Crop Response to Soil Acidity Factors in Ultisols and Oxisols in Puerto Rico V. Sweet Potato[1, 2]

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ABSTRACT

The effect of various soil acidity factors on yield and foliar composition of sweet potato (*Ipomoea batatas* (L). Lam) were determined in three Ultisols and one Oxisol. Sweet potatoes responded moderately in yield to variations in soil acidity factors of three Ultisols, but did not on the Oxisol. On the Ultisols, soil acidity factors had very little effect on leaf composition. Yield increased with increasing soil pH, decreasing exchangeable Al content and decreasing exchangeable Al/base ratio. When all the soils, except Coto, were grouped together, the ratio of exchangeable Al to exchangeable bases explained 83% of the variation, the percent Al saturation 79%, and pH only 66%. Highest yields were obtained when pH was above 5, percent Al less than 20% and the Al exchangeable bases ratio less than .2. The lack of response in the Oxisol seems to be related to a reduced Al activity resulting from a high Mn concentration in the soil solution. Apparently sweet potato is very tolerant to high Mn concentrations in the soil solution.

INTRODUCTION

Sweet potato (*Ipomoea batatas* (L.) Lam) is a staple in the diet of millions throughout the humid tropics. Knowledge concerning lime requirements of sweet potato in tropical areas is both fragmentary and often contradictory (13). Bonnet et al. (7) found that sweet potato responded to liming on two red acid soils (Ultisols) of Puerto Rico. However, Camargo et al. (9) in Brazil found no response of sweet potatoes to liming on sandy acid soils. Lugo et al. (10) reported a yield increase of 15% due to liming Corozal soil, an Aquic Tropudults of Puerto Rico. Nye and Greenland (12) reported that sweet potato yields were increased by liming in only two of a series of very acid soils in Uganda. Pérez-Escolar (14) found no response of sweet potato to liming on two Ultisols and one Oxisol in Puerto Rico. Steinbauer and Beattie (15) using lime and calcium chloride as liming materials concluded that sweet potato yields were highest on slightly to moderately acid soil and may decrease if soil is

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[2] This paper covers work carried out cooperatively between the Science and Education Administration (formerly ARS), Agricultural Research, USDA, and the Agricultural Experiment Station, College of Agricultural Sciences, Mayagüez Campus, University of Puerto Rico.

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TABLE 1.—*Characteristics of the soils at the different experimental sites*

Soil type	Classification	Origin	Predominating clay mineral	Cation Exch Capacity[1]		Ex-change able Al	pH
				Sum of exch cations	NH_4OAc pH 7.00		
				Me/100 g		*Me/100 g*	
Corozal clay	Aquic Tropudults	Tuffaceous material	Kaolin	12.9	19	4.7	4.6
Corozal clay subsoil	Do.	Do.	Do.	11.3	16	5.1	4.6
Humatas clay	Typic Tropohumults	Volcanic tuff	Do.	10.6	15	4.9	4.3
Coto sandy clay	Tropeptic Haplorthox	Limestone quartzitic sand deposits	Do.	3.7	5	.9	4.5

[1] Sum of exchange cations includes Ca, Mg, K and Al. Exchangeable bases (Ca, Mg, K) were extracted with normal ammonium acetate,

neutral or alkaline. Watts and Cooper (16) found that, on a soil whose pH was lowered with H_2SO_4, sweet potato yields were highest at pH 6.0 to 6.5, and lowest at pH 6.5 to 7.0.

The present study determined the relationship between the various soil acidity factors and yields and foliar composition of sweet potatoes in four field experiments on three Ultisols and one Oxisol.

MATERIALS AND METHODS

The experiments were carried out on 30 plots on Corozal clay soil (Aquic Tropudults), 30 on Corozal subsoil (Aquic Tropudults), 60 on

TABLE 2.—*Effect of soil acidity factors on yield and foliar composition of sweet potato*

Soil factors			Yield		Leaf composition					
pH	Al sat.	Ratio Al/bases	Actual	Relative	N	P	K	Ca	Mg	Mn
	%		*t/ha*	%	%	%	%	%	%	*p/m*
				Corozal clay soil						
5.60	3	.03	13.8	100	5.03	.69	3.00	.88	.33	—
5.00	12	.13	13.1	95	5.13	.75	3.59	.77	.27	—
4.80	26	.36	12.3	89	5.02	.58	2.64	.88	.34	—
4.60	33	.49	9.1	66	4.93	.62	3.00	.63	.34	—
4.50	43	.78	8.9	64	5.18	.63	2.58	.82	.32	—
4.40	50	.97	6.8	49	4.91	.62	2.73	.79	.35	—
4.20	66	2.03	3.1	22	4.42	.55	2.27	.79	.34	—
				Corozal clay subsoil						
5.50	5	.06	11.5	96	5.02	.69	3.00	.80	.38	—
4.95	15	.17	12.0	100	5.06	.68	3.20	.71	.40	—
4.70	25	.35	11.9	99	5.01	.65	2.99	.72	.38	—
4.60	35	.55	12.0	100	4.90	.64	2.85	.68	.36	—
4.50	43	.69	11.2	93	4.90	.69	2.86	.72	.38	—
4.35	56	1.27	8.2	68	4.80	.63	2.91	.70	.30	—
4.15	63	1.70	6.8	57	4.78	.66	2.89	.64	.36	—
				Humatas clay						
5.30	4	.04	7.37	100	3.77	.51	3.18	.86	.26	—
4.85	14	.17	5.97	81	4.04	.51	3.01	.78	.28	—
4.70	26	.34	5.78	78	3.61	.48	2.82	.69	.28	—
4.45	35	.53	6.18	84	3.95	.48	3.00	.64	.30	—
4.30	46	.85	5.23	71	3.98	.51	2.98	.69	.32	—
4.10	56	1.29	3.40	46	3.83	.53	2.82	.72	.31	—
3.80	67	2.06	1.37	18	3.71	.49	2.54	.59	.27	—
				Coto sandy clay						
5.3	5	.03	16.1	90	4.53	.54	2.89	1.27	.30	237
4.7	15	.19	16.5	92	4.61	.54	3.13	1.16	.32	286
4.5	25	.33	17.0	95	4.59	.50	3.19	1.15	.36	280
4.3	35	.56	17.9	100	4.88	.54	3.15	1.20	.30	395

Humatas clay (Typic Tropohumults) and 40 on Coto sandy clay (Tropeptic Haplorthox). All plots were 4 m^2 and were surrounded by ditches. The experimental design was a completely randomized series of plots with different concentrations of Al, Mn, Ca and Mg resulting from different lime rates.

The soil in each plot was sampled by taking 10 borings at 0-15 cm depth. The samples were air dried and passed through a 10-mesh screen.

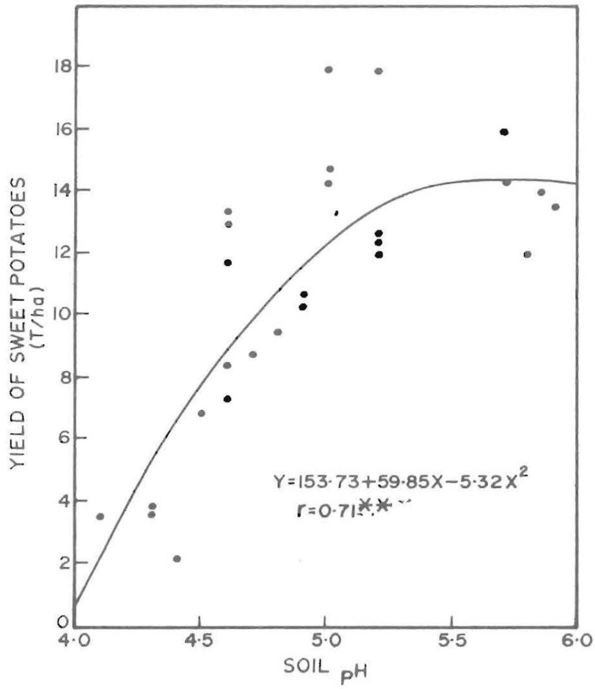

FIG. 1.—Effect of pH on yield of sweet potato grown on a Corozal clay soil.

Exchangeable bases (Ca + Mg + K) were extracted with normal ammonium acetate pH 7.0, and Ca and Mg were determined by the Versenate titration method (8). Potassium was determined by flame photometry. Exchangeable Al was extracted with normal KCl and determined by the double titration method (11). Al saturation percentage was determined by dividing the exchangeable Al by the sum of exchangeable Ca + Mg + K + Al. Soil reaction was measured with a glass electrode, using a saturated paste.

Stem cuttings of the white-fleshed Yoya variety were planted 45 cm apart on elevated beds 90 cm apart. The Corozal clay soil and Corozal clay subsoil plots were planted in October 1971 and harvested in March

1972. The Coto sandy clay plots were planted in September 1971 and harvested in March 1972. The Humatas clay plots were planted in August 1971 and harvested in February 1972.

In all experiments, rainfall was supplemented by overhead irrigations during dry spells. All plots received 1,120 kg/ha of a 15-5-10 fertilizer and were kept free of weeds by periodical hoeing.

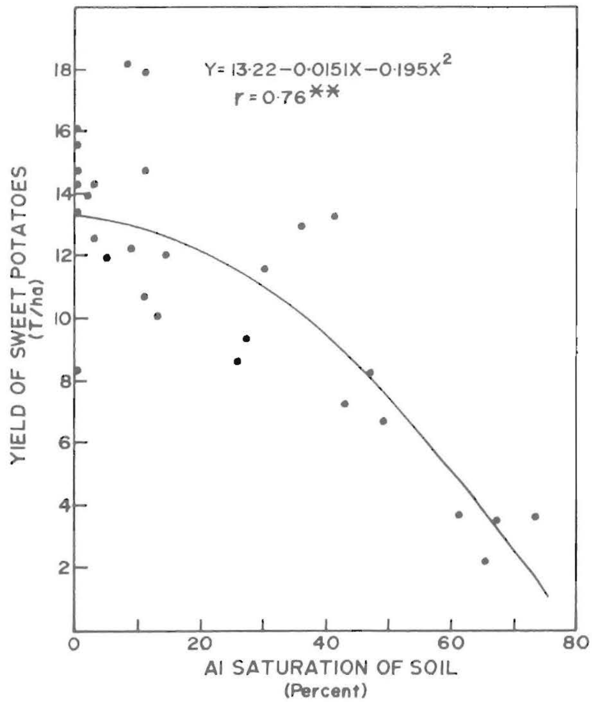

FIG. 2.—Effect of percent aluminum saturation on yield of sweet potato grown on a Corozal clay soil.

Leaf samples were taken from all plots 4 mo after planting and were analyzed for Ca and Mg by the Versenate method, K by flame photometry, Mn by oxidation with potassium periodate, P colorimetrically, and N by the Kjeldahl method.

Crop response to soil acidity factors was determined by correlating through regression analyses these factors with tuber yield and foliar composition.

RESULTS AND DISCUSSION

The main characteristics of the soils are shown in table 1.

COROZAL CLAY SOIL (AQUIC TROPUDULTS)

Table 2 shows that sweet potato yields were maximum at an average pH of 5.6 and 3% Al saturation. Below pH of 4.5 and 43% Al saturation, yields decreased rapidly.

These data also show that leaf composition was not greatly affected by soil acidity factors, unlike soybeans (6), corn (4) and green beans (3). The

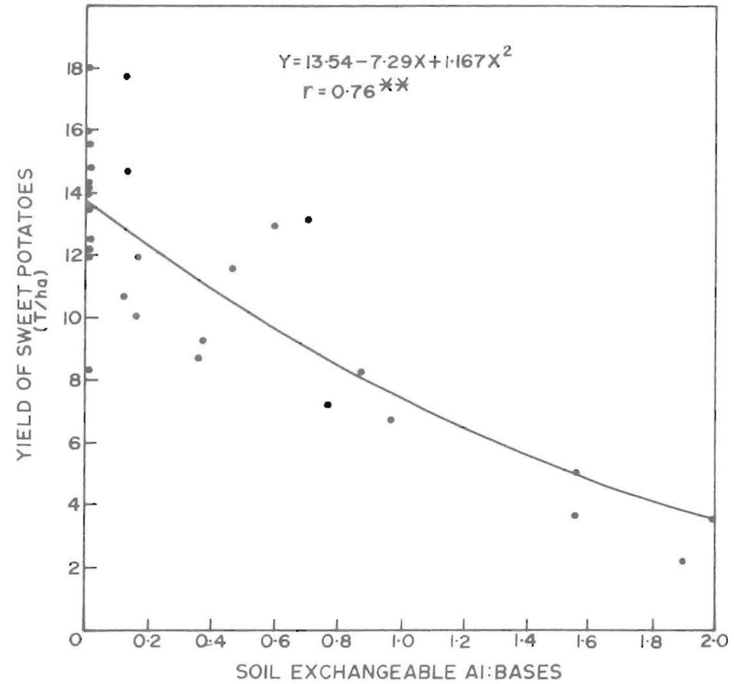

FIG. 3.—Effect of the ratio of exchangeable aluminum to exchangeable bases on the yield of sweet potato grown on a Corozal clay soil.

fact that Ca uptake by sweet potato was not significantly affected possibly explains the higher tolerance of sweet potatoes to soil acidity.

Figure 1 shows that sweet potato yields increased with pH from 4.0 to 5.3 and then levelled off. This response corresponds with the precipitation of active Al.

Figure 2 shows the relationship between percent Al saturation of the soil and sweet potato yields. Sweet potato yields were highest when Al saturation of the soil was less than 20% and lowest (20% of maximum) at about 70% saturation. This contrasts with essentially no yields of tobacco (2) at Al saturation levels of about 50%.

Figure 3 shows that yields of sweet potatoes were maximum when the ratio of exchangeable Al/bases was less than 0.2, corresponding to about 25% Al saturation.

Sweet potatoes on this soil proved to be more tolerant than tobacco (2), green beans (3), corn (4), or soybeans (6) to high soil acidity.

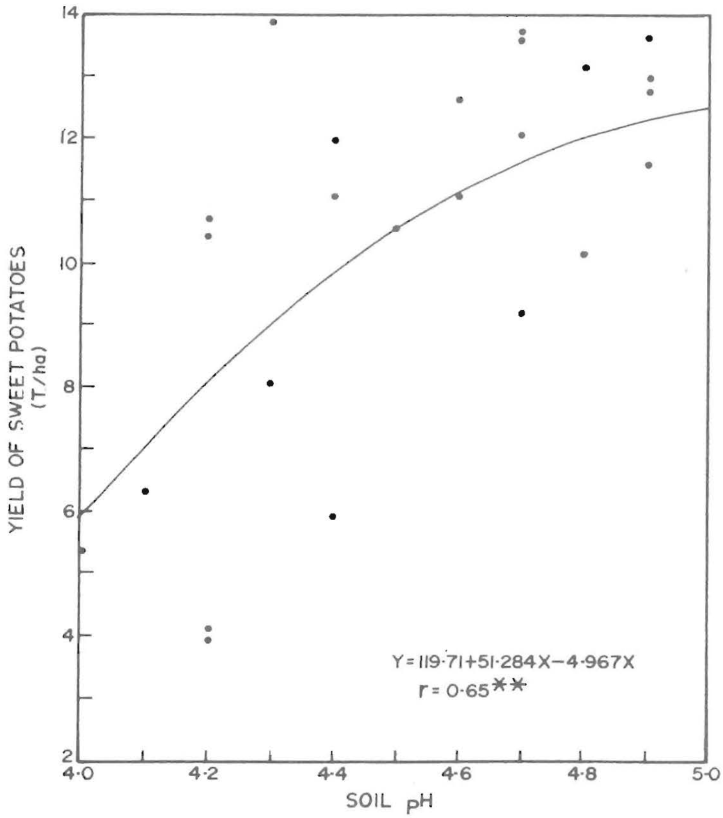

FIG. 4.—Effect of pH on yield of sweet potato grown on a Corozal clay subsoil.

COROZAL CLAY SUBSOIL (AQUIC TROPUDULTS)

Table 2 shows that at the highest lime levels yields were about 80% of those obtained on the Corozal soil and decreased as acidity increased much less than those for the Corozal soil. Even at pH 4.5 and 43% Al saturation, sweet potato yields were 93% of maximum compared with only 64% in the Corozal soil at this acidity level. Also at the lowest pH level (4.2) and highest Al saturation (63%), yields were twice as high as those for the Corozal soil.

Since the percent Al saturation, pH and Al/base ratio levels are similar in both soils, this strikingly lower response in the subsoil to liming apparently can be explained only on the basis of less active forms of Al.

There was no effect of soil acidity on foliar composition.

Figure 4 shows that in this subsoil yields were maximum at about pH 4.8, at which there was some active Al. This again suggests that this soil may have a less active Al form.

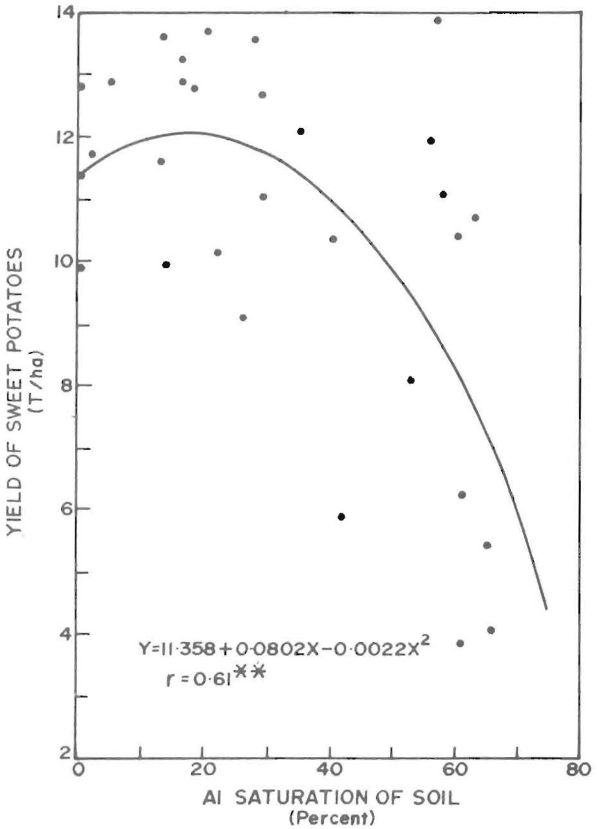

FIG. 5.—Effect of percent aluminum saturation on the yield of sweet potato grown on Corozal clay subsoil.

Figure 5 indicates that on this soil yields were maximum at about 20% Al saturation. There is a high degree of dispersion reflected in a low correlation coefficient value ($r = 0.61$).

Figure 6 shows the effect of exchangeable Al/base ratio on sweet potato yields. Like other soil acidity factors, there was a high degree of dispersion and a low correlation coefficient ($r = 0.63$). Yields were highest at about a ratio of 0.2–0.3, corresponding to about 20% Al saturation. At this level, the yields varied from 10 to 13.6 t/ha.

In general, sweet potato is much more tolerant to soil acidity factors on this soil than were tobacco (2), corn (4), green beans (5), or soybeans (6).

HUMATAS CLAY (TYPIC TROPOHUMULTS)

Table 2 shows that maximum sweet potato yields were only about 50% of those obtained on Corozal clay soil and 64% of those on Corozal clay subsoil. These low yields were probably due to planting during a season during which yields of sweet potatoes are generally lower.

Sweet potatoes on this soil responded to liming in a similar manner to that on the Corozal clay soil. Yields were maximum at pH 5.3, but were about 80% of maximum at pH's of 4.50 and 35% Al saturation.

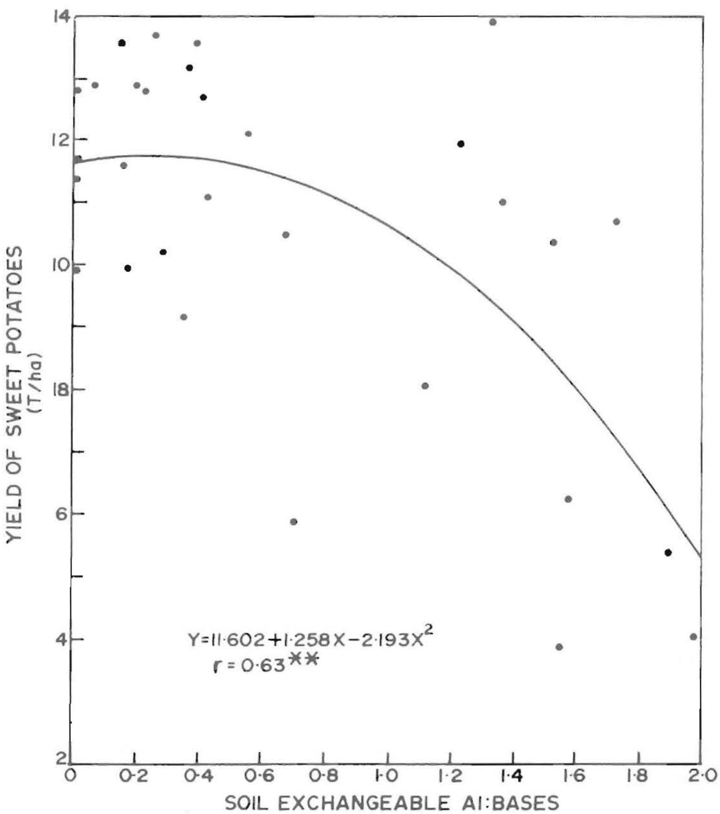

FIG. 6.—Effect of the ratio of exchangeable aluminum to exchangeable bases on yield of sweet potato grown on Corozal clay subsoil.

Soil acidity factors did not affect leaf composition except Ca content of leaves correlated with yield (fig. 7), with an *r* value of only 0.57.

Figure 8 shows a large yield response of sweet potatoes to pH levels in this soil. Yields increased rapidly with increasing pH up to about 5.0, with no further response at higher pH values.

Figure 9 shows that sweet potatoes responded sharply in yield to decreased Al saturation up to about 20%. The sweet potatoes were more

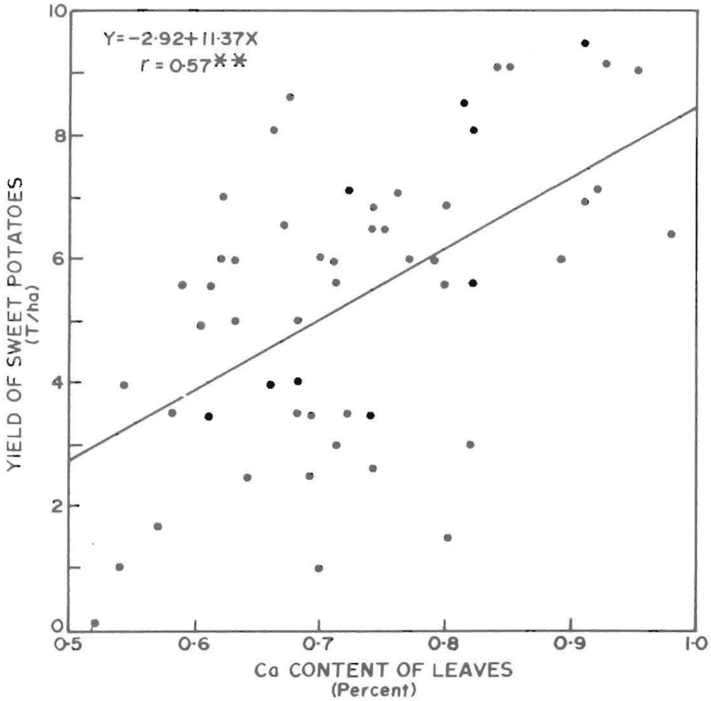

FIG. 7.—Relationship between the calcium content of the leaves and the yield of sweet potato grown on Humatas clay soil.

tolerant to high soil acidity than were sugarcane (1), tobacco (2), or soybeans (6) on Humatas clay soil.

Figure 10 shows a negative significant correlation between the ratio of exchangeable Al/bases and sweet potato yields on this soil. Yields were maximum when the ratio was less than 0.2 corresponding to less than 20% Al saturation in the soil. When this ratio increased to about 1.8, yields decreased to about 2 t/ha.

COTO SANDY CLAY (TROPEPTIC HAPLORTHOX)

This soil, the only Oxisol studied, is much higher in both exchangeable and easily reducible Mn than the Ultisols, but has a lower Al content at any given pH than the other soils. The lack of response in the soil seems to be related to a reduced Al activity in the soil solution as a result of a high Mn concentration. In addition, sweet potato seems to be very tolerant to high concentrations of soluble Mn in the soil solution.

The data in table 2 show that sweet potato yields obtained on Coto sandy clay were higher than on any of the other soils, and that there was no significant effect of liming on yields.

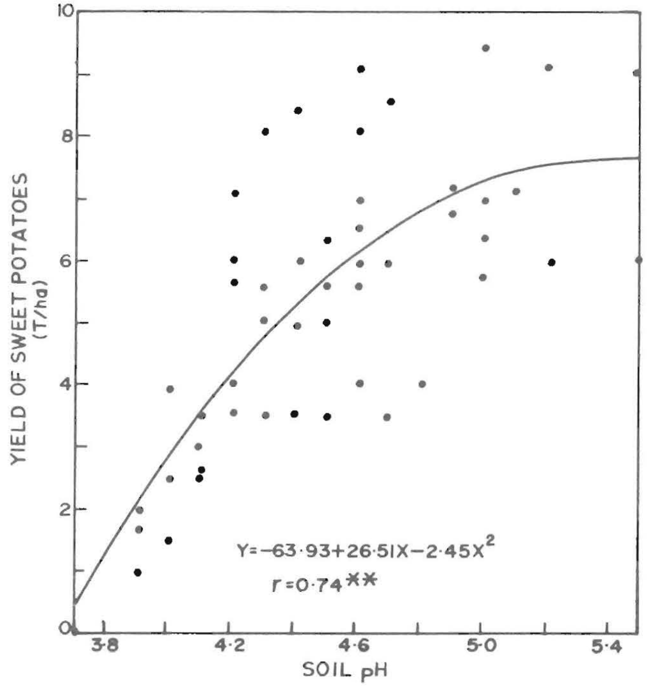

FIG. 8.—Effect of pH on the yield of sweet potato grown on Humatas clay.

Leaf composition was not significantly affected by variations in the various soil acidity factors, although Mn content increased as pH decreased.

ALL SOILS COMBINED[4]

There were close relationships between sweet potato yields and soil acidity factors when data for all soils were combined.

Figure 11 shows that, for all soils combined, yields were maximum at about pH 5.0 and lowest at about pH 4.0. This figure also shows that

[4] Data for Coto soil was not included in the statistical analysis. It was plotted to illustrate the lack of response.

yields increased sharply from about 20 to 100% of maximum as pH increased from 4.0 to 5.0. Each soil had a somewhat different yield response pattern, with the sharpest response on the Humatas soil, less response on Corozal subsoil (response only from pH 4.1 to 4.5), and no response on Coto sandy clay.

Figure 12 shows that sweet potato responded sharply to variations in

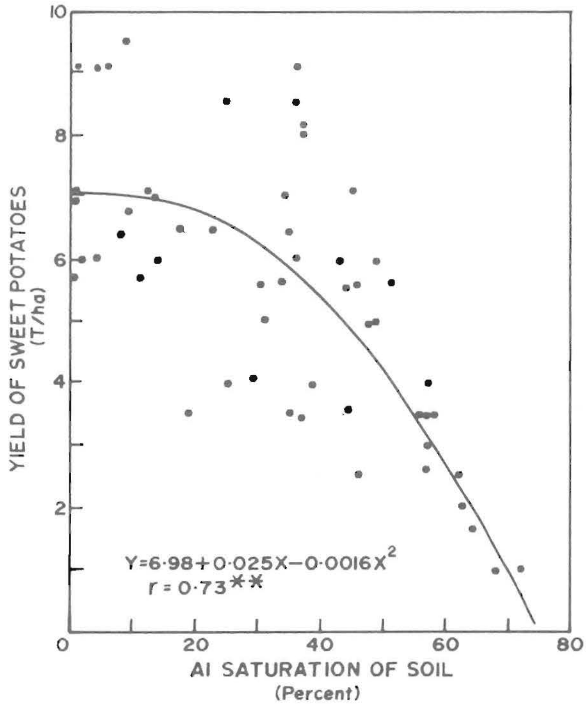

FIG. 9.—Effect of percent aluminum saturation on the yield of sweet potato grown on Humatas clay.

the percent Al saturation on the Ultisols but not on Oxisols (Coto sandy clay was the only Oxisol studied). Yields for all soils combined increased from about 20% of maximum at Al saturation of about 60% to about 100% at Al saturation of about 20% or less. Abruña et al. (5) found very weak response of corn to percent Al saturation on three Oxisols from Puerto Rico, but a strong response on Ultisols.

Sweet potatoes responded most sharply to Al content on Humatas soil and similarly on Corozal clay. The response on Corozal clay subsoil was considerably less.

Figure 13 shows, that for all soils combined (except Coto) yields of sweet potatoes correlated with the ratio of exchangeable Al to exchange-

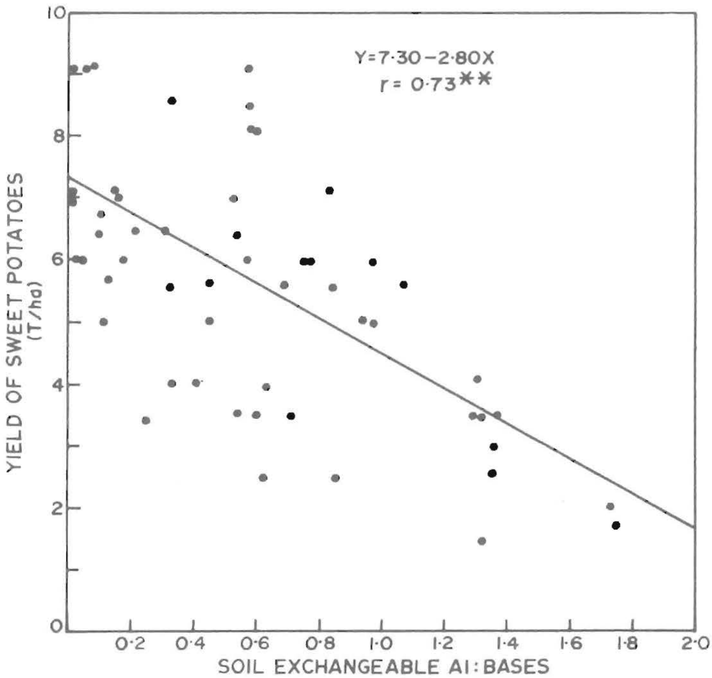

FIG. 10.—Effect of the ratio of exchangeable aluminum to exchangeable bases on yield of sweet potato grown on a Humatas clay soil.

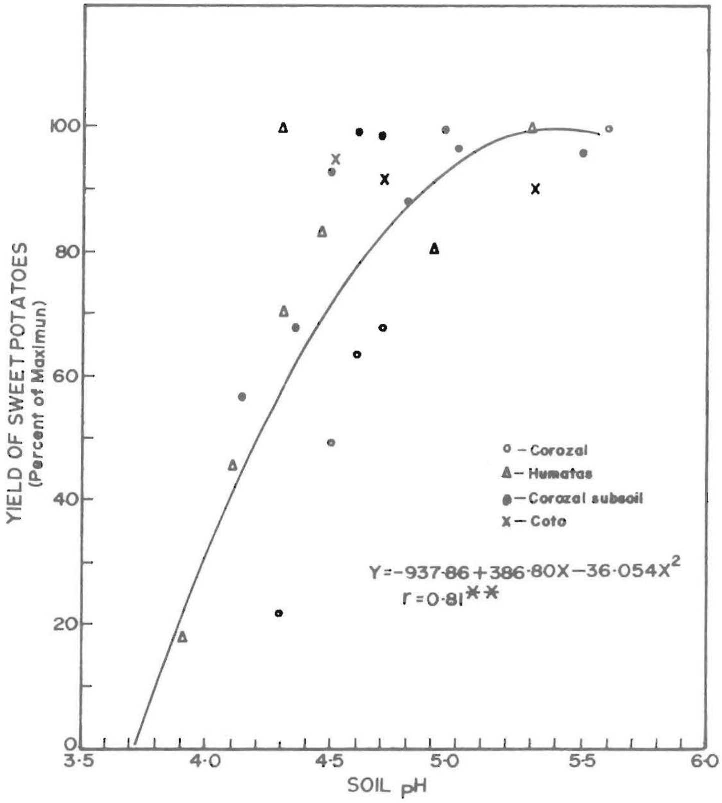

FIG. 11.—Effect of soil pH on relative yield of sweet potato grown on 3 Ultisols and 1 Oxisol.

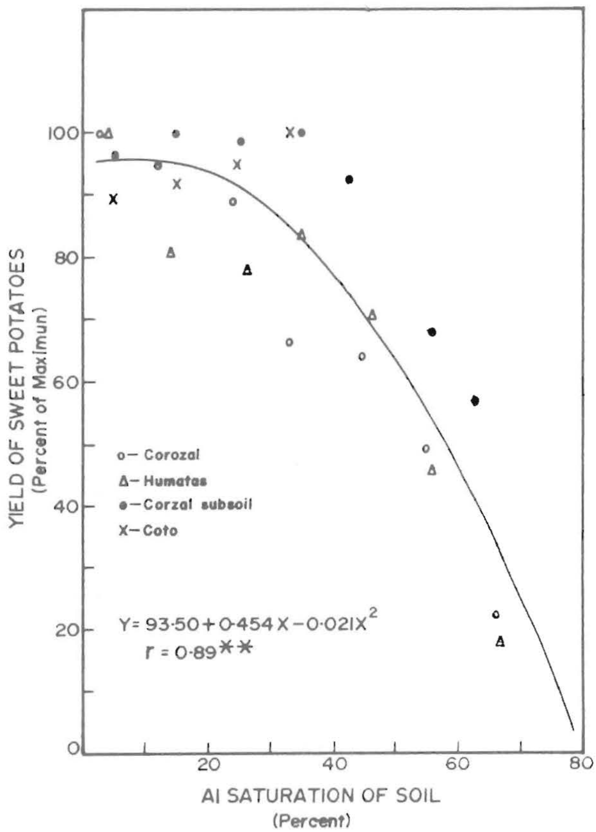

FIG. 12.—Effect of percent aluminum saturation on relative yield of sweet potato grown on 3 Ultisols and 1 Oxisol.

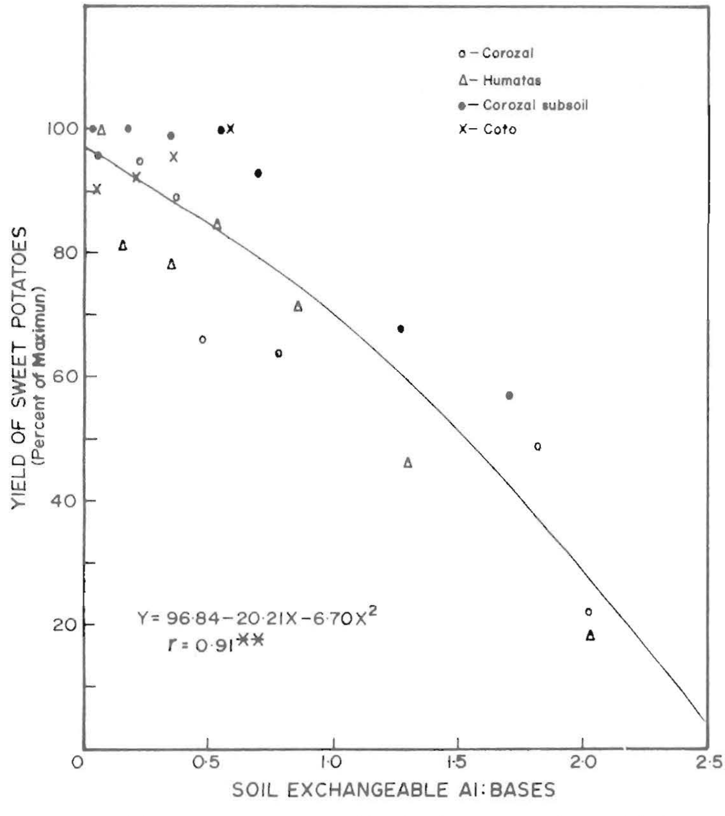

FIG. 13.—Effect of the ratio of exchangeable aluminum to exchangeable bases on the relative yield of sweet potato grown on 3 Ultisols and 1 Oxisol.

able bases. Also, the Humatas and Corozal clay soil showed the strongest response followed by the Corozal subsoil, with no response in Coto sandy clay.

In general, for all soils combined (except Coto) we obtained the highest correlation between the ratio of exchangeable Al to exchangeable bases and sweet potato yields—the equation explained 83% of the variation. Percent Al saturation correlation explained 79% of the variations, and pH only 66%.

RESUMEN

El efecto de los factores de acidez de cuatro suelos (tres Ultisoles y un Oxisol) en el rendimiento y composición foliar de la batata se estudió en la variedad Yoya.

La batata respondió señaladamente al encalado y el rendimiento se correlacionó significativamente con los distintos factores de acidez resultantes de incrementos en el encalado en los tres Ultisoles, pero no en el Oxisol, donde no hubo respuesta.

Las respuestas más pronunciadas se lograron en los suelos Corozal arcilloso y Humatas arcilloso en donde el rendimiento aumentó consistentemente hasta un pH de aproximadamente 5.0. Se lograron los mayores rendimientos cuando la saturación del complejo coloidal con aluminio fue de 20% o menos, o cuando la razón de aluminio cambiable a bases cambiables fue inferior a 0.2.

En el subsuelo del suelo Corozal arcilloso la respuesta al encado fue menor que la de los suelos Humatas y Corozal arcilloso.

La batata no respondió a las aplicaciones de cal en el suelo Coto a pesar de las variaciones notables en pH y la saturación del aluminio resultantes del encalado variable. En vista de que el Al cambiable es el factor determinante en la respuesta en el suelo Coto puede interpretarse como que la forma en que el aluminio ocurre en este suelo es mucho menos activa que en los demás.

En términos generales puede concluirse que la batata es bastante más tolerante a las concentraciones de aluminio en el suelo que el tabaco, el maíz, las habichuelas tiernas o las sojas.

La falta de respuesta en el suelo Coto parece deberse a una menor actividad del ion aluminio debido a la preponderancia del ion manganeso en la solución del suelo.

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