Crop Response to Soil Acidity Factors in Ultisols and Oxisols in Puerto Rico. VII. Dry Beans[1,2]

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ABSTRACT

Yields of dry beans on a Corozal clay (Ultisol) dropped sharply when acidity increased beyond pH 4.7 and with 30% Al saturation of the effective CEC of the soil. No crop was produced at pH 4.1 with 80% Al saturation. Similar results were obtained on a Corozal clay subsoil, but the effect of increasing acidity on bean yields was much more marked. Lower yields were obtained on a Coto clay (Oxisol) with a relatively small response to soil acidity. For all soils combined, pH and percent Al saturation of the exchange capacity of the soil correlated very closely with yields. There was also a positive correlation between Ca content of the leaves and yields. Highest yields were obtained around pH 5.2 when there was essentially no exchangeable Al in the soil. Yields decreased to about 50% of maximum when Al saturation increased to 50%, and no yields were produced when Al saturation of the soil approached 80%.

INTRODUCTION

Dry beans (*Phaseolus vulgaris* L.) are a major source of protein in much of the tropics and large quantities are imported from temperate regions. Latin America produces about 35% of world production (8). Nearly all the dry beans consumed in Puerto Rico, about 22,000 t annually, worth over $10 million, are imported.

During the last decade (4, 5, 7, 10, 12, 14) abundant information on liming of soils planted to field beans has been published, but yield responses were rarely related to soil acidity factors.

The study reported here determined the effect of soil acidity factors on yields and foliar composition of dry bean growing on a Ultisol and an Oxisol.

MATERIALS AND METHODS

Field experiments were conducted on a Corozal soil and subsoil (Aquic Tropudults) at the Corozal Substation and on a Coto sandy clay (Tropeptic Haplorthox) at the Isabela Substation. There were thirty 4 × 4-m plots at each of the Corozal sites and 40 on the Coto soil. All plots were surrounded by ditches to prevent runoff from one plot to another, and

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[1] Manuscript submitted to Editorial Board September 2, 1982.

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were arranged in complete randomized blocks. The plots had a wide range of soil acidity resulting from variable lime rates applied during previous years.

The soil in all plots was sampled before planting by 10 borings from 0- to 15-cm depths in each plot. The samples were air dried and passed through a 20-mesh screen. Exchangeable bases were extracted with *N* NH_4OAc; Ca and Mg were determined by the Versenate method (9); and K by flame photometry. Exchangeable Al was extracted with *N* KCl and determined by the double titration method (11). The Al saturation percentage of the effective CEC was calculated by dividing the exchangeable Al by the sum of exchangeable Ca, Mg, K, H, and Al. Soil reaction was measured with a glass electrode with a soil to water ratio of 1 to 1.5.

TABLE 1.—*The effect of soil acidity factors on yields and foliar composition of the Bonita variety of white beans in Puerto Rico*

Soil acidity factors		Yield	Foliar composition					
pH	Al saturation		N	P	K	Ca	Mg	Mn
	%	*kg/ha*			%			*p/n*
			Corozal clay					
6.0	0	1,810	4.87	.27	1.84	1.13	.39	228
5.1	12	1,720	5.29	.23	1.93	1.09	.35	207
4.9	24	1,680	5.45	.23	1.90	1.08	.31	320
4.7	33	1,550	5.14	.25	1.83	1.08	.39	240
4.4	51	1,030	5.31	.26	1.87	1.08	.40	306
4.3	67	400	5.23	.27	1.86	.81	.42	270
4.1	80	0	4.19	.27	1.96	.77	.35	340
			Corozal clay-subsoil					
5.6	0	1,880	5.07	.23	2.06	1.22	.50	130
5.0	12	1,370	5.24	.25	2.11	1.14	.49	140
4.7	29	1,200	5.20	.26	1.91	.89	.43	140
4.6	39	1,120	5.09	.25	1.91	.98	.52	175
4.5	52	660	5.16	.27	1.91	.99	.50	214
4.2	66	150	5.54	.30	1.63	.78	.50	202
3.9	80	0	5.52	.29	1.57	.71	.34	248
			Coto sandy clay					
5.7	0	1,450	4.69	.16	3.43	1.87	.49	333
5.0	7	1,390	4.65	.15	3.65	1.68	.42	388
4.7	18	1,380	4.71	.15	3.79	1.64	.39	414
4.5	32	1,260	4.75	.14	3.38	1.59	.39	616

All plots were planted to the bean variety Bonita February 1978. Rows were 45 cm apart with plants 5 cm apart within the rows. All plots received 1000 kg/ha of 10-10-10 fertilizer containing 25 kg/t of a minor

TABLE 2.—*Correlations between yield and plant factors of Bonita white beans and acidity factors of two Ultisols and an Oxisol*

Yield and plant factor	Soil acidity components		Exchangeable Al/ Exchangeable bases
	pH	Percent Al saturation	
	Corozal clay soil		
Grain yields	$r = .83^{**}$ $Y = 19755.9 + 7453.8X - 633.3 X^2$	$r = .91^{**}$ $Y = 1839.2 - 1.09 X - .29 X^2$	$r = .91^{**}$ $Y = 1928.3 - 980.2 X + 117.9 X^2$
% Ca content of leaves	$r = .70^{**}$ $Y = 3.77 + 1.71 X - .147 X^2$	$r = .76^{**}$ $Y = 1.1 + .0025 X - .00009 X^2$	$r = .76^{**}$ $Y = 1.14 - .17 X + .015 X^2$
Mn content of leaves (ppm)	$r = .44^{*}$ $Y = 528.7 - 53.2 X$	Nonsignificant	Nonsignificant
Ca/Mn ratio of leaves	$r = .71^{**}$ $Y = - 66.78 + 25.29 X$	Nonsignificant	Nonsignificant
	Corozal clay subsoil		
Grain yields	$r = .87^{**}$ $Y = 9795.7 + 3319.3 X - 216.8 X^2$	$r = .81^{**}$ $Y = 1758.3 - 21.8 X$	$r = .82^{**}$ $Y = 1633.8 - 997.2 X + 141.9 X^2$
% Ca content of leaves	$r = .82^{**}$ $Y = .99 - .42 X$	$r = .76^{**}$ $Y = 1.28 - .007 X$	$r = .82^{**}$ $Y = 1.22 - .3 X + .038 X^2$
Mn content of leaves (ppm)	$r = .72^{**}$ $Y = 462.7 - 61.3 X$	$r = .73^{**}$ $Y = 128.2 + 1.2 X$	$r = .75^{**}$ $Y = 131.56 + 70.57 X - 12.21 X^2$
Ca/Mn ratio of leaves	$r = .86^{**}$ $Y = 22.7 + 66.2 X$	$r = .73^{**}$ $Y = 106.4 - .83 X$	$r = .72^{**}$ $Y = 11.3 - 22.6 X$
	Coto sandy clay		
Grain yields	$r = .48^{**}$ $Y = 3243.7 + 1645.8 X = 43.8 X^2$	$r = .45^{**}$ $Y = 1415.7 + 8.2 X - .69 X^2$	$r = .45^{**}$ $Y = 1418.6 + 316.4 X - 3046 X^2$
% Ca content of leaves	Nonsignificant	Nonsignificant	Nonsignificant
Mn content of leaves (ppm)	$r = .63^{**}$ $Y = 1260.8 - 165.6 X$	$r = .51^{**}$ $Y = 351.2 + 8.34 X$	$r = .51^{**}$ $Y = 349.4 + 6 - 7.5 X$
Ca/Mn ratio of leaves	$r = .66^{**}$ $Y = -165.8 + 45.1 X$	$r = .48^{**}$ $Y = 71.4 - 76.2 X$	$r = .51^{**}$ $Y = 74.3 - 76.0 X$

element mixture containing Zn, B, Mo, Cu and Fe, 2 weeks after planting. Plots were sprayed twice during the course of the experiment for control of insects and diseases and were hand weeded as required. Irrigation was applied when weekly rainfall was less than 20 mm.

Before plants bloomed, leaves from the third pair were taken from plants in the central row of each plot, washed with distilled water, dried at 70°C, ground and analyzed for N by the Kjeldahl method; for P, colorimetrically; Ca and Mg by the Versenate method; and for Mn, colorimetrically as permanganate after oxidation with KIO_4.

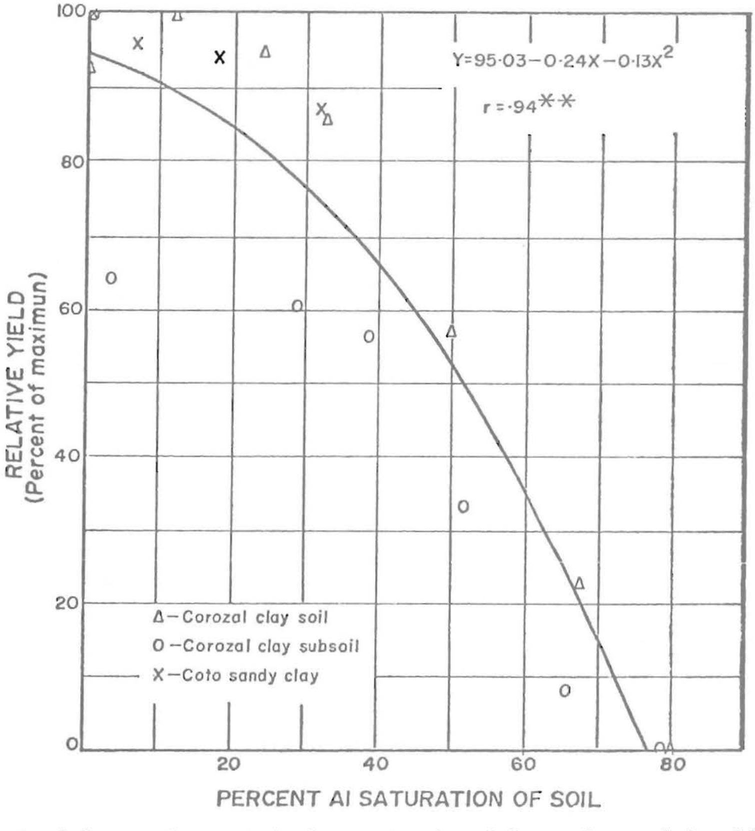

FIG. 1.—Influence of percent aluminum saturation of three soils on relative yields of Bonita dry beans in Puerto Rico.

All plots were harvested in May and the beans were dried to 14% moisture content. The relationships between yield and soil acidity components were determined by regression analysis.

RESULTS AND DISCUSSION

COROZAL CLAY SOIL

Yields were not affected by increasing soil acidity until pH dropped below 4.7 and Al saturation of the effective CEC of the soil increased beyond about 30% (table 1). As acidity increased beyond this level, bean yield dropped sharply. No crop was produced when pH reached 4.1 and Al saturation of the soil was 80% (table 1). Snap beans grown on this site have shown similar response to these soil acidity factors (1, 2).

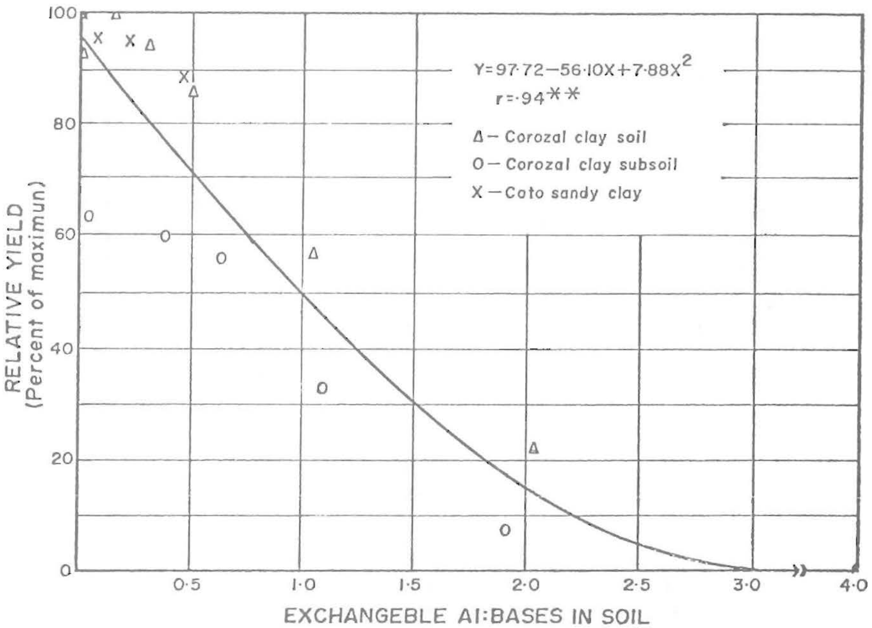

FIG. 2.—Relationship between exchangeable Al:bases and relative yields of Bonita dry beans on three soils in Puerto Rico.

Calcium content of the bean leaves was reduced when Al saturation of the soil dropped below 50% (table 1), but Mn, N, P, K and Mg contents were not appreciably affected by soil acidity.

Yields were highly correlated with soil pH, Al saturation, and exchangeable Al/exchangeable bases; and Ca content of the leaves correlated with these three soil acidity factors (table 2).

COROZAL CLAY SUBSOIL

Yields similar to those in the Corozal soil were produced on the Corozal subsoil when there was no exchangeable Al in the soil. However, the response of dry beans to increasing soil acidity was more marked in the subsoil than in the normal soil (table 1), possibly as a result of less organic matter in the subsoil (2.02% and 4.11%, respectively). Organic matter tends to reduce the effect of high Al contents on plant growth (6, 13).

Calcium content of the bean leaves decreased and Mn content increased with increasing soil acidity (table 1).

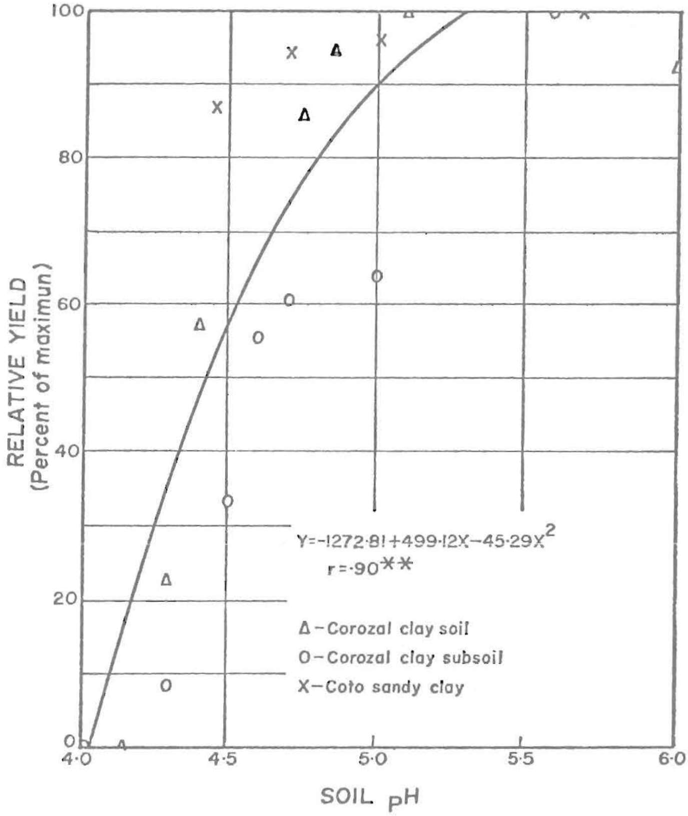

FIG. 3.—Influence of the pH of three soils on relative yields of Bonita dry beans in Puerto Rico.

Yields were highly correlated with all three soil acidity factors (table 2). Calcium, Mn and Ca/Mn content of the leaves also correlated well with all soil acidity factors. The Ca/Mn ratio has been highly correlated with snap bean yields on these soils (1).

COTO SANDY CLAY

Lower yields were obtained on the Coto than on the Corozal soil and the response to soil acidity factors was relatively small (table 1). With about 30% Al saturation and pH 4.5, the highest acidity occurring in the Coto soil (3), beans produced 87% and 86% of maximum yields on the Coto and Corozal soils, respectively.

Yields and foliar compositions correlated only weakly with the soil acidity factors (table 2).

ALL SOILS COMBINED

Regression analysis of the combined data for all soils (fig. 1, 2, 3) show that yields were closely correlated with all soil acidity factors.

Highest yields were obtained when essentially no exchangeable Al was present in the soil; yields decreased to around 50% of maximum at about 50% Al saturation of the soil and to 0 at near 80% Al saturation (fig. 1).

Yields decreased with increasing exchangeable Al/exchangeable bases

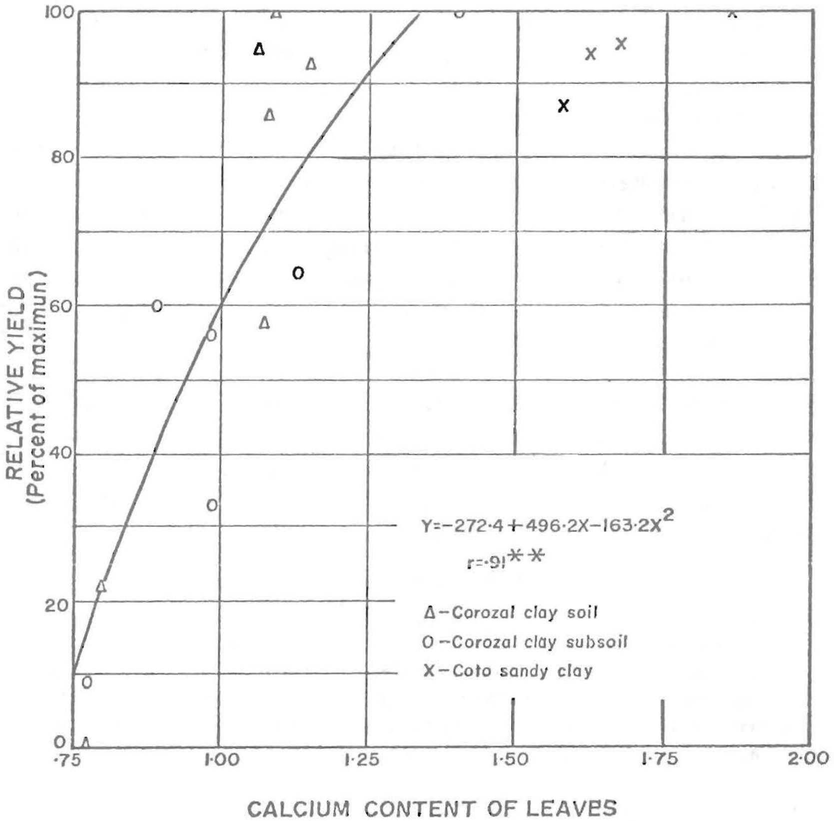

FIG. 4.—Relationship between calcium content of bean leaves and relative yield of Bonita dry beans.

(fig. 2). Yields increased with increasing pH from 0 at pH 4.0 up to 100% at around pH 5.2 (fig. 3).

Yields increased with increasing Ca content of the leaves (fig. 4) with maximum yields obtained when Ca content of the leaves was about 1.3%.

RESUMEN

Se estudió el efecto de los factores de acidez del suelo en los rendimientos y composición foliar de habichuelas blancas de la variedad Bonita en dos Ultisol en Corozal y un Oxisol en Isabela.

En el suelo Corozal (Ultisol) la producción de habichuelas no se redujo hasta que el pH bajó a 4.7, que correspondió a 30% de saturación de la capacidad de cambio del suelo con aluminio. Al aumentar la acidez sobre este nivel, se redujo señaladamente la producción de habichuelas hasta el punto en que no se produjo cosecha alguna cuando el pH del suelo bajó a 4.1, equivalente a un 80% de saturación de la capacidad de cambio con aluminio. El contenido de calcio en las hojas se redujo cuando el pH del suelo bajó de 4.4, pero el contenido de los otros nutrimentos no se afectó.

En el subsuelo Corozal se obtuvieron resultados similares aunque los efectos de los aumentos en la acidez en la producción de las habichuelas fueron más señalados que en el suelo.

En el suelo Coto (Oxisol) las habichuelas produjeron menos que en el Corozal y respondieron menos a aumentos de la acidez del suelo.

Cuando se combinaron los resultados obtenidos en los tres experimentos, se obtuvieron correlaciones altamente significativas entre rendimiento y pH, y rendimiento y saturación de la capacidad de cambio del suelo con aluminio. El contenido de calcio en las hojas correlacionó bien con la producción de las habichuelas.

Los rendimientos mayores de habichuelas se obtuvieron cuando los suelos tuvieron un pH de 5.2 o más, a cuyo nivel no había aluminio cambiable en el suelo. Los rendimientos se redujeron a un 50% del máximo cuando el nivel de saturación con aluminio alcanzó un 50% y a 0 cuando el nivel de aluminio alcanzó un 80% de saturación del complejo de cambio del suelo, a un pH de alrededor de 4.0.

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