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

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ABSTRACT

The effect of acidity factors of two Ultisols and one Oxisol on yield and foliar composition of tomatoes was determined. Yields were not markedly reduced by acidity in the Ultisols until pH dropped to around 4.6 with 45% Al saturation of the cation exchange capacity (CEC), and no yield was produced at about pH 4.1 and 80% Al saturation. In the Oxisol, tomato yields dropped steadily from 39.7 t/ha, when there was no exchangeable Al, to 17.5 t/ha at the highest level of acidity, pH 4.4 and 43% Al saturation. In all soils, yields were closely correlated with soil pH, exchangeable Al and Ca and Al/Ca.

INTRODUCTION

Commercial tomato production in tropical and subtropical regions is mainly confined to irrigated areas in semiarid zones during the winter months. However, many small farms with acid Ultisols and Oxisols produce tomatoes for local consumption.

Limited research has been conducted on the effects of soil acidity on tomato production in the tropics. Hortenstein and Blue (9) found a significant increase in tomato yields as the pH of a soil from British Honduras (Belize) was increased from 5.4 to 6.3. Bornemisza et al. (5) reported 35% increase in growth of tomato plants when pH of a Costa Rican latosol was increased from 4.5 to 5.5, but additional lime applications reduced yields to the level of the unlimed soil. Fassbender (7) found a strong response by tomatoes to lime applied to a very acid andosol from Costa Rica. Fassbender and Molina (8) reported 300% increase in the dry weight of tomato plants when pH of two volcanic soils from Costa Rica was raised from 4.2 to 4.8.

The research herein reported determined the relationship between the various soil acidity factors and yields and foliar composition of tomatoes grown in two Ultisols and one Oxisol of Puerto Rico.

MATERIALS AND METHODS

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

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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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Experiments were conducted in a Corozal clay (Aquic Tropudults) and subsoil (top soil removed about 16 years ago) near Corozal and in Coto sandy clay (Tropeptic Haplorthox) near Isabela. The Corozal soils are derived from tuffaceous materials and the Coto soil from medium-hard limestone.

There were 30 4x4-m plots at each of the Corozal sites and 42 in the Coto soil. All plots were surrounded by 15 cm-deep ditches to prevent runoff from one plot to another. The plots were planted to tomatoes of the Tropic variety at 1.2 m between rows and .7 m between plants. Wire trellises 2 m high were provided. The experiment in Coto soil was planted January 30 and those in Corozal April 10, 1979. Overhead irrigation was used with the Coto soil when required, but not at Corozal since rainfall was abundant at all times. All plots were fertilized twice with 600 kg/ha of 10-10-10. Insects and diseases were controlled by pesticide spraying as recommended by the Agricultural Experiment Station, University of Puerto Rico.

In each plot soil was sampled at planting from 10 borings at 0–15 cm depth. The samples were air dried and passed through a 10-mesh screen. Exchangeable bases (Ca, Mg and K) were extracted with *N*-neutral NH_4OAc. Calcium and Mg were determined by the Versenate titration method (6) and K by flame photometry. Exchangeable Al was extracted with 2*N* KCl and determined by the double titration method (11). Soil reaction was measured with a glass electrode with a 1 to 1.5 soil-to-water ratio. Percentage aluminum saturation of the effective CEC was calculated by dividing the exchangeable Al content by the sum of exchangeable Ca, Mg, K, and Al.

Samples of active mature leaves were taken from plants in the central row of each plot at flowering, and were analyzed for Ca and Mg by the Versenate method, K by flame photometry, P and Mn colorimetrically, and N by the Kjeldahl method.

Mature-green fruits from each plot were picked seven times during the experiment and commercial yields determined.

For statistical analysis, plots were grouped in 15% Al saturation ranges, with 0 as a separate range, and yields were related to soil acidity factors through regression analysis.

RESULTS AND DISCUSSION

The climate was hotter and more humid, and yields were lower at the Corozal than at the Coto soil site. Rainfall during the course of the experiments was 767 and 314 mm, average temperature 26 and 23° C, and relative humidity 84 and 73% at the Corozal and Coto sites, respectively. Marrero (10) in Cuba found that relative humidity above 60% hindered pollination and fruit setting of tomatoes.

COROZAL CLAY

Yields in Corozal clay were not reduced until pH dropped to 4.7 with Al saturation of about 40% of the effective CEC of the soil (table 1). Essentially, no yield was produced at the highest level of acidity, pH 4.2 with 80% Al saturation.

About 25% of the fruits rotted before ripening, but rotting was not related to soil acidity.

Fruit weight decreased with yields and with increased acidity.

Nitrogen, P, and Mg content of the leaves (table 1) did not vary with acidity levels, but K and Ca contents decreased with increasing acidity. Aluminum and Mn contents of the leaves increased with increasing soil acidity.

Tomato yields were significantly correlated with soil acidity factors: percentage Al saturation, % Ca saturation and Al/Ca (table 2). Yields were also correlated with the Ca, Al and K contents of the leaves.

COROZAL SUBSOIL

Tomato yields were low and considerably less than in the normal soil (table 1). Fruits were smaller than those in the normal soil. Highest yields were obtained at pH 6.0 with no exchangeable Al, and decreased with increasing acidity with no crop harvested at pH 4.05 with 85% Al saturation.

Fruit weight decreased with increasing acidity.

Calcium and K contents of the tomato leaves dropped sharply at the highest level of acidity (table 1). Calcium and Mg contents of the leaves at all acidity levels were lower in the subsoil than in the normal soil. Yields correlated with the various soil acidity factors (table 2).

COTO SOIL

Yields were much higher than in the Corozal soils and also decreased with increasing acidity. At the highest level of acidity, pH 4.4 and 43% Al saturation, yields were 45% of maximum. At a comparable Al saturation level in the Corozal soil, yields were about 70% of maximum, indicating that tomatoes were more sensitive to soil acidity factors in the Coto than in the Corozal soils. Acid Coto soil is high in easily reducible and exchangeable Mn; this ion exhibits a high chemical activity in the displaced soil solution (1, 2, 12) contributing to the deleterious effects of high acidity level on tomato yields.

Losses in yield caused by rotting while the fruit was still green were lower at all acidity levels in the Coto than in the Corozal soils probably due to higher rainfall, relative humidity and temperatures at the latter sites.

TABLE 1.—*Effect of soil acidity factors of two Ultisols and one Oxisol on yield and composition of tomatoes*

Soil acidity factors		Yields		Foliar composition						
pH	Percent Al saturation	Commercial t/ha	Fruit weight	N	P	K	Ca	Mg	Al	Mn
			g			%			*p/m*	
			Corozal clay (Aquic Tropudults)							
6.30	0	14.07	136	5.35	.29	4.05	2.56	.55	159	34
5.00	8	14.43	136	4.91	.31	4.35	2.34	.42	161	43
4.80	22	15.78	132	4.93	.31	4.15	2.29	.38	151	62
4.70	41	10.83	127	5.20	.35	3.75	2.39	.43	153	69
4.45	57	10.05	122	5.50	.29	3.69	2.22	.30	230	86
4.20	80	0.54	88	5.15	.29	2.59	1.33	.50	342	105
			Corozal clay-subsoil (Aquic Tropudults)							
6.00	0	9.07	114	4.84	.27	4.24	1.91	.29	—	—
4.95	11	7.98	105	4.99	.20	4.35	1.77	.23	—	—
4.85	25	6.96	100	4.98	.29	4.42	1.94	.23	—	—
4.65	36	6.53	86	5.15	.28	4.17	1.76	.23	—	—
4.55	50	4.35	87	5.20	.23	3.84	1.63	.16	—	—
4.05	85	0	0	4.52	.25	1.58	.53	.27	—	—
			Coto sandy clay (Tropeptic Haplorthox)							
5.90	0	39.71	174	4.55	.29	2.90	1.74	.90	211	274
5.00	5	33.04	160	4.46	.25	3.24	1.62	.79	228	270
4.80	15	27.16	156	4.11	.24	3.08	1.66	.74	231	282
4.65	23	23.03	148	3.94	.21	2.76	1.42	.69	235	287
4.40	43	17.53	137	3.84	.21	2.46	1.11	.60	317	320

TABLE 2.—*Correlation coefficients between soil acidity factors, yield components and chemical leaf composition of tomatoes grown in two Ultisols and one Oxisol*

Independent variable (X)	Yield components (Y)		Foliar composition (Y)			
	Commercial yield	Fruit size	Ca	Al	K	Mg
	t/ha		%	*p/m*	%	%
		Corozal clay soil				
pH	.78**[1]	.56*	.72**	.73**	.82**	N.S.
Exch. Al	–.77**	–.73**	–.72**	.94**	–.94**	N.S.
% Al saturation	–.84**	–.83**	–.75**	.87**	–.82**	N.S.
% Ca saturation	.84**	.80**	.78**	–.86**	.82**	N.S.
Al/Ca	–.84**	–.91**	–.79**	.87**	–.83**	N.S.
Ca content in leaves	.63**	—	—	—	—	—
K content in leaves	.69**	—	—	—	—	—
Al content in leaves	–.78**	—	—	—	—	—
		Corozal clay—subsoil				
pH	.86**	.73**	N.S.	—	.84**	.61**
Exch. Al	–.84**	–.74**	N.S.	—	–.81**	N.S.
% Al saturation	–.85**	–.75**	N.S.	—	–.81**	N.S.
% Ca saturation	.84**	.74**	N.S.	—	.79**	N.S.
Al/Ca	–.84**	–.76**	N.S.	—	–.79**	N.S.
		Coto sandy clay				
pH	.79**	.64**	N.S.	—	N.S.	N.S.
Exch. Al	–.76**	–.64**	–.57*	—	N.S.	N.S.
% Al saturation	–.76**	–.65**	–.58*	—	N.S.	N.S.
% Ca saturation	.60**	.56*	.61*	—	N.S.	N.S.
Al/Ca	–.75**	–.63**	–.59*	—	N.S.	N.S.
Ca content in leaves	.57*	—	—	—	—	—
Mg content in leaves	.59*	—	—	—	—	—
Ca/Mn in leaves	.59*	—	—	—	—	—

[1] Significant at the 1% probability level.

Calcium and Mg contents of the tomato leaves decreased and Mn and Al contents increased, with increasing acidity (table 2). Magnesium content of the leaves was much higher in the Coto than in the Corozal soils and was significantly correlated with yields (table 2).

Yields were correlated with all soil acidity factors, with Ca and Mg contents, and with Ca/Mn in the tomato leaves.

ALL SOILS

Regression analysis of the combined average data for all sites showed that yields of about two-thirds of maximum can be obtained with Al saturation values of around 40%, a level common in Ultisols and Oxisols (fig. 1). Maximum yields were obtained around pH 5.2 with no exchange-

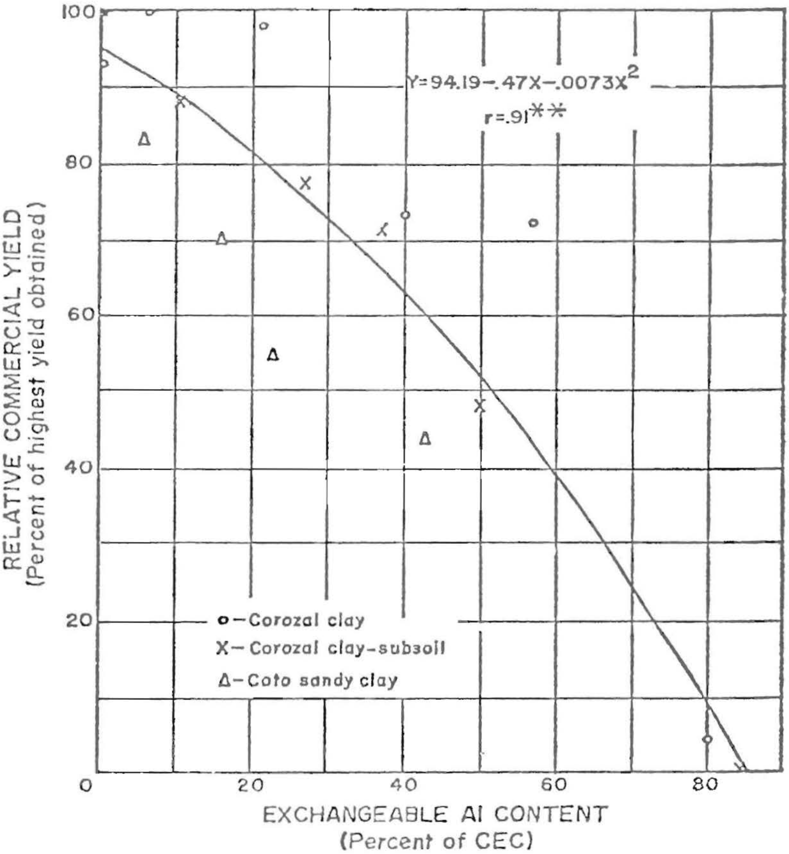

FIG. 1.—Effect of Al saturation of two Ultisols and one Oxisol on relative yield of tomatoes.

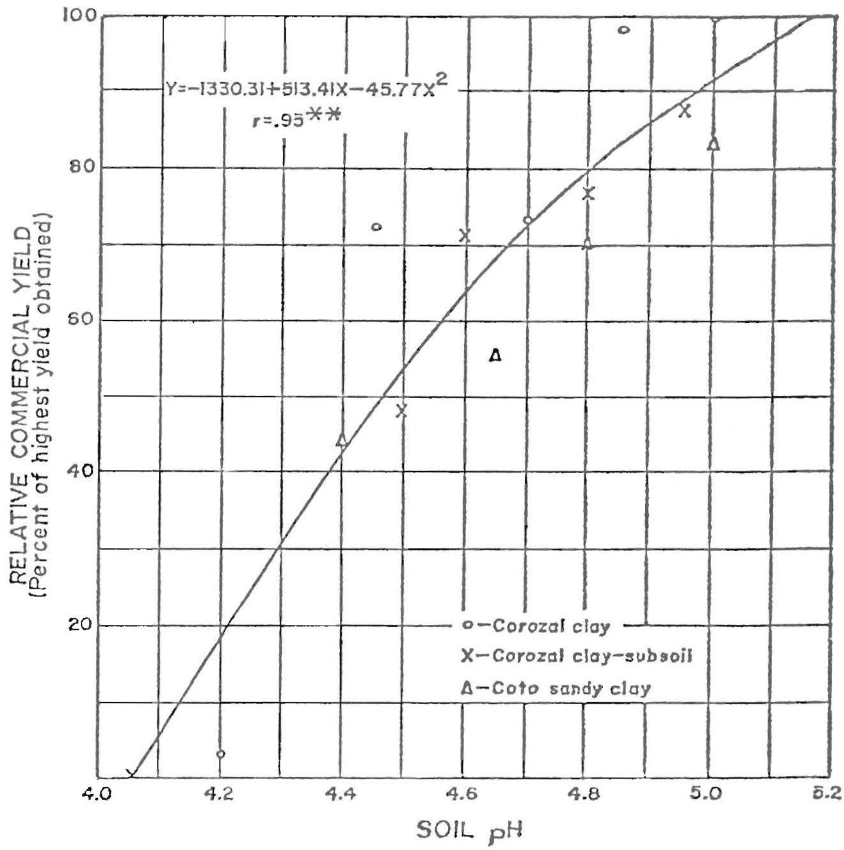

FIG. 2.—Relationship between soil pH and relative yield of tomatoes grown in two Ultisols and one Oxisol.

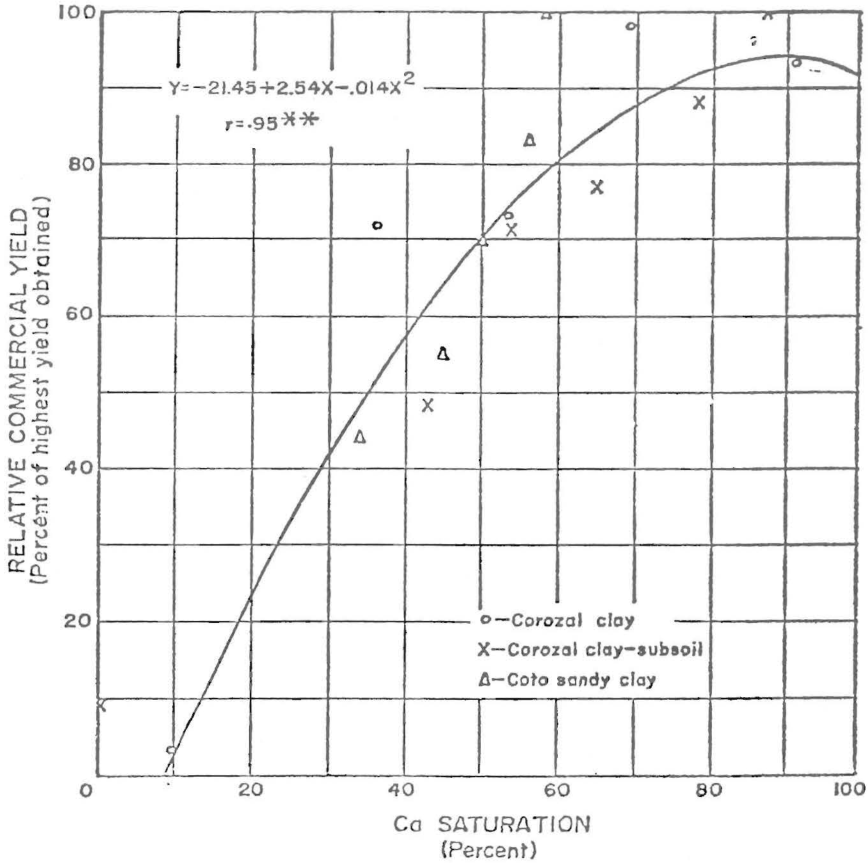

FIG. 3.—Relationship between calcium saturation of the CEC of two Ultisols and one Oxisol in relative yield of tomatoes.

able Al present in the soil (fig. 1 and 2). About 80% Ca saturation of the effective CEC was associated with maximum yields (fig. 3).

The data presented indicate that tolerance of tomatoes to soil acidity is similar to that of taniers and sweetpotatoes (3, 4).

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