Differential Response of Corn and Sweet Potatoes to Zn Applications in an Oxisol in Northwestern Puerto Rico[1, 2]

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ABSTRACT

Experiments were conducted in an Oxisol in an attempt to clarify the role of Zn in crop production. The Capó fertilizer-yield equation was applied to the first of two consecutive corn crops of Pioneer X-306B and Funk's G-795W, grown in an exposed Coto clay subsoil. The equation made possible the estimation of grain corn yields with a fair degree of precision. A crop of a white-fleshed sweet potato cultivar (Mina) was grown in a typical undisturbed Coto clay near the site where the corn experiments were conducted. Near maximum yields could be obtained with the application of only 3.3 kg/ha of Zn. Stover yields were estimated with a very high degree of precision ($r^2 = 0.98$) from the corresponding equation. No response to Zn was obtained in the second consecutive corn crop (Funk's G-795W) nor in the sweet potato crop.

INTRODUCTION

Micronutrients have been used to some extent in modern agriculture for the past 50 years. In Puerto Rico, with a sizeable proportion of highly weathered, leached, acid tropical soils, research with micronutrients has been conducted at various times, even as early as 1927. In 1942, evidence was obtained showing that a sugarcane chlorosis could be ameliorated and high yields obtained on a calcareous Fraternidad clay, Udic Chromusterts (7), with the application of S, Cu, Fe and Mn. Field experiments with micronutrients were conducted by Landrau Jr. and Samuels (8) in 1949–50. In general, no consistent yield increases were obtained attributable to the application of Mn, Na, Zn and B in sugarcane, acerola and tobacco. No response was obtained from corn, cotton, sweet peppers, plantains, yams, taniers and a tropical kudzu-Merker grass mixture. B significantly increased sweet potato yields in a Lares clay (Aquic Tropohumults) and in a Sabana Seca sandy clay (Oxic Plinthaquults). The use of Fe sprays on pineapple produced some yield increases (10). In some cases, even significant yield reductions were measured. In a Coto clay

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(Typic Haplorthox), tomato yields were dramatically depressed when 23 kg of B were used. The use of Zn produced variable results on sugar yields. Very small yield responses were obtained from the more acid soils (Coto, Lares). In 12-month plant sugar cane grown in a Coto clay, yields of sugar increased significantly; but yield increases were not significant in the succeeding ratoon crop.

There is still a growing concern about the role of micronutrients, particularly Zn, in highly weathered tropical soils. This concern is justified by observation that the application of Zn, as sulfate to the soil and as a foliar spray, relieves grapefruit and other citrus from visual deficiency symptoms in an Ultisol.[4] Such symptoms have also been observed in corn growing in Oxisols. Now and then possible Zn deficiencies in various crops have been observed. However, work on the development of nutrient deficiency symptoms on crops of economic importance in Puerto Rico has failed to include Zn treatments (5, 6, 7). This paper reports on attempts to clarify the effect of Zn in crop production and nutrient uptake in an Oxisol in northwestern Puerto Rico.

MATERIALS AND METHODS

Three experiments were conducted in a Coto soil (Typic Haplorthox, clayey, kaolinitic, isohyperthermic) at the Isabela Agricultural Experiment Substation farm in northwestern Puerto Rico at an elevation of about 122 m above sea level (9). It has a pH of 5.0, a CEC of about 13 meq and Ca saturation of 25%. It is high in Mn and low in P. Mean annual rainfall is about 1658 mm. Evaporation from a Class A pan is approximately 6 mm/day during the summer and 4 mm/day during the winter. Mean annual maximum temperature is 29.4°C while the mean minimum temperature is 18.9°C. Solar radiation ranges from an average of 300 langleys/day in the winter to 600 langleys/day in the summer.

Two experiments with corn were planted on an exposed Coto subsoil. The first experiment was planted in April 1972; the second, one year later, in an adjacent field. Five Zn levels were used: 0, 1.12, 3.36, 10.09, and 30.27 kg/ha. The source of Zn was $ZnSO_4 \cdot H_2O$ applied to the soil and disced prior to planting.

The plots were 4.55 m wide and 9.9 m long. Each plot had six rows, 76.2 cm apart. The experimental layout followed a Latin square design. Plant density fluctuated from 40,000–45,000 plants/ha. In the 1972 experiment, Pioneer X-306 hybrid was used as the test crop; Funk's G-975W was used in the 1973 trial. Each plot received a blanket application of fertilizer, prior to planting, as follows: 56 kg N as urea; 168 kg K_2O as sulfate; 224 kg P_2O_5 as triple superphosphate; and 56 kg Mg as sulfate. One month after planting, a side dressing was made of ammonium sulfate

[4] Dr. Agripino Pérez-López, personal communication, June 28, 1979.

at the rate of 112 kg/ha of N. All other management inputs, including irrigation, were kept at optimum levels. At silking time, 10 ear leaves from rows 2 and 5 were collected for nutrient uptake analyses. Yield data were collected from 15.2 m of the two inner rows. Plant height was measured and number and weight of ears and plants were recorded per harvested area.

On the sweet potato experiment, six Zn levels were tested: 0, 0.56, 1.12, 2.24, 4.48, and 8.97 kg/ha. The experimental plots consisted of four rows 1.07 m apart and 4.55 m long bordered by a blank row with 1.52 m alleys between plots. Treatments followed a randomized block design with six replications. Vines from the white-fleshed Mina cultivar, about 45.7 cm long, were planted on raised beds November 8, 1975. Diphenamid 50W[5] was applied at a rate of 15.7 kg/ha as a pre-emergence herbicide. Two weeks after planting, the growing vines received an application of 1345

TABLE 1.—*Effect of Zn levels on the yield of corn, cv. Pioneer X-306B, grown in a Coto clay exposed subsoil, Isabela, Puerto Rico*

Treatments	Yield			Plant height
	Grain	Stover	Total	
	Kg/ha			*Cm*
0	3,263 b[1]	6,417 a	9,679	278.6 a
1.12	3,748 ab	6,411 a	10,159	290.8 a
3.36	4,270 a	6,754 a	11,024	289.3 a
10.09	4,281 a	7,255 a	11,536	293.5 a
30.27	4,317 a	6,347 a	10,664	290.5 a

[1] Values in columns followed by the same letter do not differ significantly at the 5% probability level.

kg/ha of a 6-6-12 fertilizer. The Zn required for treatment differential was mixed with the fertilizer. Cultivation was mechanized as long as vine growth permitted; thereafter, weeds were removed by hand cultivation. All other management inputs were kept at optimum levels. When the crop was 5 months old, the roots were harvested with a potato digger. Prior to crop harvest, a square meter of vines was harvested from each plot to measure top yields.

RESULTS AND DISCUSSIONS

Table 1 shows that the application of 1.12 kg/ha of Zn led to a production of 485 kg/ha of additional Pioneer X-306B grain corn over

[5] Trade names in this publication are used only to provide specific information. Mention of a trade name does not constitute a warranty of equipment or materials by the Agricultural Experiment Station of the University of Puerto Rico, nor is this mention a statement of preference over other equipment or materials.

that of the zero Zn control treatment. This difference, even if apparently large, was not statistically significant when tested by the Duncan's multiple range test. However, the application of 3.36 kg/ha and higher levels of Zn led to significantly higher yields over the no Zn controls. There was no significant differences in grain yields which could be attributed to increasing Zn levels beyond the 1.12 kg/ha application. Differences in stover yields were not significant, but a clear-cut trend pointed to increased stover yields with increasing Zn levels up to 10.09 kg/ha. Increases in total dry matter yields (grain + stover) followed the same trend.

The fertilizer-yield equation developed by Capó (3) was applied to the grain yield data:

$$Y = \frac{A}{1 + B(X - C)^2},$$

TABLE 2.—*Nutrient content in corn leaves at silking stage, cv. Pioneer X-306B*

Zn treatments	Levels of indicated nutrient								
	N	P	K	Ca	Mg	Mn	Fe	Zn	Al
Kg/ha			%				*P/m*		
0	2.62	.276	1.78	.540	.216	232	100	37	69
1.12	2.64	.270	1.32	.612	.196	258	100	37	80
3.36	2.64	.274	1.80	.562	.176	229	103	37	80
10.09	2.60	.270	1.78	.578	.198	232	99	48	74
30.27	2.68	.276	1.74	.570	.190	255	103	55	79

where,

Y = yield in kg/ha

A = 4667.78; the maximum yield obtainable in the given field by fertilizing with zinc sulfate

B = 1.05×10^{-3}, is another parameter related to this equation;

C = 16.957; the Zn application required for maximum grain yield under prevalent conditions, and

X = amount of Zn applied in kg/ha.

A coefficient of determination of 52.6% was obtained. Thus, the curvilinear equation developed can be useful in predicting corn yield in terms of Zn applications within the range used in the experiment herein reported. The equation indicates that not more than 16.9 kg/ha of Zn are needed to obtain maximum grain yield of corn. However, with an application of only 3.3 kg/ha about 91% of the estimated maximum grain yield could be obtained. A similar equation was developed for the stover data. Stover yields could be estimated with a very high degree of precision, with 98% of the variability explainable on the basis of Zn applied. No significant differences in plant height attributable to Zn treatments were measured.

Table 2 shows that the Zn treatments, in general, did not affect the uptake of the other nutrients. N leaf values generally were low. All other nutrient contents were within the normal ranges as reported by Abruña et al. (1) and Pérez-Escolar et al. (11).

In the 1973 experiment with corn cultivar Funk's G-795W, no significant difference in corn grain yield attributable to Zn treatments could be measured. The corn grain yield for the entire experiment averaged 8697 kg/ha. Individual treatment averages ranged from a low 8221 kg/ha with no Zn to a high of 9150 kg/ha in the 10.09 kg/ha Zn levels (table 3). These yields are larger than those reported by Sotomayor-Ríos (12), Talleyrand et al. (13), Pérez-Escolar and Lugo-López (11) and are comparable to yields reported by Badillo-Feliciano et al. (2). The high corn

TABLE 3.—*Effect of Zn levels on the yield of corn, cv. Funks G-795W, grown in a Coto clay, exposed subsoil, Isabela, Puerto Rico*

Zn treatments	Yield			Plant height
	Grain	Stover	Total	
	Kg/ha			*Cm*
0	8,221 a[1]	2,604 ab	10,825 a	248.6 a
1.12	8,876 a	2,521 b	11,397 a	250.2 a
3.36	8, 554 a	2,507 a	11,061 a	248.9 a
10.09	9,150 a	2,029 b	11,179 a	247.1 a
30.27	8,684 a	3,252 a	11,937 a	244.8 a

[1] Values in columns followed by the same letter do not differ significantly at the 5% probability level.

yields obtained from corn hybrid Funk's G-795W indicate the potential of this cultivar for large scale corn production in Puerto Rico. If this potential could be realized there would be a locally produced valuable source of feed for livestock and milk production. The stover yield ranged from 2029 kg/ha to 3252 kg/ha but did not follow a specific trend attributable to treatment effect. Plant height on a field-wide basis averaged 248 cm with all plots being very uniform.

Table 4 shows data on marketable yields and other parameters evaluated in the sweet potato experiment. The highest yields were measured when 8.97 kg/ha Zn were applied. However, differences between treatments were not significant. Yields in all plots are considered acceptable for the area and for the cultivar with a field-wide average of 23.7 tons/ha. The percentage of culls was high in all cases (9 to 12%), mostly due to immature sweet potato edible roots at harvesttime. This condition could be attributed mainly to excessive rainfall during the growing season. Vegetative growth was larger on the check than on the Zn-treated plots.

Zn treatments seemed to have no measurable effect on leaf nutrient uptake (table 5).

On high pH, low Zn soils in central Brazil, 9 kg/ha of Zn have been sufficient to maintain high production levels for at least four consecutive crops (4). A marked difference was noted as to crop response: sorghum did not respond to Zn applications as much as did corn and soybeans. A larger production of corn in the zero Zn plots during the second consecutive crop was attributable to a possible contamination of these plots during land preparation. The results here presented are consistent with the Brazil data. All in all, there was a response in corn grain yields of

TABLE 4.—*Effect of Zn levels on the yield of sweet potato grown in a Coto clay, Isabela, P. R.*

Zn treatments	Marketable yield	Culls	Weight of vines	Root/top ratio
Kg/ha	*Tons/ha*	%	*Tons/ha*	
0	23.9	9.27	22.3	1.07
0.56	20.5	12.57	14.1	1.45
1.12	23.6	10.23	14.3	1.65
2.24	24.7	9.63	15.3	1.61
4.48	22.1	9.75	18.6	1.19
8.97	27.2	9.30	19.4	1.40

TABLE 5.—*Nutrient content of sweet potato leaves*

Zn Treatment	N	P	K	Ca	Mg	Mn
Kg/ha			%			*P/m*
0	3.09	0.30	5.45	0.417	0.433	189
0.56	3.04	0.30	5.28	0.335	0.405	207
1.12	3.02	0.32	5.48	0.293	0.426	180
2.24	2.92	0.32	5.55	0.402	0.383	216
4.48	3.06	0.33	5.64	0.320	0.432	180
8.97	3.28	0.30	5.19	0.342	0.425	207

cultivar Pioneer X-306B in northwestern Puerto Rico to the application of Zn up to 16.95 kg/ha, but near maximum yields are possible with applications of only 3.3 kg/ha of fertilizer Zn. On the other hand, cultivar Funk's G-795W showed no response to Zn applications in terms of corn grain yields, but there was an increase in stover yields at the highest Zn level. Sweet potatoes do not respond to Zn applications in the Coto Oxisol. Application of Zn in tropical soils, even in highly-weathered and leached Oxisols, depends to a large extent on both crop demands and on the reserve of available native soil Zn. In areas where the ravages of erosion have removed the topsoil, small applications of Zn—not over 3.3 kg/ha—might be valuable for sustained yields of crops such as corn.

RESUMEN

Se realizaron tres experimentos en un suelo Coto arcilloso (Oxisol) en el noroeste de Puerto Rico en un intento por clarificar el efecto de las aplicaciones de Zn sobre la producción de cosechas. Las siembras de maíz, cultivares Pioneer X-306B y Funk's G-795W, se hicieron en un sitio donde el subsuelo estaba expuesto; las de batata (cultivar Mina), en un sitio típico del suelo Coto que no había sufrido perturbación alguna. Los niveles de Zn en el caso del maíz fluctuaron de 0 a poco más de 30 kg/ha; en el caso de la batata, de 0 a 9 kg/ha. A los datos de la primera cosecha de maíz se les aplicó la ecuación abono-rendimiento de Capó. La ecuación desarrollada hizo posible la evaluación de los rendimientos de maíz Pioneer X-306B con bastante precisión. Se obtuvo más del 90% del rendimiento máximo con aplicaciones de tan sólo 3.3 kg/ha de Zn. Con la ecuación correspondiente fué posible estimar con gran precisión los rendimientos de rastrojo (r^2 = 0.98). No se obtuvo respuesta a las aplicaciones de Zn a la segunda cosecha de maíz (Funk's G-795W) ni a la cosecha de batatas.

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