Limitations to Productivity of Some Ultisol and Oxisol Subsoils[1, 2]

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INTRODUCTION

As population and agricultural land use pressure increase, both erosion and land leveling expose more subsoil to potential cultivation. Subsoils are often thought of as being irremediably inferior to surface soils. In the fight to increase world food production it is important to know where the real limitations to production lie, and accordingly this study undertook to investigate what limits exist to subsoil fertility in the Humid Tropics.

Reported instances of cases where subsoil productivity is lower than the productivity of the surface soil include that of Abruña and co-workers (1) who found in Puerto Rico plot experiments that tobacco yields on Corozal subsoil (Aquic Tropudult) were at least 23 percent lower than those on Corozal clay surface soil at comparable base saturations and rates of applied fertilizer.

Pangola grass growing on Alonso clay (Orthoxic Tropohumult) subsoil at Adjuntas gave a yield of 75 percent of that obtained on the surface soil (F. Abruña, personal communication).

A Coto subsoil (Tropeptic Haplorthox) at Isabela, although exposed for many years, remained practically barren. The infertility of the subsoil was apparently due to Zn deficiency. Maize plants not sprayed with zinc sulfate stopped growing after reaching a height of 30 cm, while Zn-sprayed plants in the next row matured normally (4).

In greenhouse tests on Carreras surface and subsoil (a Typic Tropohumult formerly called Humatas), and Cialitos surface and subsoil (Orthoxic Tropohumult), the dry weights of bean tops grown on the surface

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soils were twice those grown on the subsoils with complete fertilization including micronutrients (3).

Lathwell et al. (9) studied the nitrogen-supplying potential of 10 tropical Ultisols and Oxisols from Puerto Rico. After fertilizing with N, P, K, Mg and micronutrients, the greenhouse yield for five crops of corn and sorghum on the least productive soil, Nipe (Typic Acrorthox), was 42 percent of that on the most productive, Carreras (Typic Tropohumult); additional experiments indicated these results may have been due to high phosphorus fixing capacity in the Nipe soil (Lathwell, personal communication).

This study was undertaken for the purpose of finding the fertility factors responsible for preventing maximum growth on some Puerto Rican subsoils. In addition to conventional pot watering, a new method of watering which reduces the possibility of moisture stress was used to see if some previously reported depressed pot yields on subsoils could be partially attributed to ineffective conventional pot watering techniques.

GENERAL METHODS

Soils were collected from experimental plots[4] near Jayuya (Los Guineos soil series), Manatí (Piña soil series), Barranquitas (Catalina soil series at two field sites), and at the Corozal Substation (Carreras soil series, formerly called Humatas). The sample of the Nipe soil series was collected from Las Mesas near Mayagüez. Surface soils were collected from the plow layer (0–20 cm) and the subsoils from 20 to 50 cm depth. The soils are described in tables 1 and 2.

The thoroughly mixed air-dry soils were ground in a Quaker City Mill to 4 mm or less, mixed with liming materials and fertilizers, and placed in 2,000 and 3,000 ml capacity white plastic pots with 4 holes in the bottom (diameter of pot tops 15 or 20 cm). Where density of the soils differed greatly, equal volumes rather than equal weights of soil were used. A layer of fiberglass was used to line the bottoms of the pots.

Modifications of the wick-watering method of Dolar and Keeney (5) were used on a number of pots (Ritchey and Fox (10)). A hole was melted through the bottom of the pot with a red-hot, 1.4-cm diameter iron pipe. A wick was inserted which extended halfway up through the center of the pot and down into a container of water below the pot. A preliminary trial of the method using USP cotton fiber for wicks was made in Experiment

[4] These field plots are part of a collaborative soil fertility research project of Cornell University, the University of Puerto Rico Agricultural Experiment Station and the U.S. Department of Agriculture. This project is supported in part by the U.S. Agency for International Development.

TABLE 1.—*Chemical properties of soils used and their classification under the U.S. Soil Taxonomy*

Soil	Depth	pH[1]	OM	N	Ca	Mg	K	Al
	Cm		*Percent*	*Percent*	*Me/100 g*[2]	*Me/100 g*[2]	*Me/100 g*[2]	*Me/100 g*[2]
Carreras (Aquic Tropohumult; clayey, kaolinitic, isohyperthermic)	0–20	5.0	4.88	0.14	6.10	0.86	0.32	1.54
	33–43	4.5	1.80	.09	1.59	.35	.20	7.54
Los Guineos (Epiaquic Humoxic Tropohumult; clayey, kaolinitic, isothermic)	0–15	5.0	10.66	.65	4.86	1.71	.37	1.06
	17–35	5.0	5.27	.27	2.36	.99	.19	1.49
Piña (Psammentic Haplorthox; sandy, isohyperthermic)	0–15	5.3	1.81	.07	1.00	.18	.08	.37
	20–40	4.75	2.03	.06	.48	.24	.03	1.06
Catalina (Tropeptic Haplorthox; clayey, oxidic, isohyperthermic)	0–12	5.8	6.04	.31	5.48	.68	.42	0
	20–50	5.4	3.60	.22	3.72	.88	.64	0
Nipe (Typic Acrorthox; clayey, oxidic, isohyperthermic)	Exposed subsoil	4.8	3.22	.14	2.28	1.31	.19	0

[1] 1:2 soil:water.

[2] Exchangeable Ca, Mg and K with ammonium acetate; exchangeable Al with 1*N* potassium chloride.

TABLE 2.—*Available zinc, available phosphorus and phosphorus requirements of soils used*

Soil		Available zinc			P[3]	P requirement[4]
		0.1*N* HCl	Double[1] acid	DTPA[2] TEA		
		Ppm	*Ppm*	*Ppm*	*Ppm*	*μg/g*
Carreras	Surface	0.6	1.0	0.4	1.8	100–150
	Sub	.4	.7	.1	4.2	440–480
Los Guineos	Surface	2.2	3.5	2.1	6.3	740–800
	Sub		.6		1.8	650–700
Piña	Surface	.6	.8	.3	133	0
	Sub				53.9	0
Catalina	Surface	2	2.8	2.8	4.2	—
	Sub Site A		2		1.4	640–860
Nipe	Exposed subsoil				1.4	750–850

[1] 0.05*N* HCl plus 0.025*N* H_2SO_4.

[2] 0.005*M* diethylenetriaminepentaacetic acid, 0.01*M* $CaCl_2$, and 0.1*M* triethanolamine.

[3] Available phosphorus by Bray No. 2.

[4] Mg P per g of soil necessary to obtain 0.2 ppm P in equilibrium solution after 6 days by method of Fox and Kamprath (7).

I. For the remaining experiments fiberglass wicks 27 cm long and 1.3 cm in diameter were used.[5]

All other pots were watered conventionally. They were brought to field capacity by sprinkling water on the surface one to three times daily.

Distilled water was used in all experiments except Experiment I.

In all experiments ammonium nitrate, potassium nitrate and monocalcium phosphate were used as sources of N, P, and K, except in Experiments III and IV, where potassium sulfate was used.

Split applications of nitrogen fertilizer through the growing period were made by injecting concentrated ammonium nitrate solution into the wicks with a hypodermic needle or adding it to the conventionally watered pots with irrigation water.

Ten to 12 seeds of maize (*Zea mays* L. cv. Pioneer Tropical Hybrid X-306) were planted and thinned to 4 plants per pot. In some of the trials an effort was made to reduce fungus infection (especially severe in Carreras subsoil), by using seeds which had been germinated between moist paper towels.

The plants were grown in the greenhouse under natural light. After 2 to 3 weeks of growth (measured from the initiation of germination), plant tops were harvested, dried to constant weight at 70 C, and weighed.

EXPERIMENT I

This experiment was designed to see if the soil productivity differences between Nipe subsoil and Carreras surface soil which were observed by Lathwell et al. (9) would persist at high phosphorus rates and continuous water supply.

METHODS

Treatments of 0, 600, and 1,800 ppm P (600 mixed in plus 1,200 spot placed) were applied to 2,000 g Nipe subsoil, and a treatment of 600 ppm P was applied to 1,600 g Carreras surface soil. For spot placing, the monocalcium phosphate was divided into six parts. One part was placed in the center of the pot and the other five placed in 2-cm long glass tubes of 6 mm inside diameter and distributed around the pots at a depth of 6 cm, in order to provide a concentrated phosphorus source with a minimum possibility of soil fixation. The soils were limed to pH 5.5 to 6.0. Each soil received 200 ppm K, 300 ppm N and a micronutrient solution supplying 10 ppm Mn as $MnCl_2 \cdot 4H_2O$, 5 ppm Fe as sodium ferric diethylenetriamine

[5] Type 4608, Atlas Asbestos Co., North Wales, Pa. Product and company name included for specific information only and does not imply any endorsement or preference for the product by the Agricultural Experiment Station of the University of Puerto Rico over other products not mentioned.

pentaacetate, 2.4 ppm B as H_3BO_3, 0.5 ppm Cu as $CuSO_4 \cdot 5H_2O$, 5 ppm Zn as $ZnSO_4 \cdot 7H_2O$ and 0.1 ppm Mo as $H_2MoO_4 \cdot H_2O$.

To test the feasibility of using wick-watering methods and because the Nipe soil has a low available water content, two treatments using wick-watering were included: Nipe with 1,800 ppm P and Carreras with 600 ppm P.

RESULTS AND DISCUSSION

The oven-dry weights of the plant tops which were harvested 24 days after planting are shown in table 3. When water supply was adequate (wick-watering) and high amounts of phosphorus were added, the productivity of the Nipe subsoil equalled that of the Carreras surface soil.

TABLE 3.—*Yield and foliar phosphorus content of maize grown on Nipe subsoil and Carreras surface soil at various phosphorus rates with conventional and wick watering in Experiment I*

Soil	Applied P	Watering	Replications	Yield[1]	Foliar P
	Ppm			*g/pot*	*Percent*
Nipe	0	Conventional	4	2.72a	0.12
Nipe	600	Conventional	4	10.42 b	.39
Nipe	1800	Conventional	4	10.48 b	.74
Nipe	1800	Wick	2	13.00 bc	.45
Carreras	600	Wick	3	11.57 bc	.54
Carreras	600	Conventional	4	12.82 c	

[1] Yields not followed by the same letter are significantly different at the 5-percent probability level according to Duncan's Multiple Range Test as modified by Kramer for unequal replication (11).

With Nipe the addition of 1,200 ppm spot-placed phosphorus to the 600 ppm P mixed in had no effect on yield, but there was a considerable increase in phosphorus content of the leaves.

The previously reported low yields on Nipe subsoil in greenhouse experiments were probably due mainly to insufficient application of phosphorus. Phosphorus adsorption isotherm measurements [using the methods described by Fox and Kamprath (7)] showed that approximately 800 mg P/g of soil were necessary to maintain an equilibrium solution concentration of 0.2 ppm P (table 2), regarded as sufficient for plant growth in pots. In this experiment 600 ppm apparently provided sufficient P in the pots, as 1,800 ppm gave no higher yields.

The rates of P applied to satisfy phosphorus requirements of plants grown in pots are far higher than those necessary in the field. Baker and Woodruff (2) observed in pot experiments with maize that a disproportionately large increase in rates of P fertilization was necessary as pot size was decreased. Fox and Kamprath (7) attributed this to interception of plant roots by the container walls causing "piling-up" of the roots which results in reducing their effectiveness for phosphorus uptake. Because of this observed amplification of P requirements in pots, one can expect to reach plateau levels of P response in the field with much lower levels of P fertilization than were necessary here.

Use of the automatic wick-watering method to maintain a continuous supply of easily available water did not significantly increase the yield in the fertilized Nipe.

EXPERIMENT II

In a nitrogen experiment described by Fox (6), marked differences in productivity at the same level of nitrogen had been observed on different areas of a field of Carreras soil. It appeared that yields decreased as the amount of subsoil mixed in with the surface soil increased.

A preliminary experiment on surface soils, a partially exposed cropped subsoil, and a subsoil from the field showed that the yield relationship observed in the field could be reproduced in the greenhouse. All the soils received 300 ppm N, 300 ppm P, 200 ppm K, 50 ppm Mg and the micronutrients described in Experiment I. The yield on the subsoil was only 69 percent of the yield on the surface soil. Yields were proportional to both soil organic matter content and Bray No. 2 available P. In the preliminary experiment the addition of 2 percent organic matter in the form of dried, partially decomposed coffee leaves increased yields on the subsoil by 18 percent. Foliar analysis indicated that Mg, Zn, and P might be insufficient.

Experiment II was carried out to see if the reduction in productivity of the Carreras subsoil could be eliminated with mineral amendments or if organic matter additions were also necessary.

METHODS

Three levels of phosphorus (100, 200, and 300 ppm P) were applied to 1,600 g Carreras subsoil receiving zero or 36 ppm Zn. An additional treatment receiving 300 ppm P, 36 ppm Zn and 1 percent ground, dried, partially decomposed coffee leaves was included. For comparison, Carreras surface soil with and without added Zn was included. All soils were limed to pH 5.1 to 5.5, fertilized with 300 ppm N and 200 ppm K, and all but Treatment 10 received 100 ppm Mg as magnesium sulfate. Three replicates per treatment, all wick-watered, were arranged in Random Complete Blocks, and the experiment was harvested 24 days after the initiation of germination.

RESULTS AND DISCUSSION

The results (shown in table 4 and fig. 1) indicate that when 300 ppm P and 36 ppm Zn were added to the subsoil, the yield was as high as that obtained on surface soil with Zn or on subsoil plus organic matter. Apparently 5 ppm Zn, as supplied by the micronutrient solution used in the preliminary experiment, was not sufficient. The response to Zn, particularly at high phosphorus level, was striking, exceeding 100 percent (fig. 1). There was also a marked response to the application of Zn in the surface soil. It is clear that both Zn and P are needed to maximize yields in Carreras surface and subsoil.

TABLE 4.—*Treatments and yields on Carreras surface and subsoils in Experiment II*

Treatment number	Treatment			Yield[1]
	Zn	P	Cu	
	Ppm	*Ppm*	*Ppm*	*g/pot*
Subsoil				
1	0	100	21	4.60a
2	0	200	21	5.60a
3	0	300	21	6.97a
4	36	100	21	6.63a
5	36	200	21	11.23 b
6	36	300	21	14.23 bc
7[2]	36	300	21	13.33 bc
8	36	300	0	15.27 c
Surface soil				
9	0	300	21	7.70a
10	36	300	21	14.30 b

[1] Yields not followed by the same letter are significantly different at the 5-percent probability level by the Duncan's New Multiple Range Test.
[2] Plus 1-percent coffee leaves.

The subsoil showed no significant response to added Cu nor to the addition of 1 percent dried ground partially decomposed coffee leaves when adequate Zn and P were present.

The results of foliar analysis are shown in table 5. These emission spectroscopy measurements were unreplicated so the possibility of error cannot be eliminated. The phosphorus content was erratic in the zinc-deficient plants but in the zinc-sufficient treatments P content increased with applied phosphorus to 0.30 percent P at 300 ppm P added, which is within the sufficient range for maize according to Jones (8). Zinc content was deficient at all levels of phosphorus when no zinc was applied, but when 36 ppm Zn was applied the plant zinc content was sufficient in the 200 and 300 ppm P treatments.

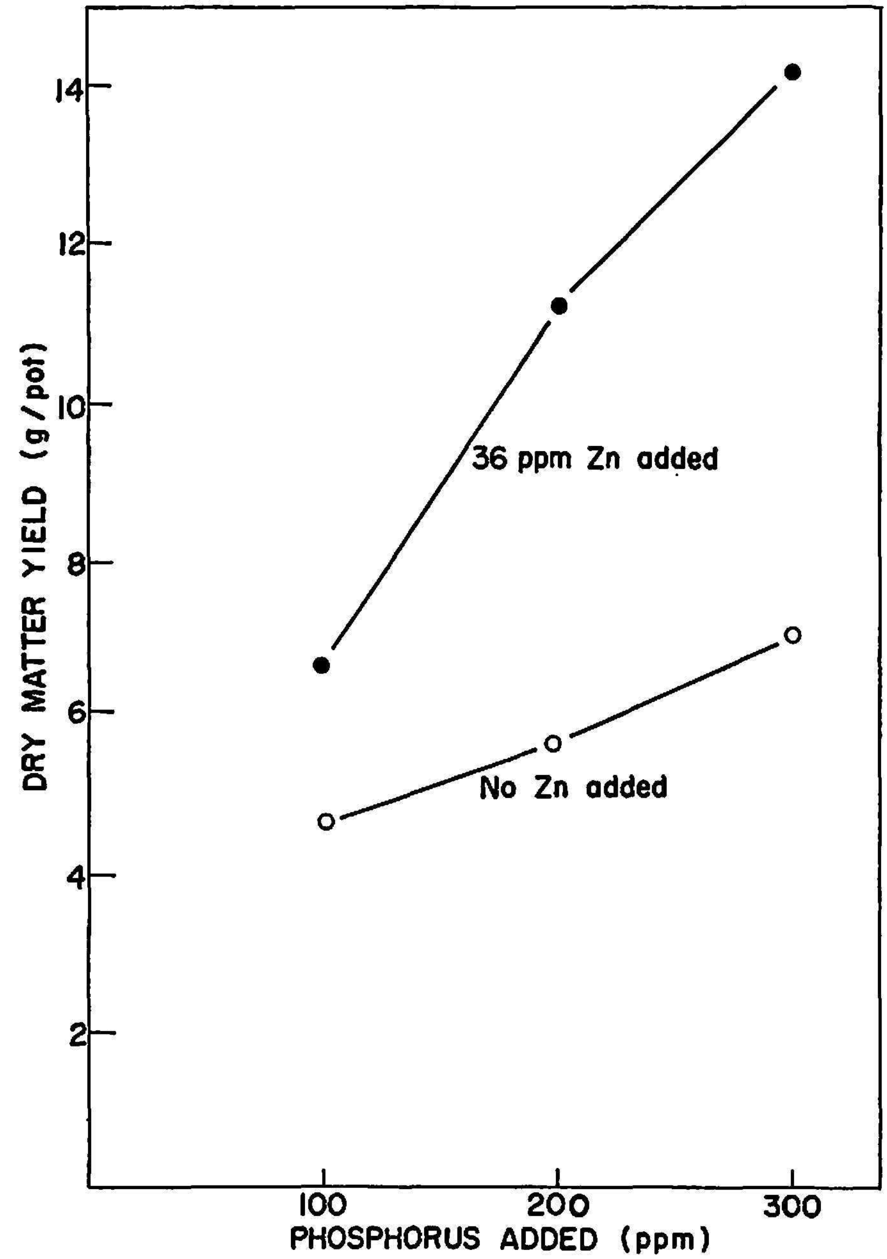

FIG. 1.—Relationship between phosphorus application and dry matter yield of maize with and without added zinc.

In spite of the addition of 100 ppm Mg as magnesium sulfate the magnesium content was unusually low in all the subsoil treatments. The plants from the highest yielding treatment, No. 8, contained 0.04 percent Mg which is in the deficiency range for maize according to Jones (8). At these low levels of Mg, however, the results of emission spectroscopy are not extremely accurate because the precision of the instrument is only ±0.02 percent for Mg. Unusually low magnesium contents in Pioneer X-306 maize growing in field plots have been observed by the authors and other workers in Puerto Rico (F. Abruña, personal communication).

EXPERIMENT III

The differences in productivity thus far tested had disappeared completely with sufficient mineral fertilization. In an effort to find additional cases where a marked difference in productivity existed, the following were compared: Surface and subsoil of Los Guineos (Epiaquic Humoxic Tropohumult); surface soil of Carreras (Aquic Tropohumult); surface and subsoil of Piña (Psammentic Haplorthox); and surface and two subsoils of Catalina (Typic Haplorthox).

TABLE 5.—*Foliar analyses of maize plants from Experiment II*

Treatment number	Yield	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Mo
	g/pot	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Ppm*	*Ppm*	*Ppm*	*Ppm*	*Ppm*	*Ppm*	*Ppm*
1	4.60	2.9	0.12	4.69	0.65	0.05	69	57	8	7	8	62	2.1
2	5.60	3.5	.31	4.70	1.36	.17	106	106	15	19	10	84	2.2
3	6.97	3.2	.20	5.79	.52	.04	51	41	9	4	7	44	1.8
4	6.63	2.7	.09	3.86	.25	<0.01	21	36	5	3	12	53	1.7
5	11.23	2.3	.19	3.77	.62	.06	57	93	15	12	56	71	2.1
6	14.23	2.0	.30	3.39	.35	.04	41	69	13	10	46	48	2.1
8	15.27	2.1	.21	3.43	.46	.04	46	72	12	9	54	48	1.8
9	7.70	2.9	.34	2.73	.75	.29	119	236	14	19	13	64	1.8
10	14.30	2.5	.24	1.61	.34	.12	40	98	12	11	46	57	2.1

METHODS

The basic fertilizer treatment applied to each soil (1,600 g per pot) included Zn where a zinc deficiency was suspected, 270 ppm N, 200 ppm K and 350 to 400 ppm P (table 6). Piña surface and subsurface soil (2,000 g per pot) received 320 ppm N and 200 ppm K but no P. No blanket micronutrient treatment was applied. Where necessary, soils were limed to a pH between 5.1 and 5.7 with an equimolar mixture of magnesium and calcium hydroxides. Two watering regimes were used to ensure adequate water supply. Three wick-watered and three conventionally watered pots per treatment were arranged in a Completely Random Design.

Because of the variable emergence due to inadequate initial watering of the soil, the plants were harvested 13 days after the average plant height per pot reached 13.2 cm (20 to 22 days after the initiation of germination). At harvest the plants were 50 to 71 cm high. This procedure allowed growth rate to be measured and eliminated the effect of initial emergence differences.

RESULTS AND DISCUSSION

Table 6 shows that all the soils in this survey except Catalina subsoil at site A and Catalina subsoil at site B produced yields which were within 15 percent of, and not significantly different from, the Los Guineos surface soil yield (which was the highest yielding), under the watering regime most effective for that soil. The yields from the wick-watering method replicates were as good or better than those on the conventionally watered pots except on the Carreras surface soil, where low hydraulic conductivity

TABLE 6.—*Watering method, fertilizer treatment and yield of maize on eight soils surveyed in Experiment III*

Soil		Watering	Treatment P	Zn	Lime[1]	Yield[2]
			Ppm	*Ppm*	*Ppm*	*g/pot*
Los Guineos	Surface	Wick	350	0	1906	15.33 g
		Conventional	350	0	1906	12.73 cdef
Carreras	Surface	Conventional	400	18	1119	14.73 fg
		Wick	400	18	1119	11.27abcd
Piña	Surface	Conventional	0	18	241	14.00 efg
		Wick	0	18	241	13.30 defg
Los Guineos	Sub	Wick	400	18	1906	13.67 defg
		Conventional	400	18	1906	9.30a
Piña	Sub	Wick	0	18	393	13.37 defg
		Conventional	0	18	393	10.43abc
Catalina	Surface A	Wick	400	0	0	13.07 defg
		Conventional	400	0	0	12.87 def
Catalina	Sub B	Wick	400	0	1184	12.63 cdef
		Conventional	400	0	1184	11.67 bcde
Catalina	Sub A	Wick	400	0	659	9.80a
		Conventional	400	0	659	9.17a

[1] Equimolar mixture of magnesium hydroxide and calcium hydroxide.

[2] Yields not followed by the same letter are significantly different by Duncan's New Multiple Range Test.

at low moisture contents may have reduced the availability of water during high transpiration periods.

EXPERIMENT IV

TRIAL ONE

A further experiment was made comparing the lowest and highest yielding of the eight soils surveyed in the previous experiment.

Methods

Four levels (0, 300, 300 banded, and 600 ppm) of phosphorus were applied to 1,600 g of the lowest yielding, the Catalina subsoil location A.

Since the Catalina subsoil had not previously received any zinc, 36 ppm Zn were added to each treatment. Two levels of phosphorus (300 and 600 ppm) were applied to the highest-yielding soil of the previous trial, the Los Guineos surface soil, to see if phosphorus fertilization was optimal. The soils were limed with an equimolar mixture of $Ca(OH)_2$ and $Mg(OH)_2$ to pH 5.4 to 5.7, and received 360 ppm N and 100 ppm K. All were wick-watered. The plant tops were harvested 23 days after planting.

Results and Discussion

Table 7 presents the results of the comparison at higher P rates of the highest and lowest yielding soils of the previous experiment. Yields on both soils still exhibited a strong response to phosphorus. Banding the 300 ppm phosphorus application was no more effective than mixing. The yield of Catalina subsoil receiving 600 ppm was almost identical to that of the Los Guineos surface soil receiving 300 ppm P, but significantly less than the Los Guineos with 600 ppm P.

TABLE 7.—*Treatments and yields of maize on Catalina subsoil and Los Guineos surface soil in Experiment IV, Trial One*

Soil	Number of replicates	Treatment		Yield[2]
		P	Zn	
		Ppm	*Ppm*	*g/pot*
Catalina subsoil	3	0	36	3.20a
	3	300	36	12.57 b
	3	300[1]	36	13.33 b
	3	600	36	16.77 c
Los Guineos surface soil	4	300	18	16.90 c
	4	600	18	21.15 d

[1] Phosphorus was banded.

[2] Yields not followed by the same letter are significantly different at the 5-percent probability level according to Duncan's New Multiple Range Test as modified by Kramer for unequal replication (11).

TRIAL TWO

Results of the previous trial indicated that yields on both soils were still responding to phosphorus applications.

Methods

Another trial was therefore run, as part of a larger experiment, using the same soils, which were dried, pooled, and repotted after the addition of 205 ppm K and 47 ppm Mg to the Catalina subsoil and 226 ppm K and 52 ppm Mg to the Los Guineos surface soil. Two levels of additional phosphorus were applied to each soil (566 ppm and 1,132 ppm to the Catalina subsoil and 520 ppm and 1,025 ppm to the Los Guineos surface soil). The 520 ppm P treatment Catalina subsoil also received 0.6 ppm B. Each treatment consisted of four replicates, all of which were wick-watered.

Results and Discussion

Results of this trial, given in table 8, showed that response to phosphorus in both soils was now at or near plateau level, and that the yields on the two soils were not significantly different.

This demonstrated that the previously low subsoil yield could be brought to the level of a highly fertile surface soil by the addition of phosphorus and zinc.

TABLE 8.—*Treatment and yield of maize on Catalina subsoil location F and Los Guineos surface soil in Experiment IV, Trial Two*

Soil	P added	Yield[1]
	Ppm	*g/pot*
Catalina subsoil Site A	520	20.22a
	1025	20.70a
Los Guineos surface soil	566	20.74a
	1132	21.59a

[1] Yields followed by the same letter are not significantly different at the 5-percent probability level according to Duncan's New Multiple Range Test.

CONCLUSION

This study shows that differences in productivity of soils observed in previous experiments were not due to inherent limitations of the subsoils, but arose because of their higher requirements for phosphorus, zinc and available water.

As the requirements of mechanized agriculture increase the amount of land-leveling and subsequent exposure of subsoils in the Tropics, there is a growing need to be able to obtain maximum yields on these soils. The results of this study indicate that with careful water management, liming and fertilization (with P and Zn especially) the Oxisol and Ultisol surface and subsoils tested can all be equally productive. It will be necessary to conduct field experiments to determine how high the rates of P fertilization must be to reach near-maximum yields but it can be assumed it will be less than the 1000 ppm P required in the greenhouse pots.

SUMMARY

Greenhouse experiments with maize were carried out to see if the reported infertility of some subsoils could be improved with mineral fertilization and efficient watering.

It was shown that the Nipe soil series (Typic Acrorthox; clayey, oxidic, isohyperthermic) exposed subsoil was as productive as the Carreras series (Aquic Tropohumult; clayey, kaolinitic, isohyperthermic) surface soil when N, K, micronutrients and 600 ppm P were added and the pots were watered by means of wicks.

Carreras subsoil, when limed and fertilized with N, K, 300 ppm P, 100 ppm Mg and 36 ppm Zn produced as well as Carreras surface soil, even though it contained only about one-third as much organic matter.

A comparison among eight surface and subsoils showed that yields on limed, liberally fertilized, well-watered Los Guineos series (Epiaquic Humoxic Tropohumult; clayey, kaolinitic, isothermic) surface soil, Carreras surface soil, Piña series (Psammentic Haplorthox; sandy, isohyperthermic) surface soil, Los Guineos subsoil, Piña subsoil and Catalina series (Tropeptic Haplorthox; clayey, oxidic, isohyperthermic) surface soil were not significantly different. However, the yield on the least productive of two Catalina subsoils was only 64 percent of the yield on the Los Guineos surface soil. But with the addition of Zn and slightly over 1,000 ppm P, greenhouse pot yields on the two soils were essentially the same. Field experiments will be necessary to determine optimum P rates under field conditions.

It was concluded that the productivity in greenhouse pots of surface and subsoils of the Ultisols and Oxisols studied can all be brought to the same high level, provided adequate mineral fertilization (including Zn and high P rates), lime and water management are used.

RESUMEN

Para comprobar si es posible corregir mediante el abonamiento y el riego adecuado la infertilidad que se ha informado respecto a algunos subsuelos, se llevaron a cabo experimentos con maíz en un invernadero.

Se encontró que el subsuelo expuesto de un suelo de la serie Nipe (Acrorthox típico; arcilloso, oxídico e isohipertérmico) era tan productivo como un suelo superficial de la serie Carreras (Tropohumult ácuico; arcilloso, caolinítico e isohipertérmico) cuando se le añadieron N, K, elementos menores y 600 ppm de P, y los tiestos se regaron por medio de mechas.

El subsuelo Carreras, cuando se encaló y se abonó con N, K, 300 ppm de P, 100 ppm de Mg y 36 ppm de Zn fue tan productivo como la capa superficial, a pesar de contener solo una tercera parte de la materia orgánica.

En un estudio comparativo entre ocho suelos superficiales y subsuelos se observó que los rendimientos de un suelo superficial encalado, bien abonado y regado adecuadamente de la serie Los Guineos (Tropohumult epiácuico humóxico; arcilloso, caolinítico e isotérmico); uno superficial de la serie Carreras; otro superficial de la serie Piña (Haplorthox psaméntico; arenoso e isohipertérmico); un subsuelo Los Guineos; otro subsuelo de la serie Piña; y uno superficial de la serie Catalina (Haplorthox tropéptico; arcilloso, oxídico e isohipertérmico) no eran significativamente diferentes. Sin embargo, el rendimiento del menos productivo de los dos subsuelos Catalina solo fue 64 por ciento del rendimiento del suelo superficial Los Guineos.

Pero al añadírsele Zn y un poco más de 1,000 ppm de P, el rendimiento de ambos suelos en invernadero fue casi igual. Para determinar la cantidad óptima de P que debe aplicarse en condiciones de campo será necesario llevar a cabo experimentos de campo.

Se concluyó que la productividad de los suelos superficiales y los subsuelos de los Ultisoles y Oxisoles que se estudiaron en tiestos en invernadero puede elevarse al mismo nivel alto si se abonan con minerales (incluyendo Zn y aplicaciones elevadas de P), se encalan y se riegan adecuadamente.

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