca+Mg	Al sat.		N	P	K	Ca	Mg	Mn
	me/100 g	*soil*	%	*t/ha*			%			*p/m*
			Corozal clay							
5.90	0	15.12	0	21.2	3.10	.10	2.11	1.68	.42	224
5.10	1.17	7.51	13	11.7	3.20	.11	2.10	1.66	.51	275
4.90	2.36	7.52	23	9.8	3.10	.12	2.28	1.62	.43	172
4.75	3.46	5.04	39	3.0	3.00	.10	2.15	1.59	.50	188
4.60	5.65	5.25	50	4.0	2.90	.09	2.09	1.57	.42	117
4.30	8.13	3.96	65	3.9	2.93	.10	2.24	1.39	.43	212
4.15	10.91	2.08	81	1.1	2.93	.10	1.92	1.17	.40	203
			Corozal clay-subsoil							
5.60	0	9.92	0	18.8	3.04	.12	2.22	1.56	.48	144
5.05	.58	8.82	6	11.8	3.13	.09	2.46	1.46	.51	126
4.80	2.84	8.12	25	5.9	3.00	.10	2.15	1.42	.51	136
4.60	4.42	5.73	42	6.7	2.99	.10	2.00	1.44	.43	148
4.50	5.94	5.08	52	3.9	3.15	.11	1.95	1.36	.48	153
4.25	7.38	3.73	64	1.6	3.12	.12	2.02	1.37	.41	164
4.10	10.06	2.03	81	1.6	2.92	.09	1.98	1.12	.34	160
			Coto sandy clay							
5.70	0	4.06	0	26.6	3.15	.06	3.19	1.30	.37	613
5.05	.26	3.15	7	27.8	3.02	.06	3.16	1.33	.37	646
4.75	.59	3.08	15	27.7	3.25	.06	3.64	1.35	.38	734
4.60	.78	2.60	21	26.2	3.22	.06	3.17	1.48	.33	760
4.40	1.44	2.60	33	24.3	3.35	.06	3.31	1.45	.41	760

There were thirty 4 × 4-m plots at each of the two Corozal sites and 40 plots on the Coto soil. All plots were surrounded by ditches to prevent runoff from one plot to another. In the spring of 1977 the Corozal sites were planted to the yam cultivar Smooth Statia, and the Coto site to a yam cultivar of the same species known locally as Ñame de Palo (1).

Tuber sections weighing about 200 g each were planted in hills at 1 × 0.5 m. Wire trellises 2 m high were provided to support the vines. All plots were fertilized with 500 kg/ha of a 10-5-20 fertilizer, containing 30 kg/t of a mixture of 6% Mg, 7.7% Mn, 4.8% Cu, 7% Fe, 8% Zn and 2.5% B, at planting and again 5 months later. The plants were sprayed monthly with a fungicidal solution to control leaf spot caused by a species of *Colletotrichum*.

Samples consisting of young mature leaves were taken from plants in the center row of each plot 6 months after planting. The leaves were washed with distilled water, dried at 70° C and analyzed for N by the Kjeldahl method; for P, colorimetrically; for K, by flame photometry;/ for Mn, colorimetrically as permanganate after oxidation with KIO_4; and for Ca and Mg by the Versenate method (5).

The soil in each plot was sampled 2 months after planting; ten borings were taken at 0-15-cm depths. The samples were air dried and passed through a 30-mesh screen. Exchangeable Ca, Mg, K and Mn were extracted with normal neutral *N* NH_4OAc. Potassium was determined by flame photometry; Ca + Mg by the Versenate method (5); and Mn, colorimetrically as permanganate after oxidation with KIO_4. Exchangeable Al was extracted with *N* KCl and determined by the double titration method (9). Percentage Al saturation of the soil was calculated by considering the sum of exchangeable Ca + Mg + K + Al + H as the effective cation exchange capacity of the soil (6). Soil reaction was measured in a 1:1.5 soil to water ratio with a glass electrode pH meter.

Yield of tubers in each plot was determined when the plants matured, about 10 months after planting.

Data on yield and foliar composition was related to the various soil acidity factors by regression analysis.

RESULTS AND DISCUSSION

COROZAL CLAY SOIL

Yields of yams were sharply reduced by even fairly low levels of exchangeable Al in the soil (table 1 and figure 1). Furthermore, yields were depressed by about 50% when pH dropped from 5.9 to 5.1 (table 1, figure 1), a level at which most crops show little or no response to liming. Yields were only 19% of maximum at 50% Al saturation and plants barely grew at the highest level of acidity.

Regression analysis of the data shows that all the soil acidity factors were highly correlated with yield (table 2).

Foliar composition was not affected by soil acidity factors, except that Ca content of the leaves decreased with increasing acidity (table 1). Phosphorus content of the leaves was low at all soil acidity levels, an indication that even high Al levels in the soil did not affect P solubility, or else requirements of yams for this nutrient are very low.

COROZAL CLAY SUBSOIL

Somewhat lower yields were obtained in the Corozal soil than in the subsoil at all acidity levels (table 1).

The effect of the soil acidity factors on yields was similar to those occurring in the Corozal soil. Yields decreased with decreasing pH and increasing Al saturation of the soil (table 1, figures 1 and 2). At pH 4.6

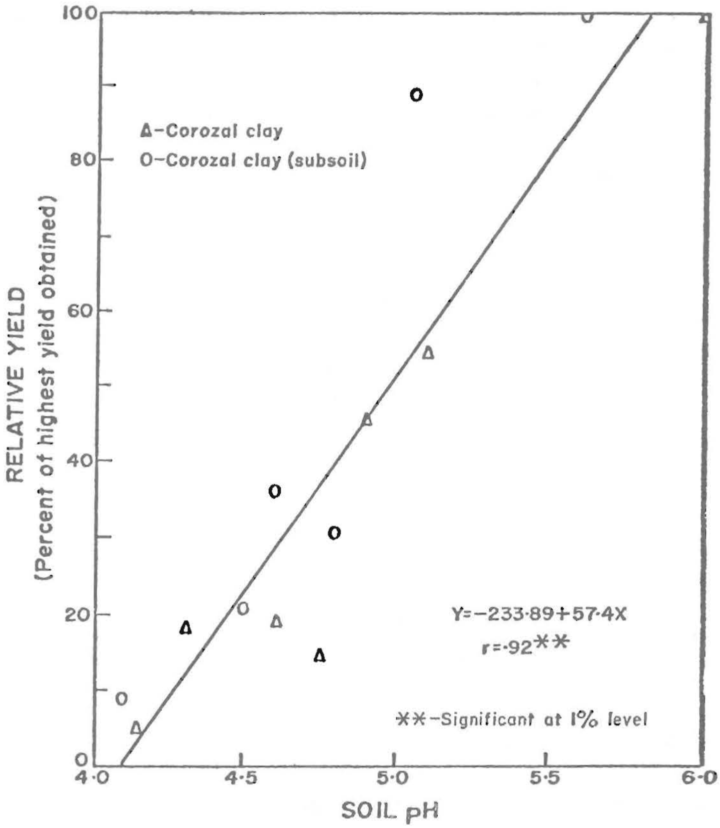

FIG. 1.—Relationship between pH of Corozal soil and subsoil (Ultisols) and relative yields of yam cultivar Smooth Statia.

with Al saturation of 56%, a level very common in Ultisols of the tropics, yams produced only about 20% of maximum yields. This 20% figure compares with 68% of maximum yields produced by sweet potatoes on this site at this soil acidity level as determined by Abruña et al. (3).

Regression analysis of the data shows that all soil acidity factors were highly correlated with yields (table 2). Best correlations were obtained with pH and percent Al saturation of the soil.

Chemical composition of the leaves was not significantly affected by soil acidity levels except for Ca content, which decreased consistently as soil acidity increased. This drop in Ca content of the leaves is similar to that reported by Abruña et al. (2) for corn grown on this subsoil, although corn was more tolerant to high acidity levels than yams are.

COTO SANDY CLAY

The yam cultivar Ñame de Palo was tolerant to the soil acidity levels in the Coto soil. At the lowest acidity level (pH 5.7) yields of Ñame de Palo on the Coto soil were about 25% higher than those produced by Smooth Statia on Corozal clay. Soil pH as low as 4.4 together with 33% Al saturation did not decrease significantly yields of Ñame de Palo (table 1).

TABLE 2.—*Relationships between soil acidity factors and yield of yams grown on two Ultisols and one Oxisol in Puerto Rico*

Soil Acidity Factors (X)	Yield (kg/ha) (Y)	
	Corozal clay soil	
pH	$Y = 34.4 + 8.7X$	$r = .72^{**}$
Al saturation (%)	$Y = 19.2 - .50X + .0036X^2$	$r = .82^{**}$
Exch. Al/exch. bases	$Y = 12.9 - 7.43X + .99X^2$	$r = .70^{**}$
Exch. Ca + Mg	$Y = 1.6 + 2.24X$	$r = .89^{**}$
	Corozal clay subsoil	
pH	$Y = 47.6 + 11.79X$	$r = .83^{**}$
Al saturation (%)	$Y = 18.4 - .42X - .0026X^2$	$r = .83^{**}$
Exch. Al/each bases	$Y = 15.1 - 10.23X + 1.53X^2$	$r = .79^{**}$
Exch Ca + Mg	$Y = 2.9 - 2.72X$	$r = .72^{**}$
	Coto sandy clay	
pH	Non significant	
Al saturation	Non significant	
Exch. Al/exch. bases	Non significant	
Exch. Ca	Non significant	
Exch. Ca + Mg	Non significant	

Increasing acidity of Corozal clay to this level resulted in a decrease in yields from about 21 to 4 t/ha. Abruña (2, 3) has reported less marked effect of acidity factors in Oxisols than in Ultisols on yields of various crops.

Regression analysis of the data (table 2) shows that there were no significant correlations between yields of cultivar Ñame de Palo and soil acidity factors in the Coto soil.

Soil acidity did not affect the chemical composition of the leaves. Phosphorus content of the leaves of variety Ñame de Palo was extremely low, whereas K content was considerably higher, and Ca and Mg contents somewhat lower than those of Smooth Statia cultivar. Manganese content was high at all soil acidity levels. The Coto soil, as well as many other Oxisols in Puerto Rico, has a higher content of both exchangeable and easily reducible Mn, and a higher ionic activity of this element than Corozal clay as well as other Ultisols at similar soil pH levels (11).

The ameliorated effect of soil acidity on yams growing in Coto (Oxisol) as compared to that in Corozal (Ultisol) soil may be explained by a higher

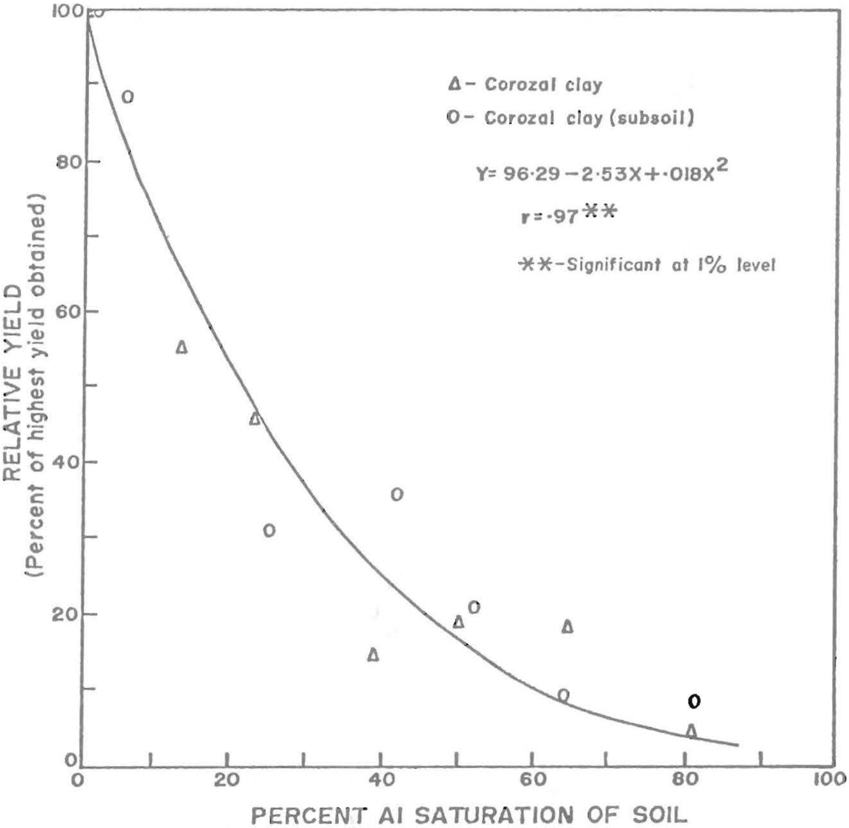

FIG. 2.—Relationship between percent Al saturation of the exchange capacity of Corozal soil and subsoil (Ultisols) and relative yields of yam cultivar Smooth Statia.

tolerance to acidity of Ñame de Palo cultivar or by less activity of Al in the former soil. Abruña (3) has suggested that the strong activity of the Mn in Coto clay reduces Al activity in such a way that crops sensitive to Al toxicity but tolerant to Mn respond less to liming on this soil than on Corozal.

Regression analyses of the combined data for the Corozal soil and subsoil (figures 1, 2, 3) show that the cultivar Smooth Statia is very sensitive even to low levels of soil acidity. Only about 20% of maximum yields would be expected when pH drops to about 4.5 and Al saturation of the soil is about 50%. As a matter of fact these acidity levels are common among Ultisols in Puerto Rico. Maximum yields were attained only when pH exceeded 5.5 and yields dropped to about half when pH dropped to the neighborhood of 5.0.

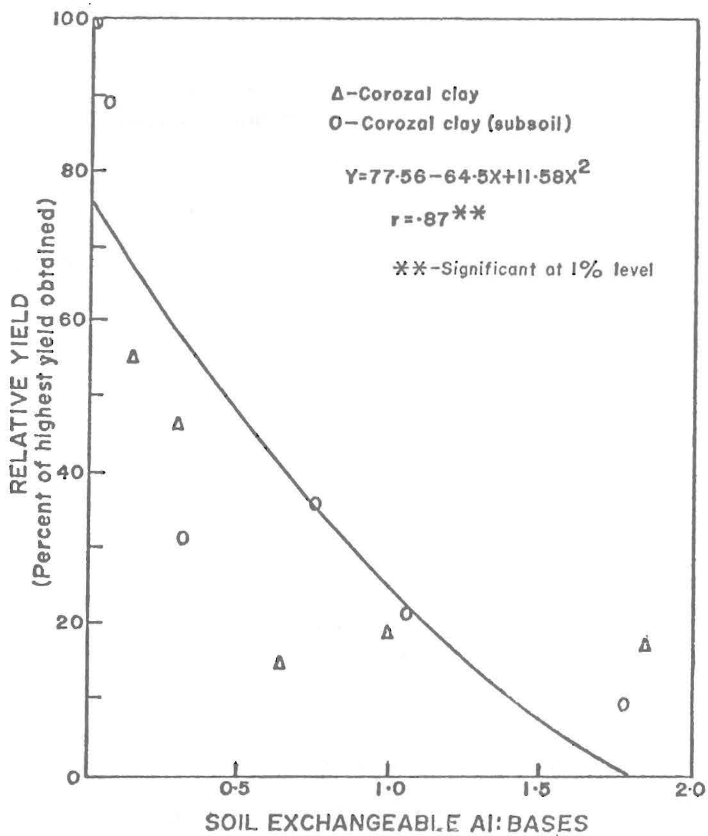

FIG. 3.—Relationship between Al/base ratio of a Corozal soil and subsoil (Ultisols) and relative yields of yam cultivar Smooth Statia.

RESUMEN

Se estudió el efecto de los factores de acidez en los rendimientos y composición foliar de dos variedades de ñame en dos Ultisol y un Oxisol típicos de extensas regiones tropicales.

Los rendimientos de la variedad Smooth Statia (*Dioscorea alata* L.) creciendo en dos Ultisol disminuyeron señaladamente según aumentó la acidez del suelo. Los rendimientos bajaron a alrededor de un 60% del máximo cuando la saturación del suelo con Al cambiable fue de aproximadamente 10%, bajando hasta sólo un 20% de la producción máxima cuando la saturación con Al cambiable alcanzó el 50%, grado de acidez muy común en los Ultisol de Puerto Rico. La producción máxima sólo se logró cuando el pH sobrepasó 5.5 y bajó a cerca de la mitad cuando la acidez alcanzó un pH de 5.0, nivel al cual muchas cosechas se aproximan a su máxima capacidad de producción, lo cual señala la sensitividad de los ñames a la acidez del suelo.

La composición foliar no se afectó por la intensidad de la acidez del suelo, excepto que el contenido de Ca disminuyó a medida que aumentaba la acidez.

La variedad conocida localmente como Ñame de Palo mostró ser tolerante a la acidez en un suelo Coto (Oxisol) arcilloso.

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