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Soil Fertility Management Investigations on a *Rhodic Paleustult* in South Western Nigeria

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Abstract

A trial was carried out at Isoya in south-western Nigeria to determine the effect of N, P and K applications and weeding on the yield potential of maize grown on the Itagunmodi soil series. This soil is classified as clayey, oxidic, isohyperthermic Rhodic Paleustult. Following a short mixed fallow cycle of four years, N and P responses were observed in the first year of cropping and K response in the second cropping year after land clearing. The soil which has a moderate P sorption capacity is very deficient in P. Results of incubation studies showed that under laboratory conditions about 5 ppm of fertilizer P was required to increase the Bray P-1 test level by 1 ppm. High maize yield of above 4.6 tons/ha was obtained with variety TZPB during the first season and above 2.0 tons with variety TZE in the second season with weeding. The maize crop can compete effectively with weeds under high fertility.

Introduction:

Information on productivity and suitable soil fertility management practices for continuous food production for the major soils in the humid tropics of West Africa is still limited, despite the fact that some fertility management investigations have previously been carried out (Milne, 1968). However, most of these trials were not related to well characterized major soil types. Therefore, in order to obtain more information on the potential productivity and the fertility management problems of the major soils in the region, maximum yield cultural trials were carried out on several well defined bench mark soils in southern Nigeria. This study reports the information obtained in Itagunmodi soil with the aim of: (a) determining the extent to which cultural factors influence crop yield level, and (b) investigating the long term effect of optimized crop production practices on soil properties.

Materials and Methods:

The experiment was carried out in Isoya, located near Ife in the forest zone of southern western Nigeria. Average annual precipitation in the area is 1300 mm, with a rainy season extending from March till November. The experimental area was cleared from a mixed short cycle fallow bush regrowth. The study was conducted on the Itagunmodi soil series of south-western Nigeria. The soil is classified by Moormann *et al* (1981) according to the United States Soil Taxonomy as clayey, *oxidic, isohyperthemic Rhodic Paleustult (Dystric Nitosol* according to FAO legend and sol *ferrallitique moyennement desature appauvri modal* according to CPCS classification). The soil parent material is derived from drift or colluvium from amphibolite weathering. The surface has a slightly gravelly clay texture.

Seven treatments (see Table 2) were compared in this experiment using a randomized compete block design with three replications. Maize cultivar TZPB was used in the experiment, except for the second season of 1979 when the early maturing variety TZE was used. Maize was planted in an area of 3.75x6m and spacing of 75cmx25cm at a density of 53,200 plants/ha. The N, P, K fertilizer was applied at the rate of 120 kgN/ha as urea, 60 kg P/ha as single superphosphate and 40kg K/ha as muriate of potash. One-third of N, P and K was applied at sowing. The remaining N, P and K was banded at four weeks after sowing. Weeding was done manually.

To determine changes in soil properties, surface soil samples (0-15cm) were collected at initiation and at the beginning of each cropping. Soil pH was measured using 1:1 soil: water ratio with a glass electrode; soil organic carbon by the Walkley and Black method; exchangeable cations were extracted with IN ammonium acetate and ECEC was estimated from the sum of exchangeable cations including H and Al; total N by Kjeldahl digestion and available P was extracted by the Bray No. 1 method. The phosphate sorption isotherm of the soil was determined using the procedure developed by Fox and Kamprath (1970).

Weed samples were collected using 1 m^2 grids from unweeded plots to determine weed weight and nutrient composition. Maize earleaf samples were also collected at silking time to determine the plant nutrient status. Plant tissue samples were wet-digested using a mixture of HNO_3-$HClO_4$. The P content of the digest was measured using a colorimeter, K and Ca by flame photometer, while Mg, Mn and Zn contents were determined using a Perkin Elmer 403 atomic absorption spectrophotometer.

Harvested plot size was 13.5m^2. Maize yield was adjusted to 12% moisture content.

A laboratory experiment was conducted using the procedure developed by Peck *et al* (1971) to determine the changes in Bray P-1 test values resulting from addition of P fertilizers. Surface soil samples taken from the no fertilizer plots were used in this study.

Results:

Soil Analysis:

The chemical composition of the surface soil before the 1979 cropping is shown in Table 1. It is apparent that the soil was very deficient in phosphorus. Cropping decreased the soil organic matter level particularly in the control and no nitrogen treatments. The increase in the inorganic total nitrogen level with cropping may be the result of soil organic matter decomposition. Soil pH and magnesium levels showed little changes with three years of cropping. Soil potassium was not increased even in the plots receiving K fertilizer, a confirmation of the findings by Obigbesan and Amalu (1985) on a 7 year cassava/maize rotation plantation at Texagric, Opeji.

Table 1: SOME PHYSICAL AND CHEMICAL PROPERTIES OF SURFACE SOILS (0-15cm) SAMPLED AT INITIATION OF TRIAL IN 1976 AND BEFORE CROPPING IN 1979

Treatments*	Sand — %	Silt 2mm-	Clay	pH H_2O	Org. C %	Total-N (%)	Exch.Cations (me/100g) K	CA	Mg	Bray-1-P (ppm)
Prior to trial	38	22	40	5.90	2.64			1976		
No Fertilizer +			1979			0.31	0.30	8.50	2.11	2.6
No Weeding	—	—	-	6.10	2.16			1979		
No Fertilizer +			1976			0.37	0.29	8.51	2.30	2.4
Weeding	—	—	- -	5.87	2.16	0.39	0.31	8.08	2.39	2.3
PK + Weeding	—	—	—	5.93	2.08	0.37	0.29	9.03	2.02	6.4
NK + Weeding	—	—	—	5.76	2.30	0.42	0.31	8.43	2.35	2.2
NP + Weeding	—	—	—	5.83	2.34	0.42	0.28	9.45	2.33	5.5
NPK No Weeding	—	—	—	5.87	2.32	0.38	0.31	9.49	2.36	5.6
NPK + Weeding	—	—	—	5.90	2.35	0.38	0.29	9.53	2.15	5.8

*Fertilizer rate: 120N - 60P - 40K in kg/ha

Table 2: EFFECT OF FERTILIZER APPLICATION AND WEEDING ON GRAIN YIELD OF MAIZE GROWN ON ITAGUNMODI SOIL

Treatment*	Grain Yield (Kg/ha) 1976**	1978**	1979**	X	1979***
No Fertilizer No Weeding	1235	1704	1088	1342	505
No Fertilizer + Weeding	2680	2735	3008	2808	1331
PK + Weeding	2341	2758	2965	2688	870
NK + Weeding	3575	3292	3475	3447	1428
NP + Weeding	4281	3309	3552	3714	1367
NPK No Weeding	4352	4626	4261	4413	2649
NPK + Weeding	4989	5231	4630	4950	2389
LSD 05	1608	1753	1138	1197	691

*Fertilizer rate 120N-60P-40K in Kg/ha/maize crop

**Grain yield early crop variety TZPB

***Grain yield late crop variety TZE

$\overline{X}$ = mean grain yield, early season

Crop Yield:

The effect of fertilizer treatments and weeding on maize grain yield is shown in Table 2. There was a significant effect of fertilizer application on maize grain yield when compared to the no fertilizer no weeding treatment. With no fertilizer application and weeding maize yield was reduced to less than one third.

After a short cycle of mixed fallow period, the maize crop showed significant responses to NK, NP and NPK treatments (Table 2). The P and K responses were restricted to plots receiving N fertilizer. Phosphorus and K by themselves tended to depress yield due probably to nutrient inbalance. The Itagunmodi soil appears to have high fertility potential for maize production as observed in Table 2 indicating that in the absence of fertilizer the yield on the weeded plots remained high. It was rather surprising to observe nitrogen response in this first year of cropping after fallow particularly considering the high soil organic matter content. This trend is indicative of the high N requirement of maize in the Itagunmodi soil.

There was a significant response to phosphorus application resulting from the low phosphorus status of the soil. The Itagunmodi soil as shown in Figure 1 has a moderate phosphorus sorption capacity if compared to the Egbeda soil which is known to have a low phosphorus sorption capacity (Fox and Kang, 1978; Juo and Fox, 1977). Kang *et al* (1977) estimated the critical Bray P-1 value for maize grown on Alfisols as 14 ppm P. Results of incubation studies as shown in Figure 2 showed, that under laboratory conditions about 5 ppm of fertilizer phosphorus was required to increase the Bray P-1 test level by 1 ppm. Under field conditions for the Itagunmodi soil the initial phosphorus rate required was thus estimated at 110 kg P/ha. Though some phosphorus contribution can be expected from decomposition of organic matter, (Adepetu and Corey, 1979), the rate of 60 kg P/ha initially appeared to be inadequate. With repeated phosphorus application, there was a significant build up in phosphorus status (Table 1), even though the final Bray P1 values were still below the critical level (8 ppm) required by maize.

Potassium application in the presence of N and P significantly increased grain yield in 1978 and 1979 (Table 2), despite the rather high exchangeable potassium level in the soil (Table 1). Though infrequent, Foster (1972) also observed potassium response on some Ugandan soils with high exchangeable potassium levels of about 0.4 me/100g. However, data from the area showed lower critical potassium levels for maize production. Sobulo (1980) reported potassium response of maize grown in soils of the Forest and Derived savannah zones of Western Nigeria with extractable potassium levels of about 0.18 me K/100g. Kang (1980) reported much lower deficient potassium levels of 0.15 me K/100g for an Alfisol and Entisol in south-western Nigeria. It thus appears that the high potassium status of the Itagunmodi soil is uncommon for the area.

Weeding had a more pronounced effect on maize grain yield without fertilizer than with fertilizer application (Table 2). In the no fertilizer treatment, the absence of weeding reduced the mean maize grain yield by 35%, but there was a low yield reduction of only 8% with fertilizer application in the presence of weeds.

Plant Nutrient Status

The nutrient composition of the ear leaves sampled at silking is shown in Table 3. The mean weight of the ear leaves as affected by fertilizer and weeding treatments showed the same trend as those of the grain yield, indicating, that the ear leaf weight can be used as an indicator for effects of fertilizer treatments.

Table 3: EFFECT OF FERTILIZER APPLICATION AND WEEDING ON DRY WEIGHT AND NUTRIENT COMPOSITION OF EAR LEAD OF MAIZE VARIETY TZPB SAMPLED EARLY CROP 1979

Treatments*	Dry Weight** (g)	N	P	K	Ca	Mg	Zn	Mn
No Fertilizer No Weeding	23.8	2.19	0.22	2.35	0.30	0.38	27	62
No Fertilizer + Weeding	31.4	2.23	0.22	2.35	0.36	0.39	32	65
PK + Weeding	33.4	1.96	0.25	2.33	0.40	0.45	26	67
NK + Weeding	30.7	2.60	0.21	1.77	0.36	0.41	22	52
NP + Weeding	38.1	2.90	0.27	1.63	0.51	0.59	33	78
NPK No Weeding	35.7	2.76	0.31	2.05	0.36	0.38	29	62
NPK + Weeding	40.0	2.85	0.26	2.54	0.44	0.47	25	66
LSD 05	10.5	0.35	0.05	0.71	0.10	0.13	8	15

**Average of five leaves
*Fertilizer rate: 120N - 60P - 40K (kg/ha).

Nitrogen, phosphorus and potassium applications increased their percentages in the ear leaves. Without application of these nutrients, their content in the ear leaves were below the critical levels of 2.9% N, 0.25% P and 1.9% K as reported by Jones and Eck (1973). Without weeding the nitrogen percentage was sharply reduced particularly in the no fertilizer treatment. Application of nitrogen, phosphorus and potassium and weeding treatment has no effect on the calcium, magnesium, zinc and maganese status of the ear leaves.

Weed Yield and Nutrient Uptake

The effect of fertilizer application on weed weight, weed composition and nutrient uptake is shown in Table 4. There was no significant effect of fertilizer application on weed weight. However, fertilizer application significantly increased the nitrogen and phosphorus concentrations of the weed. On the other hand, fertilizer application significantly reduced the calcium and magnesium levels in the weeds. There was no effect of fertilizer application on the percentage of the other nutrients.

As shown in Table 4, weeds take up substantial amounts of nitrogen, potassium, calcium and magnesium. Fertilizer application increased the removal of nitrogen, phosphorus and potassium by the weeds.

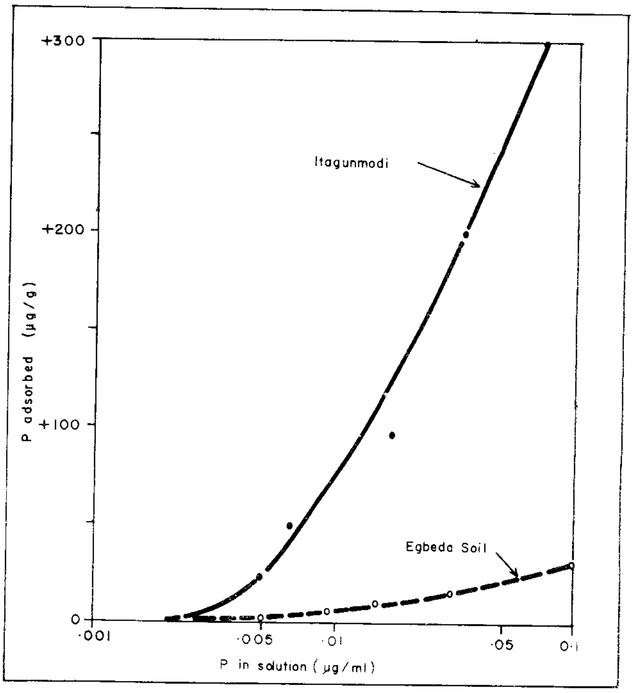

Fig.1 : Phosphate adsorption curves for Itagunmodi and Egbeda Soil series.

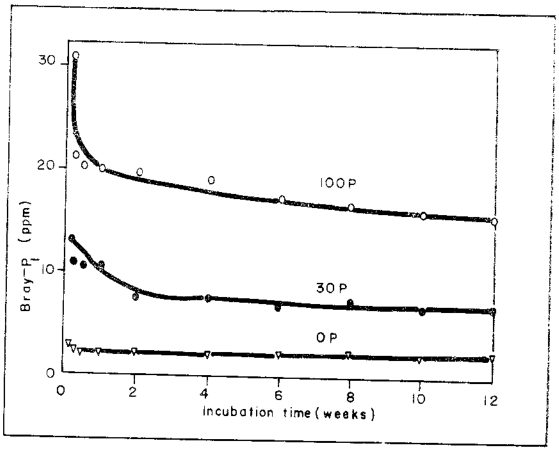

Fig. 2 : Effects of P application and reaction time on the Bray P-1 test values of Itagunmodi Soil series determined under Laboratory conditions. (P rates applied; 30 ppm P (30 P); and 100 ppm P (100 P))

Table 4: EFFECT OF FERTILIZER APPLICATION TO MAIZE ON DRY WEIGHT, NUTRIENT COMPOSITION AND NUTRIENT CONTENT OF WEEDS FROM UNWEEDED TREATMENTS, SAMPLED EARLY CROP 1979.

Treatments*	Dry Weed Weight (Kg/ha)	N	P	K	Ca	Mg	Zn	Mn
				%			(ppm)	
No Fertilizer	1800	1.86	0.18	2.22	0.84	0.60	33	226
+ Fertilizer	1920	2.20	0.21	2.24	0.56	0.52	31	239
LSD 05	478	0.26	0.02	0.21	0.08	0.04	6	94
		Nutrient Content* (kg/ha)						
No Fertilizer		34.0	3.2	40.0	15.1	11.0		
+ Fertilizer		42.2	4.0	43.0	10.8	10.0		

Discussion

In the experimental area there is already a high intensity of cropping. The fallow cycle which consists mainly of mixed fallow of Eupatorium and a variety of shrubs is usually short, 4-5 years. This fallow period appears not to be insufficient to regenerate the needed soil fertility for obtaining high maize yield. Application of nitrogen and phosphorus is needed to obtain high maize yield already in the first year of cropping after a fallow period of 4 years. Potassium is needed in the second year of cropping. This view is depended on the financial value of an increase in yield of 700 kg/ha of maize which was obtained in the first year when K was added to the NP fertilizer. The results of the three years experimentation, clearly indicated that high maize grain yield of about 4.6 tons/ha can be obtained during the first season cropping with adequate fertilization and weeding. Double cropping with early maturing maize variety grown in the second season also yielded reasonably high maize yield of over 2.0 tons/ha.

The trial also showed that the maize crop can effectively compete with weeds at high fertility conditions. This observation confirms the findings of Nieto and Staniforth (1961) and Kang *et al* (1977) for other conditions. With no fertilizer application competition for nitrogen became important as shown by the large removal of nitrogen by the weeds which also resulted in depression of nitrogen status in the maize ear leaf with no weeding.

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