Effect of Soil pH and Related Acidity Factors on Yields of Sweetpotatoes and Soybeans Grown on Typical Soils of the Humid Tropics[1, 2]

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ABSTRACT

The effects of soil pH and related acidity factors on the yields of sweetpotatoes, Miguela var., and soybeans, Jupiter var., were determined on typical Oxisols and Ultisols of Puerto Rico. The study revealed no significant effect of pH and acidity factors on the yield of the sweetpotato variety, which was quite tolerant to high soil acidity and exchangeable Al. Yields were similar to those obtained by other researchers who worked with other varieties. Soybeans, although relatively tolerant to high levels of exchangeable Al, were adversely affected when values surpassed 5.5 meq/100 g of soil in a clayey Ultisol. Exchangeable base content was directly related to soybean yield grown on a light textured Oxisol. Yields obtained are considered excellent. Highly significant correlations between soybean leaf N content and yield was found in the clayey Ultisol.

INTRODUCTION

Considerable work on the usefulness of lime applications to increase soil pH and inactivate harmful ionic Al and Mn, has been conducted in both the temperate zone and in the humid tropics. The widely different results found may be attributed to a number of factors, including the test crop itself, soil mineralogy, cation exchange capacity, soil moisture, and type of liming material applied.

Sweetpotatoes are among the crops that seem to respond in a limited manner to lime applications. Watts and Cooper (14) determined the effect of soil acidity on the growth and yield of sweetpotato (var. Porto Rico) grown on a Ruston fine sandy loam, by lowering the pH with H_2SO_4 to between 5.0 and 5.5, compared to pH ranges of 5.5 to 6.0, 6.0 to 6.5 and 6.5 to 7.0. The average marketable yields of plants were: For the very acid plots, 339 bu/acre; for the slightly acid, 383 bu/acre; for the very slightly acid, 453 bu/acre; and for the neutral, 375 bu/acre. Boswell (2) has indicated that, with other factors favorable, sweetpotatoes produce highest marketable yields on moderately to slightly acid soils. Steinbauer and Beattie (13), working with three sweetpotato varieties, concluded that the crop does best in slightly to moderately acid soil, and

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that yields may decrease when the soil becomes neutral or alkaline. Nye and Greenland (8) reported that sweetpotato yields were increased by liming in only two of a number of trials in Uganda on soils with pH below 5.0. In similar tests in Brazil, Camargo (3) showed that sweetpotatoes did not respond to liming. On the other hand, Lugo-López et al. (4) reported yield increases of about 36% when an acid Aquic Tropohumult was limed.

Research with lime on soybeans has received attention in many parts of the world. Rogers et al. (10) studied the effect of soil pH on soybean yields produced on a Benndale sandy loam. Their yields increased from 13 bu/acre at pH 4.8 to more than 30 bu/acre at pH 6.1 Mascarenhas et al. (7) found that dolomitic lime increased soybean yields 30% in a Red Latosol in Brazil, even though the initial soil pH was 5.5, with no exchangeable Al. Mascarenhas (6) also found that another Red Latosol with pH 4.8 was not responsive to lime applications. Soares (11) found that when Al saturation was reduced to 10%, soybean yields increased sharply on two Red Latosols. Spain et al. (12) reported lime responses with up to 6 tons/ha on an unlimed pH 4.3 Colombia Oxisol, even though most of the effect occurred with the application of the first 2 tons/ha.

The present study investigates the behavior of two high yielding sweetpotato and soybean varieties growing under different pH conditions.

MATERIALS AND METHODS

The experiments in which sweetpotatoes, *Ipomoea batatas* Miguela var., were used, were conducted in a Bayamón loamy sand (an Oxisol) and in Los Guineos clay and Corozal clay (Ultisols). Bayamón loamy sand, near Manatí, is a Typic Haplorthox from quartzitic sand deposits. Its organic matter content averages 0.5% and it has a cation exchange capacity of 1.3 meq/100 g. Los Guineos clay, located in Barrio Mameyes in Jayuya, is an Epiaquic Tropohumult from tuffaceous material. Its organic matter content is 8.1% and the cation exchange capacity is 16.0 meq/100 g. The Corozal clay, derived from tuffaceous material, is located at Corozal Agricultural Substation in Corozal. Its organic matter content is 4.7% and its cation exchange capacity is 19.0 meq/100 g.

The sweetpotato and soybean crops to be discussed were the third and fourth in a series of experiments performed at each of the above sites to study the effects of soil pH and acidity factors. Lime applications were made in Bayamón loamy sand and in Los Guineos clay during July 1970, and in Corozal clay during March 1971 before the first two experiments (field corn and snap beans). Those results have been reported by Abruña et al. (1). Five treatments, replicated five times, were arranged in a Latin square design in the Bayamón loamy sand and Los Guineos clay, and in a complete randomized design in the Corozal clay. They consisted of: check, 337 kg/ha of $Ca(OH)_2$ and sufficient lime to bring soil pH to 5.5, 6.0 and 7.0.

The sweetpotato experiment in Corozal clay was planted on December 30, 1971; in Los Guineos clay, on February 18, 1972; in the Bayamón loamy sand, on December 27, 1972. Sweetpotato vines, 30 cm long, were planted in rows 75 cm apart and 20 cm within the row in plots 4.5 × 9 m. A month after planting, 1120 kg/ha of a 10-10-10 fertilizer mixed with 57 kg/ha of Mg as Epsom salt were applied to each plot in a band. Just before budding, leaf No. 3 samples were taken to determine N, P, K, Ca, Mg and Mn. When the crop was 6 months old, the two center rows were harvested. Soil samples from 0- to 15-cm and 15- to 30-cm depth were collected right after harvest and analyzed for pH, and exchangeable Ca, Mg, and Al extracted with 1.0 N KCl.

Soybeans, *Glycine max* (L) Merrill, Jupiter variety, were planted next on all but the Corozal clay site. Before planting, a fertilizer mixture containing 285 kg/ha of P_2O_5, 148 kg/ha of K_2O and 114 kg/ha of Mg as Epsom salt was broadcast and mixed with the 0 to 15 cm soil layer. Soybean seed were inoculated with Nitragin "S"[4] and, therefore, no N was applied.

The seed were planted in rows 45 cm apart, but due to different germination rates at the two sites, the average distance between plants within rows was 15 cm in Los Guineos clay and 7.5 cm in Bayamón loamy sand. Harvest at both sites was 4 months after planting. Soil samples from 0- to 15-cm and 15- to 30-cm depth, were collected right after harvest and analyzed for pH and exchangeable Ca and Mg and for Al extracted with 1.0 N KCl. Whenever relationships between yields, foliar composition and soil acidity factors were apparent, regression analyses were run on both sweetpotato and soybean data.

RESULTS AND DISCUSSION

SWEETPOTATOES

The effect of soil pH and related acidity factors on sweetpotato yield is shown in table 1. The effect of soil pH on foliar composition is shown in table 2. No statistically significant relationships were found between yield and soil pH, nor between yield and soil acidity factors in any of the three soils. In Bayamón loamy sand the yields were rather low, probably because of scant rainfall (435 mm) and the formation of a hardpan at 15

[4] Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico or an endorsement over other equipment or materials not mentioned.

cm which causes mechanical impedance, particularly when the soil dries out.

In Los Guineos clay and Corozal clay, both producing more than twice the amount of sweetpotatoes obtained in the Bayamón loamy sand, yields were high even at the lower pH values. In Los Guineos clay the plots in the 4.0 to 4.3 pH range with 4.48 meq of exchangeable Al produced about the same yields as those having higher pH values and correspondingly lower exchangeable Al content. In this soil all but one plot had pH values below 5.0. These were recorded 1½ years after lime

TABLE 1.—*Effect of soil pH (0- to 15-cm depth) and soil acidity factors on yields of sweetpotatoes, Miguela variety*[1]

Soil pH	Exchangeable Al	Exchangeable Ca + Mg	Base saturation	Al saturation	Yield
	Meq/100 g	*Meq/100 g*	%	%	*Kg/ha*
		Bayamón loamy sand (Oxisol)			
4.4 to 4.8	0.35	0.69	66	34	4,571
4.9 to 5.3	.14	.83	86	14	4,738
>5.3	0	1.22	100	0	5,703
		Los Guineos clay (Ultisol)			
4.0 to 4.3	4.48	5.51	55	45	12,612
4.4 to 4.7	3.09	6.06	66	34	13,369
>4.7	.86	11.06	92	8	12,430
		Corozal clay (Ultisol)			
4.6 to 4.8	1.32	5.24	80	20	12,777
4.9 to 5.1	.70	5.50	89	11	13,004
>5.1	.18	8.40	98	2	13,360

[1] Values of acidity factors are given by plot averages over the selected pH range values shown in the first column.

application, at which point the average pH value at the 15- to 30-cm depth was 4.69; at the 0- to 15-cm depth the average value was 4.56, indicating a tendency toward a downward movement of bases. Seventeen out of 25 plots showed pH increases in subsurface samples 15 to 30 cm deep.

In Corozal clay, pH values were not as low as in Los Guineos clay. Yields in the lowest pH range—4.6 to 4.8—did not differ statistically from these in the higher pH ranges. The average pH at the 0- to 15-cm depth was 5.19 and at 15 to 30 cm it was 4.59. Bases did not move in this soil to the degree that they did in Los Guineos clay.

The nutrients in the leaves taken just before budding seem adequate. The Mn content in the leaves in Los Guineos clay was considerably lower than that in Bayamón loamy sand and Corozal clay experiments. Yet, no visual deficiency symptoms were observed while the crop was growing. In Bayamón loamy sand, where yields were quite low, leaf Mn content exceeded 350 p/m. Yields were lower as the leaf Mn content increased to 508 and 631 p/m.

The results from these experiments generally agreed with those of Steinbauer and Beattie (12). They stated that their results with three sweetpotato varieties suggested that this crop was not very exacting with respect to soil acidity. They indicated that sweetpotatoes did best in slightly to moderately acid soils and yields may be decreased when the soil becomes neutral or alkaline. Unfortunately, there were no pH values above 6 in order to corroborate their statement. If exchangeable

TABLE 2.—*Effect of soil pH (0- to 15-cm depth) on foliar composition of sweetpotatoes, Miguela variety*

Soil pH	Foliar composition[1]					
	N	P	K	Ca	Mg	Mn
	%	%	%	%	%	*P/m*
			Bayamón loamy sand (Oxisol)			
4.4 to 4.8	4.44	0.74	2.24	0.77	0.45	631
4.9 to 5.3	4.37	.75	2.17	.72	.52	508
>5.3	4.37	.75	2.27	.83	.48	352
			Los Guineos clay (Ultisol)			
4.0 to 4.3	4.87	.39	2.53	.87	.33	51
4.4 to 4.7	4.79	.44	2.58	.88	.33	43
>4.7	5.01	.46	2.60	1.27	.38	27
			Corozal clay (Ultisol)			
4.6 to 4.8	5.69	.66	3.85	.54	.39	146
4.9 to 5.1	5.66	.62	3.88	.54	.39	163
>5.2	5.55	.60	3.92	.64	.30	129

[1] Foliar composition presented was calculated by plot averages over the selected pH ranges shown in the first column.

Ca and Mg are available in spite of low pH, then the results obtained are explainable and reasonable. For instance, plots with pH values in the 4.0 to 4.3 range in Los Guineos clay included average exchangeable Ca + Mg values of 5.51 meq/100 g. This is more than enough, in spite of the high exchangeable Al (4.48 meq/100 g). General experience with crops having cycles of 6 or more months indicates that they are more tolerant to Al than short cycle crops (9). However, there are short cycle crops, such as certain wheat and barley varities, that are highly tolerant to Al (4).

SOYBEANS

The effects of soil pH on yield and foliar composition of soybeans, variety Jupiter, produced in Bayamón loamy sand and Los Guineos clay are shown in table 3, and table 4 presents the effect of soil acidity factors on yield. No statistically significant relationship existed between soil pH and yield or between exchangeable Al and yield in Bayamón loamy sand. Yet, exchangeable Ca + Mg was related to yield with a highly significant correlation ($r = 0.57^{**}$). A 60% higher yield was obtained at high exchangeable Ca + Mg levels. Percentage base saturation was significantly related to soybean yield, ($r = 0.44^{*}$). Even though pH is primarily a function of the hydrolysis of adsorbed and solution cations, in a highly weathered light-textured soil like Bayamón loamy sand the magnitude of the hydrolysis is limited. Cation adsorption and solution

TABLE 3.—*Effect of soil pH (0- to 15-cm depth) on yields and foliar composition of soybeans, Jupiter variety*

Soil pH	Yield	Foliar composition					
		N	P	K	Ca	Mg	Mn
	Kg/ha	%	%	%	%	%	*P/m*
		Bayamón loamy sand (Oxisol)					
4.8 to 5.1	1905	3.89	0.44	1.63	0.90	0.34	185
5.2 to 5.5	1786	3.78	.42	1.64	.94	.34	159
5.6 to 5.9	1955	3.51	.36	1.68	.99	.34	144
6.0 to 6.3	2100	3.97	.44	1.65	1.03	.36	122
>6.3	2584	4.17	.38	1.80	1.08	.34	144
		Yield vs. Σ Ca, Mg, K, $r = 0.71^{**}$					
		Los Guineos clay (Ultisol)					
4.0 to 4.2	1402	4.99	.20	2.08	.59	.39	27
4.3 to 4.5	2194	5.70	.21	2.26	.90	.42	22
4.6 to 4.8	2509	6.05	.21	2.11	1.13	.40	16
>4.8	2452	6.12	.22	2.10	1.14	.40	16
		Yield vs. soil pH, $r = 0.62^{*}$					
		Yield vs. leaf N, $r = 0.84^{**}$					
		Yield vs. leaf Ca, $r = 0.79^{**}$					
		Leaf N vs. soil pH, $r = 0.57^{*}$					

Al are low and therefore, pH may not be a good criterion for prediction of yields. Likewise pH 5.0, which is generally acceptable, does not mean that the amounts of bases are adequate. A pH value of this order may be due largely to the acidity of the suspension water.

Neither N, P nor Mn content of the leaves was affected by soil pH differences. This was also true for leaf Ca, Mg and K when individually related to yields. When Ca, Mg and K were combined and their values related to yields, a highly significant correlation coefficient, $r = 0.71^{**}$, was obtained. This agrees with the significant relation between exchangeable bases and yields reported above.

In Los Guineos clay, the effect of soil pH on yield was significant ($r = 0.62^{*}$), and the relationship was quadratic ($Y = -24195 + 10046.4X - 929.2X^2$). When exchangeable Al was related to yields, the correlation coefficient, r = 0.80**, was highly significant and the effect was also quadratic ($Y = 188.7 + 62.2X - 137.1 X^2$). When exchangeable Al surpassed 5.5 meq/100 g, soybean yield diminished by 50%. Exhangeable Al played a more important role in reducing yields than the exchangeable base content did in increasing production. Percent base saturation was significantly related to soybean yields (r = 0.66*).

Leaf N and Ca were related to yields (table 3) in a highly significant way, with 0.84 and 0.79 correlation coefficients, respectively. N values increased from 4.99 to 6.12%, while those of Ca increased from 0.59 to 1.14%. Soil pH was significantly correlated with leaf N content (r = 0.57*). As pointed out before, N was not applied to the soybean crop

TABLE 4.—*Effect of soil acidity factors on soybean (Jupiter var.) yields grown in Bayamón loamy sand and in Los Guineos clay*

Bayamón loamy sand		Los Guineos clay	
Exchangeable Al	Yield	Exchangeable Al	Yield
Meq/100 g	*Kg/ha*	*Meq/100 g*	*Kg/ha*
0 to 0.1	2131	0.5 to 3.0	2465
0.2 to 0.3	1679	3.1 to 5.5	2049
>0.3	1584	>5.5	1270
r, N.S.		r = 0.80**	
Exchangeable Ca + Mg		Exchangeable Ca + Mg	
0.6 to 1.1	1528	1.6 to 2.0	1389
1.2 to 1.7	2024	2.1 to 3.0	1691
>1.7	2402	3.1 to 4.0	2384
r = 0.57**		>4.0	2390
		r, N.S.	
Base saturation		Base saturation	
%		%	
60 to 75	1433	25 to 50	1716
76 to 90	1779	51 to 75	2464
>90	2125	>75	2577
r = 0.44**		r = 0.66**	

since seed was inoculated with Nitragin "S". Increasing soil pH not only inactivated ionic Al but also favorably affected the fixation of molecular N to available forms.

These results agree with those reported by Rogers et al. (10). Soybeans can be considered a relatively tolerant crop to exchangeable Al, especially if cationic nutrients are found in adequate amounts. As in sweetpotatoes, Mn values appear to be quite low, yet soybean yields were excellent. No visual deficiency symptoms for this element could be observed in the field.

RESUMEN

Se presentan los resultados de dos experimentos en los que se estudió el efecto del pH y los factores de acidez del suelo en los rendimientos de batata, variedad Miguela, y de habas sojas, variedad Júpiter, sembradas en oxisoles y ultisoles típicos de Puerto Rico.

Ni el pH ni los factores de acidez del suelo afectaron el rendimiento de batatas y su composición química foliar. Los resultados concuerdan en términos generales con los obtenidos por otros investigadores.

Las habas sojas, aunque tolerantes a altos contenidos de aluminio intercambiable, fueron afectadas cuando éstos sobrepasaron 5.5 meq./100 g. en una arcilla del orden ultisol. En el suelo de textura liviana del orden oxisol se encontró una relación positiva entre las bases intercambiables y la producción de habas sojas. El contenido de N en las hojas de soja sembradas en el ultisol arcilloso y el rendimiento estaban correlacionados en forma altamente significativa. El pH de este suelo tuvo un efecto significativo en la absorción de N por las habas.

LITERATURE CITED

1. Abruña, F., Pearson, R. W., and Pérez-Escolar, R., Lime repsonse of corn and beans grown on typical Oxisols and Ultisols of Puerto Rico, 261-81. In Elemer Bornemisza and Alfredo Alvarado (editors) Soil Management in Tropical America. North Carolina State University Press, 1975.
2. Boswell, V. R., Commercial growing and harvesting of sweetpotatoes, USDA Farmers Bull. 2020, 1950.
3. Camargo, P., Freire, E. S., and Venturini, W. R., Efeito da calagem e de diversas adubações na batata-doce e no cara em solos de baixa fertilidade, derivados do arenito Botucatu, Brangantia 21: 143-61, 1962.
4. Foy, C. D., Armiger, W. H., Briggle, L. W., and Reid, D. A., Differential aluminum tolerance of wheat and barley varieties in acid soils, Argron. J. 57: 413-17, 1965.
5. Lugo-López, M. A., Hernández-Medina, E., and Acevedo, G., Response of some tropical soils and crops of Puerto Rico to applications of lime, Agr. Exp. Sta. Univ. P.R. Tech. Paper No. 28, 1959.
6. Mascarenhas, H. A., Miyasaka, S., and Igue, T., Adubaçao de soja VII. Efeito de doses crescentes de calcario, fósforo e potássio em solo Latosol Roxo com vegetação de Cerado recem desbravado, Bragantia 27: 279-89, 1968.
7. Mascarenhas, H. A., Miyasaka, S., Igue, T., Freire, E. S., and di Sordi, G., Respostas da soja a calagem e a adubações minerais com fósforo e potassio em solo Latosolo Roxo, Bragantia 28: 17-21, 1969.
8. Nye, P. H., and Greeland, D. J., The soil under shifting cultivation, Commonwealth Bur. Soils Tech. Comm. 51, 156 pp. 1960.
9. Pearson, R. W., Soil acidity and liming in the Humid Tropics, Cornell Int. Agr. Bull. 30, 1975.
10. Rogers, Howard, T., Thurlow, D. L., Adams, F., Evans, C. E., and Wear, John I., Soybean Production-Research Findings, Auburn Univ. Agr. Exp. Sta. Bull. 413, 1971.
11. Soares, W. V., Lobato, E., González, E., and Naderman, G. C. Jr., Liming soils of the Brazilian Cerrado, p. 283-98. *In* Elemer Bornemisza and Alfredo Alvarado, (editors) Soil Management in Tropical America. North Caroline State University Press. 1975.
12. Spain, J. M., Frances, C. A., Howeler, R. W., and Calvo, F., Differential species and varietal tolerance to soil acidity in tropical crops and pastures, p. 308-29. *In* Elemer Bornemisza and Alfredo Alvarado, (editors) Soil Management in Tropical America. North Carolina State University Press, 1975.
13. Steinbauer, C. E., and Beattie, J. H., Influence of lime and calcium chloride applications on growth and yields of sweetpotatoes, Proc. Hort. Amer. Soc. Hort. Sci. pp. 526-32, 1938.
14. Watts, V. M., and Cooper, J. R., Influence of varied soil reactions on growth and yield of vegetable crops in Newtonia silt loam and Ruston fine sandy loam soils, Arkansas Agr. Exp. Sta. Bull. 433, 1943.