Effect of Four Levels of N, P, K, and Micronutrients on Sweetpotato Yields in an Oxisol[1]

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ABSTRACT

An experiment to determine the effect of four levels of N, P, K, and micronutrients on sweetpotatoes was conducted in an Oxisol in northwestern Puerto Rico. Treatment differentials included banded, postplant N at the rates of 0, 39, 78, and 157 kg/ha; P at the rates of 0, 17, 33, and 67 kg/ha; K at the rates of 0, 67, 134, and 269 kg/ha; and a micronutrient mixture at the rates of 0, 33, 67, and 134 kg/ha. The soil was high in organic matter and fairly well supplied with N, Ca, K, and Mg. It was apparently low in extractable P. In general, the amounts of a given nutrient absorbed by the plants were not consistently related to the amount of nutrient applied, except in the case of N. Apparent fertilizer recovery was very low in all cases. Nonfertilized plots produced only 9.7 tons of marketable roots, while yields of 16 *t*/ha were obtained with the application of 39 kg/ha of N. The Capó fertilizer-yield equation appears to be useful in predicting sweetpotato yields in terms of the N fertilizer applied in this Oxisol. High N levels tend to induce vine growth at the expense of edible roots. Marketable root yields were not affected by P, K, and micronutrient applications.

INTRODUCTION

Sweetpotatoes are of paramount importance in any program geared to increase food production in the tropics. Their potential cannot be overlooked as they can produce 968 kcals/kg; thus, they produce more energy than Irish potatoes, yams, and taniers, being second only to cassava in this respect (5). Moreover, Badillo (2) has shown that some cultivars are capable of high yields at any time of planting. Because the crop season extends for only 5 months, two crops can be reaped in 1 year from the same tract of land if favorable climatic conditions prevail.

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Fertilizers are considered important for sustained high crop yields in the acid soils of the humid tropics. Of particular importance is the use of N fertilizer (4). In these soils, large leaching losses of N are likely to occur. In addition, the current high prices of fertilizers and their expected shortage suggest the need to develop efficient management systems to obtain high crop yields at the lowest levels of fertilizers. Talleyrand and Lugo-López (9) recently reported on a study comparing various levels and sources of N on sweetpotato yields in an Ultisol. They obtained maximum yields of 14.6 metric tons (*t*)/ha with applications of 40 kg/ha of N as ordinary urea. The Capó fertilizer-yield equation (3) appeared useful in predicting sweetpotato yields in terms of the N applied within the range used in their experiment.

The main objective of the work herein reported was to determine the effect of various levels of N, P, K, and micronutrients to help realize the productivity potential of a deep, acid, rather infertile Oxisol. An additional objective was to determine the usefulness of the fertilizer-yield equation in this kind of soil.

MATERIALS AND METHODS

The location of the experiment was the Isabela Substation farm on the gently rolling land of northwestern Puerto Rico at about 122 m above sea level. The mean annual maximum temperature at this site is 29.4° C while the mean annual 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. The 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. The soil at the experiment site is Coto clay, a Tropeptic Haplorthox, clayey, kaolinitic, isohyperthermic (7). Soil samples were taken at 0 to 25 and 25 to 50 cm and analyzed for organic matter, pH, N, P, cation exchange capacity, and exchangeable Ca, Mg, K, Mn, and Al by standard, well-known methods.

The experiment followed a partially balanced incomplete block design with 14 treatments replicated four times. The treatments included variable rates of application of N, P, K, and micronutrients, as follows: N, as ammonium sulphate, at the rates of 0, 39, 78, and 157 kg/ha; P, as triple superphosphate, at the rates of 0, 17, 33, and 67 kg/ha; K, as potassium chloride, at the rates of 0, 67, 134, and 269 kg/ha; and micronutrients, as Esminel,[3] at the rates of 0, 33, 67, and 134 kg/ha. All plots received also a blanket preplant application of lime to bring the pH

[3] 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.

to 6.5 and of Mg, as magnesium sulphate, at the rate of 56 kg/ha. All the fertilizer was banded as a postplant application 2 weeks after planting.

Each plot consisted of four ridges (rows) 1.06 m apart and 5.33 m long bordered by a blank row and 1.52 m alleys between plots. The white-fleshed Mina cultivar was used as indicator crop. It was planted from selected vines on October 15, 1974, and harvested on March 11, 1975. A preventive insect control program was followed during the development of the crop, which consisted of Diazinon AG 500 sprays every 20 days at the rate of 1168 cm^3/957 l/ha of water. No visible insect or disease pests were observed. Harvesting was done by using a potato digger. Data on top growth and marketable and total root yields were recorded for each plot and statistically analyzed. The fertilizer-yield equation developed by Capó (3) was applied to the mean total yield obtained from the N treatments. Leaf samples, from leaves number 3 or 4, including the petiole, were taken on January 7, 1975, (12 weeks after planting) and analyzed for N, P, K, Mg, and Mn. At harvesting (21 weeks after planting), leaf samples were also taken and analyzed to determine nutrient recovery.

RESULTS AND DISCUSSION

SOIL NUTRIENT STATUS

Results of selected chemical analyses of the soils are given in table 1. Organic matter was rather high at both the 0- to 15- and 15- to 30-cm depths. The soil seems to be fairly well supplied with N. Cation exchange capacity is normal for Coto clay (7). It is slightly acid, but it can supply nearly 3000 lb of exchangeable Ca from the upper 30 cm. It is also well supplied with Mg and K. Levels of Al are low, particularly in the upper 15 cm, and no toxicity problems are likely to arise. P levels appear low by both the Olsen and Bray No. 2 extracting methods. P values below 20 p/m by the Bray No. 2 method are considered too low in Alabama.[4]

LEAF NUTRIENTS

N treated plots

A comparison of the results of chemical analysis (table 2) of leaf samples collected at 12 weeks (midseason) and at 21 weeks (harvesttime) shows that leaf N was generally higher at the latter. Leaf N, as expected, generally increased as amounts of applied N increased. Leaf P in the N treated plots was also higher at harvesttime than at midseason. Leaf K decreased with an increase in the rate of N applied. The percentage of leaf K at harvesttime was smaller than at midseason. Mg levels on the

[4] Pearson, R. W., Personal communication.

TABLE 1.—*Selected chemical properties of soil samples taken prior to planting sweetpotatoes at the fertilizer experimental site, Coto clay, Isabela, October 1974*

Property	Depth	Value
	Cm	
Organic Matter	0–15	4.21%
	15–30	2.91%
N	0–15	.17%
	15–30	.16%
pH	0–15	5.0
	15–30	5.5
CEC (NH_4OA)	0–15	13.3 meq
	15–30	10.6 meq
Exchangeable Ca	0–15	3.17 meq
	15–30	3.71 meq
Exchangeable Mg	0–15	1.83 meq
	15–30	1.46 meq
Exchangeable Al	0–15	.6 meq
	15–30	1.4 meq
Exchangeable K	0–15	33 p/m
	15–30	14 p/m
Exchangeable Mn	0–15	1.6 p/m
	15–30	1.6 p/m
P		
Bray	0–15	7.7 p/m
	15–30	2.4 p/m
Olsen	0–15	18.0 p/m
	15–30	20.8 p/m

leaves were unaffected by N rates or time of sampling. Mn levels were higher at midseason than at harvesttime. Mn tended to increase with increasing N rates.

P treated plots

Leaf N and P, in the P treated plots, were affected neither by rate of P application nor time of sampling. Leaf K levels were lower at harvesttime than at midseason. Neither leaf Mg nor leaf Mn followed specific trends.

K treated plots

The amounts of N, P, and Mn in the leaves of the K treated plots followed no specific trend. However, leaf K was higher at midseason than at harvesttime. The least amounts of K were found in the higher K level treatments.

Micronutrient treated plots

Amounts of leaf N and Mn in the micronutrient treated plots did not follow a specific trend or relationship to rates applied or time of

TABLE 2.—*Leaf nutrient composition of sweetpotatoes, Mina variety, at midseason (12 weeks) and at harvesttime (21 weeks)*

Treatment				Content of nutrient at indicated age, in weeks									
N	P	K	Micro-nutri-ents	N 12	N 21	P 12	P 21	K 12	K 21	Mg 12	Mg 21	Mn 12	Mn 21
	Kg/ha			%		%		%		%		*P/m*	
0	33	134	0	3.45	4.18	0.30	0.40	3.76	3.05	0.53	0.48	118	86
39	33	134	0	3.75	4.06	.32	.38	3.30	2.83	.52	.51	127	90
78	33	134	0	3.60	4.24	.30	.37	3.46	2.92	.52	.53	108	112
157	33	134	0	4.55	4.40	.35	.34	3.13	2.64	.54	.53	176	116
78	0	134	0	4.25	3.96	.31	.34	3.21	2.51	.56	.53	146	110
78	17	134	0	4.10	3.76	.32	.31	3.10	1.96	.54	.80	131	155
78	33	134	0	3.60	4.24	.30	.37	3.46	2.92	.52	.53	108	112
78	67	134	0	4.35	3.84	.33	.33	3.47	2.47	.54	.61	123	139
78	33	0	0	3.90	3.80	.33	.32	3.72	2.91	.51	.61	157	122
78	33	67	0	3.80	3.34	.35	.29	3.76	2.72	.50	.76	176	193
78	33	134	0	3.60	4.24	.30	.37	3.46	2.92	.52	.53	108	112
78	33	269	0	4.30	3.92	.31	.27	3.03	2.00	.52	.71	132	165
78	33	134	0	3.60	4.24	.30	.37	3.46	2.92	.52	.53	108	112
78	33	134	33	4.20	3.92	.32	.35	3.13	2.60	.52	.57	138	144
78	33	134	67	4.10	3.94	.31	.36	3.23	2.51	.53	.63	100	149
78	33	134	134	4.10	4.22	.33	.34	3.26	2.80	.53	.56	146	116
0	0	0	0	4.00	4.58	.39	.41	3.97	3.21	.51	.44	155	93

sampling. Leaf P or K did not increase with increased rates of micronutrients. However, leaf P was higher at harvesttime than at midseason, but amounts of K decreased at harvesttime as compared to midseason.

It is evident from the data in table 2 that the apparent fertilizer recovery[5] was very low in all cases. This might have been associated with the generally observed lack of response to the various fertilizer elements in this Oxisol. In the case of N fertilizer, the apparent low recovery might be further associated with the high rainfall recorded soon after the postplant application. This fact was previously postulated by Fox et al. (4) from their N fertility work with corn and sorghum in Oxisols and Ultisols of Puerto Rico.

YIELDS

The yield responses of sweetpotatoes to N, P, K, and micronutrients are shown in table 3. N applications increased marketable yields from 10.9 *t*/ha in the zero-N plots to 16.2*t*/ha in the 78 kg/ha of N plots, which is equivalent to a 48.6% increase with the higher N level. Although, at the

[5] Apparent fertilizer recovery = (Fertilized plant nutrient level minus check plant nutrient level) ÷ Quantity of indicated element applied.

TABLE 3.—*Marketable root yields, top yields, and top:root ratio from a sweetpotato crop grown in an Oxisol*

Treatment				Marketable yields	Top yields[1]	Top: root ratio[2]
N	P	K	Micro-nutrients			
Kg/ha				*Metric tons/ha*	*Metric tons/ha*	
0	33	134	0	10.9 b[3]	12.6 bd	1.20 a
39	33	134	0	15.9 ab	19.4 acd	1.19 a
78	33	134	0	16.2 ab	21.3 acd	1.30 a
157	33	134	0	14.2 ab	25.3 a	1.70 a
78	0	134	0	15.6 ab	18.4 acd	1.14 a
78	17	134	0	13.7 ab	19.7 acd	1.29 a
78	33	134	0	16.2 ab	21.3 acd	1.30 a
78	67	134	0	13.2 ab	22.4 ac	1.53 a
78	33	0	0	17.0 a	13.9 bd	0.85 a
78	33	67	0	15.4 ab	22.5 ac	1.40 a
78	33	134	0	16.2 ab	21.3 acd	1.30 a
78	33	269	0	14.3 ab	25.7 ac	1.75 b
78	33	134	0	16.2 ab	21.3 acd	1.30 a
78	33	134	33	13.0 ab	19.5 acd	1.57 a
78	33	134	67	13.8 ab	21.8 ac	1.54 a
78	33	134	134	13.5 ab	19.2 acd	1.26 a
0	0	0	0	9.7 b	10.2 b	0.94 a

[1] Leaves and stems.

[2] Total root yields instead of marketable yields were used for these calculations.

[3] Values in the same column followed by the same letter(s) do not differ statistically at the 5% level.

level of probability tested, the mean differences are not significant, there is a definite clear-cut trend of increasing yields with increasing N levels up to 78 kg/ha. Furthermore, it is noticeable from table 3 that, when N was increased beyond 78 kg/ha, marketable yields tended to decrease, with a corresponding increase in top growth. The marketable yields obtained with 157 kg/ha of N are similar to those obtained with a 39 kg/ha of N application. These data are in agreement with those reported by Talleyrand and Lugo-López (9) from an Ultisol in the hilly central region of Cidra.

The 157 kg/ha of N treatment yielded significantly higher amounts of tops than the zero-N treatment. However, top yields measured from the 39, 78, or 157 kg/ha of N levels did not differ significantly.

The Capó fertilizer-yield equation (3) was applied to the mean yield data obtained from the differential N treatments. This equation is as follows:

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

where,

Y = Yield;
A = maximum yield obtainable in the given field with the optimum fertilizer application;
B = another parameter related to this equation;
C = the optimum fertilizer application with regard to crop yield under prevalent conditions; and
X = amount of N applied.

Table 4 shows the results of fitting the Capó fertilizer-yield equation to the data obtained from the N differential treatments. The statistics of the equation show a very good fit of the curve with a coefficient of determination of 0.87. Therefore, 87% of the variability in sweetpotato yields in this Oxisol, under the prevailing conditions, can be explained in terms of the N fertilizer applied, at least within the range used in the experiment herein reported.

Marketable root yields were not affected by P or K applications. However, top yields increased significantly as K levels were increased.

The fertilized check plots yielded only 9.7 *t*/ha marketable roots. Mean yield differences between this treatment (no fertilizer) and those from all other fertilizer treatments, except the N(78)-P(0) treatment, are not statistically significant. It can be inferred from this evidence that this Coto clay experimental field contains available K in amounts sufficient to meet the minimum requirements of a sweetpotato crop. Neither marketable yield nor plant tops were affected by micronutrient applications.

In general, sweetpotato yields in this experiment appear to be low when considering the variety potential (2) and the soil production potential (7). This can be, to some extent, explained on the basis of the slow start of the crop due to excessive rainfall. The crop received 292.9 mm

TABLE 4.—*Results obtained from fitting the fertilizer yield equation to data from the N differential treatments in an experiment on an Oxisol*

N units[1]	Estimated marketable sweetpotato yields from		Statistics of fitted equation
	Analysis of variance	Equation	
	Metric tons/ha		
0.00	10.87	11.58	A = 17.05
.10	15.88	14.71	B = 8.310
.20	16.17	16.84	C = 0.2383
.40	14.17	14.01	CD[2] = .868

[1] 1 Unit = 392.4.
[2] Coefficient of determination.

of rainfall in the first 15 days after planting. This unexpected amount of rainfall caused stunting in vine growth during early plant development which seems to have affected sweetpotato yields.

As shown in table 3, top:root ratios ranged from 0.85 in the N(78)-P(33)-K(0) plots to 1.75 in N(78)-P(33)-K(269) plots. These extreme mean differences are significant. In general, top:root ratios are higher than 1, indicating that the crop had more abundant vine development than roots. Increases in top:root ratios have been attributed by Sánchez (8) to excessive amounts of N. Landrau and Samuels (6) also reported heavy vine growth and low, poor quality roots due to excessive quantities of N.

All in all, it appears as though the Coto clay in the Isabela Substation farm is well supplied with K to meet minimum sweetpotato crop requirements. Maximum yields of 17 *t*/ha were obtained with the postplant application of 78 kg/ha and 33 kg/ha of N and P, respectively, even when K was omitted from the fertilizer mixture. N applications in the vicinity of 33 kg/ha appear essential for good crop production. When N is omitted from the fertilizer, even in the presence of 33 kg/ha of P and 134 kg/ha of K, yields are almost as low as when no fertilizer is applied (10.9 vs. 9.8). When N is applied at the rate of 78 kg/ha, together with K at the rate of 134 kg/ha, near maximum yields are obtained even in the absence of P (15.6 *t*/ha of marketable sweetpotatoes; 5.8 tons more than the no-fertilizer plots).

It appears that the influence of N and K are rather clearly defined for sweetpotato production in this Oxisol. However, the situation concerning P and micronutrients is not so well defined. Applications of P should be omitted until needs are shown under field conditions. Applications of micronutrients should wait for the development of deficiency symptoms at early crop stages.

The results herein reported are in agreement with those reported earlier by Landrau and Samuels (6) from the Corozal (Lares series: Aquic Tropohumults, clayey, mixed, isohyperthermic), Sabana Seca (Sabana Seca series: Oxic Plinthaquults, clayey, mixed, isohyperthermic), and Loíza (Cataño series: Typic Tropopsamments, carbonatic, isohyperthermic) areas and more recently by Talleyrand and Lugo-López (9) from the Cidra (Torres series: Orthoxic Tropudults, clayey, mixed, isohyperthermic) area. The lack of response to K is also in agreement with results obtained with other crops by other investigators working with the same Oxisol (1, 3).

Planting sweetpotatoes in northwestern Puerto Rico appears to have good possibilities in view of the yield obtained. Badillo (2) obtained even higher yields in some years. The information herein reported further confirms the benefits of planting in October (2) since a clean crop free of visible insect or disease damage was obtained. The fact that all operations could be fully mechanized further points to the possibilities of high yield at low costs.

RESUMEN

Se informan aquí los resultados de un estudio diseñado para determinar el efecto de cuatro niveles de N, P, K y micronutrimentos sobre la producción de batatas en un Oxisol del noroeste de Puerto Rico. Los tratamientos incluyeron diferentes niveles de aplicación de N, a razón de 0, 39, 78 y 157 kg./ha.; de P, a razón de 0, 17, 33 y 67 kg./ha.; de K, a razón de 0, 67, 134 y 269 kg./ha. y de una mezcla de micronutrimentos, a razón de 0, 33, 67 y 134 kg./ha. Todas las parcelas se encalaron hasta alcanzar un pH de 6.5 y además se les aplicaron 56 kg./ha. de Mg. Todo el abono se aplicó en franjas dos semanas después de la siembra.

Los resultados indican que el suelo Coto arcilloso, donde se realizó el experimento, era rico en materia orgánica y con una capacidad bastante buena para el suministro de N, Ca, K y Mg. Era aparentemente pobre en P. En términos generales, las cantidades de un nutrimento absorbidas por la planta no se relacionaron consistentemente con la cantidad aplicada excepto en el caso del N. La recuperación aparente del abono fue muy baja en todos los casos. Las parcelas que no se abonaron produjeron sólo 9.7 Tm. de raíces comerciales por hectárea, mientras que con la aplicación de 39 kg./ha. de N, se obtuvieron rendimientos de 16 Tm./Ha. La ecuación rendimiento-abono desarrollada por Capó parece ser útil para predecir los rendimientos de batata en términos del N aplicado en este Oxisol. Altos niveles de N tienden a inducir el crecimiento vegetativo a expensas de la producción de raíces comestibles. Los rendimientos de raíces no se afectaron con las aplicaciones de P, K y micronutrimentos.

LITERATURE CITED

1. Abrams, R., Cruz Pérez, L., Pietri-Oms, R., and Juliá, F. J., Effect of fertilizer N, P, Ca, Mg, and Si on tomato yields in an Oxisol, J. Agr. Univ. P.R. 59 (1): 26–34, 1975.
2. Badillo, J., The effect of planting season in the yields of sweetpotatoes, J. Agr. Univ. P.R. 60 (2): 163–71, 1976.
3. Capó, B. G., Additional evidence on the applicability of the new fertilizer-yield relation, J. Agr. Univ. P.R. 51 (2): 97–120, 1967.
4. Fox, R. H., Talleyrand, H., and Bouldin, D. R., Nitrogen fertilization of corn and sorghum grown in Oxisols and Ultisols in Puerto Rico, Agron. J. 66 (4): 534–40, 1974.
5. Gurney, J. M., Nutritional considerations regarding staples, Paper presented at the 12th Annual Meeting, Caribbean Food Crops Society, Kingston, Jamaica, July 1974.
6. Landrau, P., and Samuels, G., The effect of fertilizers on the yield and quality of sweetpotatoes, J. Agr. Univ. P.R. 35 (2): 71–87, 1951.
7. Lugo-López, M. A., Bartelli, Lindo J., and Abruña, F., An overview of the soils of Puerto Rico: Classification, and physical, chemical and mineralogical properties, Agr. Exp. Sta. Univ. P.R. Publ. 79, 16 pp., 1973.
8. Sánchez, P. A., Nitrogen fertilization, In P. A. Sánchez, ed, A review of soil research in tropical Latin America, N.C. Agr. Exp. Sta. Tech. Bull. 219, 90–150, 1972.
9. Talleyrand, H., and Lugo-López, M. A., Effect of five levels and three sources of N on sweetpotato yields on an Ultisol, J. Agr. Univ. P.R. 60(1): 9–14, 1976.