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CROP AND SOIL MANAGEMENT SYSTEMS TO REDUCE NUTRIENT STRESS IN THE CARIBBEAN. I. SOIL ACIDITY AND LIMING : BEAN AND PUMPKIN RESPONSES.

N. RAFOLS-SALLABERRY, V. SNYDER, N. CAVALLERO, G. MARTINEZ, and A. GONZALEZ.

Puerto Rico Agricultural Experiment Station

ABSTRACT

Differentially limed plots were established on acid soils at the Corozal and Isabela Experimental Farms of Puerto Rico Agricultural Experiment Station (PRAES). The soil at Corozal is an Ultisol with relatively high levels of exchangeable Al and low Mn under natural acid conditions, whereas the soil at Isabela (an Oxisol) presents lower Al values but higher concentrations of Mn. Two crops, one of beans (Phaseolus vulgaris) and one of pumpkins (*Cucurbita moschata*), were planted at all sites and response to liming observed. Yields were affected both by lower surviving plant populations and developmental factors. At Corozal the fungus Microphomyna caused nearly a 50 percent loss in plant population at soil pH values of around 4.5 or lower. Addition of lime drastically reduced the level of infection in 3 out of 4 bean varieties currently being evaluated in Puerto Rico. In Isabela, during the first crop of beans, a yield increase was observed with lime addition. Yields in the second crop dropped sharply on those plots where lime additions were kept low suggesting inadequate residual effects of low lime application rates. A strong response to liming by the pumpkin crop was observed in Corozal, whereas no data could be obtained in Isabela due to crop failure to fungal attack.

RESUME

SYSTEMES DE CONDUITE SOL-PLANTE POUR REDUIRE LE DEFICIT EN NUTRIMENT DANS LES CARAIBES. I. ACIDITE DU SOL ET CHAULAGE : REPONSES DU HARICOT ET DU GIRAUMON

Des parcelles ont été installées sur des sols acides des fermes expérimentales de Corozal et d'Isabela de Puerto Rico (P.R.A.E.S.) avec différentes doses

de chaux.

Le sol de Corozal est un ultisol à niveaux élevé de Al échangeable et bas de Mn en condition naturelle acide, tandis que l'oxisol d'Isabela présente des teneurs basses en Al et élevées en Mn.

la réponse au chaulage est observée sur haricots (*Phaseolus vulgaris*) et sur giraumon (*Curcubita moshata*). Les récoltes sont affectées par le petit nombre de plantes qui survivent et par des facteurs de développement.

A Corozal le champignon Mycrophomyna a causé environ 50 % de pertes de plants à des valeurs de ph ≤ 4,50. L'apport de
chaux réduit de façon drastique le niveau d'infection de 3 des 4 variétés de haricots testés couramment à Puerto Rico.
A Isabela l'apport de chaux entraîne une augmentation de la production de la 1ère culture de haricots. Les récoltes de la 2ème culture diminuent considérablement sur ces parcelles où les apports de chaux sont maintenus faibles et se révélant insuffisants pour des effets résiduels.
Le giraumon répond bien au chaulage à Corozal, alors qu'à Isabela, l'échec de la culture par suite d'attaque fongique ne fournit aucune donnée.

INTRODUCTION

Acid soil infertility is a major cause of low crop yields throughout the humid tropics, where world's greater potential for meeting its future food requirements lie (Mc Lean, 1976 ; Kamprath, 1978 ; Adams, 1978, 1981). Soils are acid because their parent materials were acid and initially low in basic cations (Ca^{++}, Mg^{++}, K^{+}, and Na^{+}) or because these elements have been removed from the soil profile by rainfall leaching or the harvesting of crops (Kamprath and Foy, 1972). Soil acidification is intensified by the use of acid forming nitrogenous fertilizers (Pearson et al., 1961 ; Abruna et al., 1964). Specific factors responsible for low yields on acid soils include Al and Mn toxicity, H^{+} toxicity, and deficiencies or unavailabilities of certain essential elements, particularly Ca, Mg, P, and Mo (Jackson, 1967 ; Kamprath and Foy, 1972 ; Foy et al., 1978).

Considerable work on the usefulness of lime applications to increase soil pH and/or inactivate harmful ionic Al and Mn, has been conducted in the humid tropics. It has been found that crops frequently respond to liming on Oxisols and Ultisols. Abruna et al. (1974) found that tobbaco responded strongly to liming on an Ultisol in Puerto Rico and that yields were inversely correlated with percent Al saturation of the soil. They also found that Mn toxicity was the most important acidity factor affecting tobbaco yields on an Oxisol. Working on two Ultisols and an Oxisol, Abruna et al. (1975) found that corn and green beans responded strongly to liming, and that the response was inversely correlated with exchangeable Al in the soil; these crops responded less to liming in the Oxisol. Soares (1975) found that when Al saturation was reduced to 10 % soybean yields increased on two Oxisols of the Brazilian Cerrado. Lime responses with up to 6,000 kg/ha on an unlimed pH 4.3 Oxisol in Colombia have been reported (Spain et al., 1975). Perez-Escolar (1977) found that soybeans responded to liming when exchangeable Al values surpased the 5.5 cmol/kg soil. On an Ultisol, yields of dry beans dropped sharply when acidity increased beyond pH 4.7 and with 30 % Al saturation (Abruna et al., 1983).

The purpose of this study was to evaluate the effect of soil acidity and liming on yields of several bean cultivars and a local pumpkin (*Cucurbita moschata*) variety which are currently under study in plant breeding programs in Puerto Rico. Although the yield response of beans to liming has been previously well documented, information is lacking on the relative responses of specific cultivars being evaluated in Puerto Rico. Virtually no information exists on the response
of pumpkin to liming. The experiments were conducted on an Ultisol and Oxisol of Puerto Rico characterized by high levels of exchangeable Al and easely-reducible Mn, respectively, under natural acid soil conditions.

MATERIALS AND METHODS

Laboratory

The soil in all plots was sampled for analysis both, before the lime applications and at the end of the experiment. Soil cores were taken in each plot at 0 to 15 cm depths, air dried and passed through a 20 mesh sieve. Soil pH was measured with a glass electrode pH meter using 1:2 soil-water suspension. Potassium, Ca, Mg, Mn, and Al were determined by atomic absoption with a Perkim Elmer 2380 spectrophotometer. Sample preparation for the analyses followed the standard methods as described by the Soil Science Society of America, Methods of Analysis (1982).

Field Work

Isabela Substation

The soil at Isabela, Coto clay, is classified as a Tropeptic Haplorthox; clayey, Kaolinitic, isohyperthermic (USDA-SCS, 1967). Some soil characteristics at the beginning of the experiment are shown in Table 1. Figure 1 emphasizes

Table 1 : SOME CHARACTERISTICS OF THE SOILS AT LIMING EXPERIMENTAL SITES

SOIL TYPE	CLASSIFICATION	PH	CATIONS (cmol/kg)	AL SATURATION (%)	MN * (ppm)
Coto clay	Tropeptic Haplorthox	4,5	5,51	66	101
Corozal clay	Aquic Tropudult	4,64	11,12	68	2

* Easily reducible Mn.

Table 2 : CHANGES IN TOPSOIL CHEMICAL PROPERTIES - ISABELA SITE

TREATMENT*	Soil reaction	AL	P	K (cmol/Kg)	Ca	Mg	AL Saturation (%)
1	4,5	3,61	0,4	0,2	1,3	0,4	66
2	4,62	2,6	0,4	0,2	1,8	0,5	51
3	4,75	1,93	0,3	0,2	2,2	0,5	39
4	4,85	1,32	0,4	0,2	2,7	0,6	27
5	4,86	1,26	0,4	0,2	2,6	0,6	27
6	5,01	1	0,4	0,2	2,9	0,5	23
7	5,22	0,28	0,4	0,2	3,4	0,5	6

* Treatments : 1) No CaOH ; 2) 336 Kg/ha CaOH ; 3) Kg/ha CaOH ; 4) 1008 Kg/ha CaOH
5) 134 Kg/ha CaOH ; 6) 1680 Kg/ha CaOH ; 7) 2240 Kg/ha CaOH

Table 3 :EFFECT OF SOIL ACIDITY ON BEAN YIELDS - ISABELA

PH	CATIONS (cmol/kg)	AL SATURATION (%)	YIELDS (KG/HA) * 1	YIELDS (KG/HA) * 2
4,5	5,51	66	1491.5 ± 438.3	436.5 ± 322.8
4,62	5,1	51	1379.5 ± 241.7	553.0 ± 374.7
4,75	4,93	39	1590.7 ± 220.0	704.3 ± 292.0
4,85	4,82	27	1548.2 ± 302.1	1135.7 ± 237.2
4,86	4,66	27	1620.7 ± 421.5	1269.5 ± 279.4
5,01	4,6	23	1667.8 ± 292.2	1347.8 ± 209.5
5,22	4,38	6	1787.2 ± 250.5	1757.5 ± 116.8

* 1 : First crop, 2 : Second crop .

Figure 1 : Relationship between pH and Aluminium saturation Coto and Corozal Clay

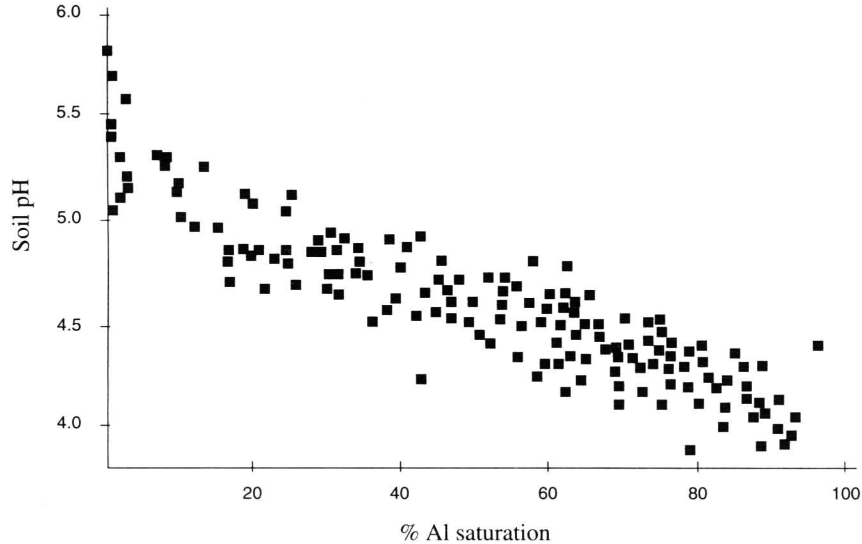
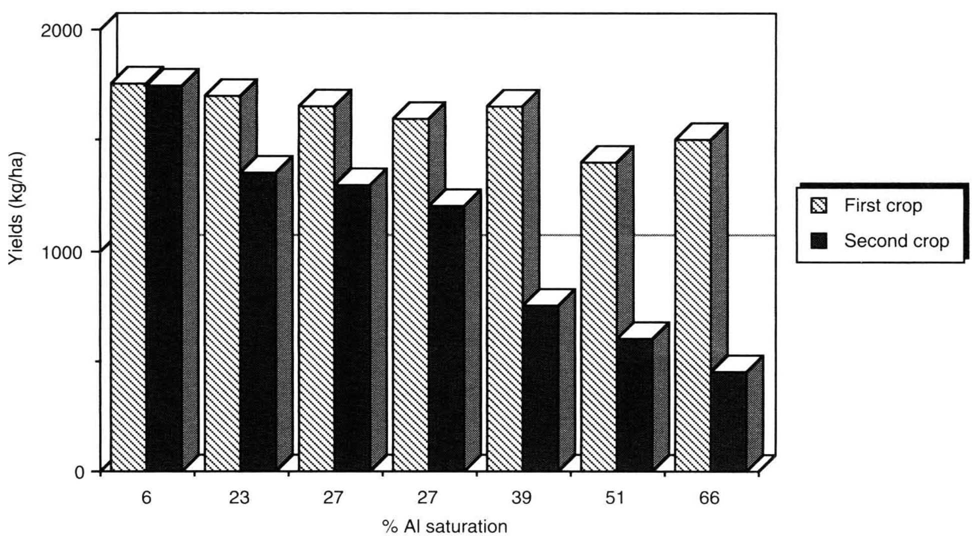


Fig. 2 : Effect of Aluminum saturation on bean yields. Coto Clay



the relationship between soil pH and the Al saturation of the soil. Calcium hydroxide, $Ca(OH)_2$, was applied and incorporated in the first 7.5 cm of soil one month before planting, at rates ranging from 0 to 2240 Kg/ha. Two successive crops of beans (*Phaseolus vulgaris* var. LW-227) and a third crop of pumpkin (*Cucurbita moschata* var. P.R.-B-8) were grown in 3.65 m x 3.65 m differentially limed plots arranged in a completely randomized block design. The crops were managed in accordance with the intensive management techniques recommended by the Puerto Rico Agricultural Experiment Station (1979) and were harvested at optimum stage of maturity. Data on crop production was recorded at harvest.

Corozal Substation

The soil at Corozal, Corozal clay, has been classified as an Aquic Tropudult ; clayey ; mixed, isohyperthermic (USDA-SCS, 1967). Some soil characteristics are shown in Table 1. The relationship between pH and Al saturation of the soil was essentially the same as that of the Coto soil (Fig. 1). Calcium hydroxide, $Ca(OH)_2$ was applied and incorporated with the first 7.5 cm of soil one month before planting, at rates ranging from 0 to 6000 kg/ha. A crop of beans (*Phaseolus vulgaris*) was grown in 7.30 m x 7.30 m plots. The main plots were divided in four 3.65 m x 3.65 m subplots where four bean varieties, LW-227, 8542-22S, Pompadour, and Guayamera, were planted in a completely randomized block design. After the bean experiment five plants to pumpkin (*Cucurbita moschata*) were grown on each of the main plots. To assure optimum growing conditions, agronomic practices followed the Puerto Rico Agricultural Experiment Station recommendations (1979). Crops were harvested at optimum stage of maturity and data crop production and succeptibility to fungal attack recorded.

RESULTS

Isabela Substation

Changes in topsoil chemical properties as a function of lime application are shown in Table 2. Liming increased the levels of Ca and decreased exchangeable Al levels whereas P, Mg and K levels remained relatively constant. The percent Al saturation decreased drastically from 66 % to 6 % at the highest lime application rate. Yields from the first crop ranged from 1491.5 kg/ha to 1787.2 kg/ha (Table 3). Even though there appears to be a yield increase with an increase in $Ca(OH)_2$ application and pH, the differences between treatments in the first crop were non-significant. The tendency, however, was for highest yields to be obtained at around pH 5.2 when there was essentially no exchangeable Al in the soil. Yields declined with increases in percent Al saturation. In the second crop, yields decreased drastically to

Table 4 : CHANGES IN TOPSOIL CHEMICAL PROPERTIES - COROZAL SITE

TREATMENT *	SOIL REACTION	AL	K (cmol/Kg)	Ca	Mg	AL SATURATION (%)
1	4,64	7,58	0,83	2,19	0,52	68
2	4,88	4,58	0,84	4,59	0,59	43
3	5,4	0,66	0,99	9,64	0,59	6
4	6,61	ND **	0,82	15,69	0,47	ND**

* 1. Control, 2. 1500 Kg/ha Ca $(OH)_2$; 3. 3000 Kg/ha Ca $(OH)_2$; 4. 6000 Kg/ha Ca $(OH)_2$.

** Non-dedectable.

Table 5 : EFFECT OF SOIL ACIDITY ON PUMPKIN YIELDS.

pH	CATIONS (cmol/Kg)	AL SATURATION (%)	YIELDS (Kg/plant)
4,64	11,12	68	0,41
4,88	10,6	43	0,92
5,4	11,88	6	3,76
6,61	16,98	ND *	5,7

* ND : Non detectable.

Figure 3 : Effect of pH on bean yields - Corozal Clay

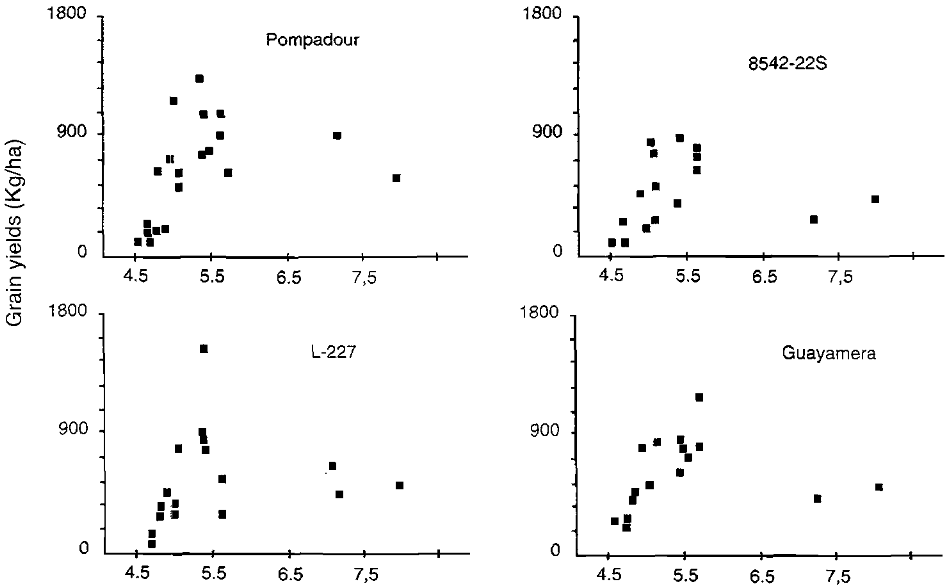
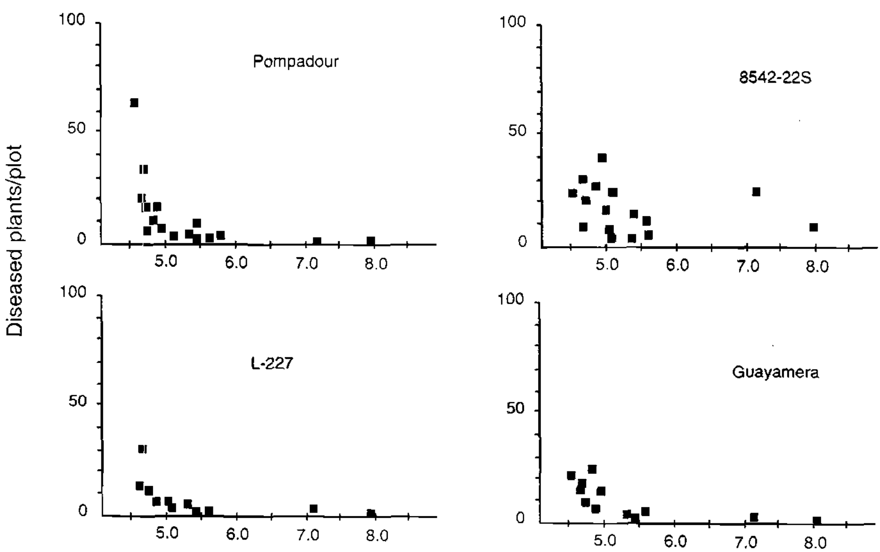


Figure 4 : Effect of soil pH on plant resistance to fungal attack - Corozal Clay



about 50 % of maximum when Al saturation increased to 39 % ; those treatments where the Ca(OH)2 applications were kept low (Fig. 2), showed the lowest yields. The pumpkin crop was severly affected by the powdery mildew (*Erysiphe cichracearum*) to the point were no production data could be obtained.

Corozal Substation

Soil chemical properties at the end of the experiment are shown in Table 4. There was an increase in the levels of Ca and a drastic decrease in Al saturation with liming, whereas the Mg and K concentration remained relatively constant. A response to liming was observed in each of the bean varieties tested (Fig. 3) ; with maximum yields occurring close to pH 5.5 corresponding to the point where exchangeable Al levels were reduced to zero. The data in Fig. 3 indicate a rather sharp decrease in yields above pH 5.5, suggesting it is very important to avoid overliming in the case of beans. The fungus *Macrophomyna* caused a nearly 50 % loss in plant population at pH values of around 4.5 or lower (Fig. 4). Addition of lime reduced the level of infection in 3 out of the 4 bean varieties being evaluated.

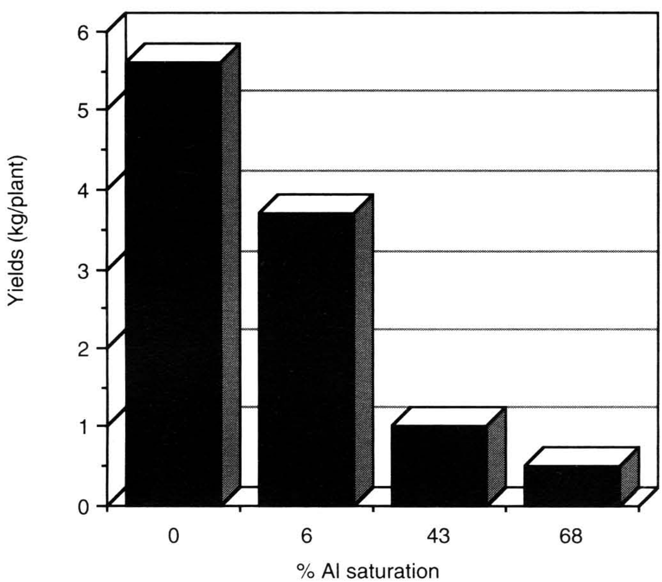
A strong response to liming was also observed with the pumpkin crop (Table 5). Highest yields were obtained around pH 6.6 when there was essentially no exchangeable Al in the soil (Fig. 5). When the Al saturation increased to 43 %, yields dropped drastically to only 16 % of the maximum which shows succeptibility of pumpkin to Al. The strong overliming effect observed with beans did not seem evident in the case of pumpkin.

SUMMARY AND CONCLUSIONS

The data presented shows the effects of liming on crop production on an Oxisol and an Ultisol in Puerto Rico. Yield increases were obtained with each increase in lime application in both the Oxisol and Ultisol soils. The high Mn concentration of the Oxisol did not seem to have had any effect on bean production. Differences in bean yield trends in Isabela may have been related to factors such as : 1) increases in the Al saturation with time for the low lime rates, and 2) increased Ca movement into the subsoil with time of cultivation. The data are not shown, but the decreased bean yields in the second crop were strongly associated with lower plant populations at higher acidity levels. The decrease in plant populations was not observed in the first crop. At the Corozal site, the beneficial effects of liming on bean production included a higher resistance to fungal attack accompanied by higher yields.

Attention should be paid to the pumpkin responses to liming. It has always been believed that the pumpkin is not sensitive to acidity factors, therefore

Fig. 5 : Effect of Aluminum saturation on pumpkin yields. Corozal Clay.



limited research has been done on the matter. The results herein reported open new avenues for research on pumpkin and its response to different soil acidity factors.

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