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Sulphur Fertilization Requirements of Southwestern Nigerian Soils

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Abstract

Studies were conducted in the greenhouse and in the field to evaluate the sulphur requirements of maize in selected South Western Nigerian soils.

The internal critical sulphur concentration in maize tissue averaged 0.130%. The values were lower in savanna soils (0.112—0.130%) than in the forest soils (0.173—0.204%). The external critical level of sulphur for optimum growth of maize was found to be 5.9 ppm when soil was extracted with $Ca(H_2PO_4)_2$. The sulphur fertilizer need of South Western Nigerian soils ranged from nil to 15kg/ha. There was an appreciable residual effect of sulphur fertilizer application.

Introduction

For a long time it was believed that, under the existing farming systems and fertilization practices, the level of sulphur in South Western Nigerian Soils was adequate and that the problem of sulphur deficiencies was not a serious one. It was anticipated that the sulphate of ammonia (with 21% S) and ordinary superphosphate (11—13% S) fertilizers commonly recommended for Nigerian soils would provide the sulphur needs of the soils. In recent years, however, Nigerian agriculture has begun to receive some of the sulphur-free, high analysis fertilizers, now being used so widely in temperate agriculture. Observations at various fertilizer depots across South Western Nigeria revealed that the bulk of nitrogen fertilizer supplied during the 1984 planting season was urea which contains no sulphur. The Nitrogen fertilizer plant established by the Federal Government produces only granulated Urea.

The continued use of non-sulphur nitrogen fertilizers would generate sulphur deficiency problem in Nigeria, particularly since rainfall is not a major source of soil sulphur in this country (Bromfield, 1974; Fox *et al.*, 1977). The results of earlier studies in Northern Nigeria (Bromfield, 1972, 1973), South-Eastern Nigeria (Enwezor, 1976) and South-Western Nigeria (Kang and Osiname, 1976; Osiname, 1977; Fox *et al.*, 1977) have indicated that sulphur deficiency exists in some Nigerian soils. However, the degree of the sulphur deficiency as well as parameters for ascertaining the requirements must be determined as the basis for evaluating soil sulphur adequacy status and the sulphur fertilization requirements of soils. It seems, therefore, appropriate that investigations should be conducted to determine the level of soil sulphur required for optimum crop yield and on the sulphur fertilization requirements of crops in the soils.

The present study was conducted to determine the optimum internal and external sulphur requirements of maize, and the sulphur fertilization needs of South Western Nigerian soils.

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Materials and Methods

Bulk samples of soil were collected from five locations in South Western Nigeria, namely, Ede (Egbeda series), Aiyetoro (Agege series), Ile-Ife (Egbeda series), Ibodi (Itagunmodi series), and Okitipupa (Alagba series) representing savanna and forest vegetational zones as well as metamorphic/igneous and sedimentary parent material sources (Table 1). The samples were used in green house studies.

TABLE 1: SOME CHARACTERISTICS OF THE EXPERIMENTAL SOILS.

	pH	Available S	N	CEC	Ca	Mg	K	P	O.M.	Sand	Silt	Clay	Surface absorbed S
		ppm.	%		m.e./100g			ppm	%	%	%	ppm	
EDE	6.6	3.8	0.120	11.5	3.32	1.76	0.39	21.2	1.6	79.2	8.0	12.8	2.0
AIYETORO	6.1	4.5	0.105	10.5	4.95	1.11	0.28	16.2	1.89	56.4	14.0	29.6	0.5
ILE IFE	6.1	5.4	0.116	5.9	3.30	0.39	20.0	2.56	66.8	14.7	18.5	0.6	
IBODI	5.1	9.8	0.140	4.10	1.81	0.96	0.21	3.2	2.93	48.5	16.9	34.6	2.2
OKITIPUPA	5.3	6.2	0.098	3.8	1.82	0.18	0.30	20.4	2.90	73.8	8.7	16.5	2.7

One kg of air dried soil sample was weighed into each pot. Sulphur as $Na_2 SO_4$ was applied in water solution at 7 levels (0, 10, 20, 25, 30, 40, and 50 kg S/ha). The pots were arranged in the green house in a randomised complete block design with 3 replicates to give 105 pots. All treatments received initially 100 ppm N as NH_4NO_3, 50 ppm P as NaH_2PO_4, 60 ppm K as KCl, 10 ppm Mg as $MgCl_2$, 5 ppm Fe as NaFeEDTA, 5 ppm Mn as $MnCl_2$, and 5 ppm Zn as Na_2 Zn EDTA. The nutrients were mixed thoroughly with the soil. The soils were watered to 75% field moisture capacity.

Maize *(zea mays.* L), cultivar FARZ—34, was pregerminated in cottonwool. The seedlings were transplanted at 1 seedling per pot 7 days after planting. The maize plants were harvested 38 days after transplanting, oven dried and ground with Wiley mill. Sulphur content of milled samples was determined turbidimetrically after wet digestion with 1:1 HNO_3; $HClO_4$.

Protein sulphur in the plant samples was determined by extracting the plant material with hot ethanol according to the method of Freney *et al.* (1977). The non-protein sulphur was estimated as the difference between total sulphur and protein sulphur.

A field experiment was also conducted using randomised complete block design with four replicates in three locations, namely, Aiyetoro (Agege series), Ile-Ife (Egbeda series) and Okitipupa (Alagba series). The experiment was established during the rainy and dry seasons of 1984 in all the 3 locations and a third planting was done at Ile-Ife during the rainy season of 1985 to evaluate residual effect of previous sulphur applications.

Maize cultivar, FARZ-34, was planted 30cm apart on ridges of 1 metre apart. Sulphur at the rates of 0, 10, 20, 30 and 40kg/ha as elemental sulphur was applied banded. Each experimental plot received basal dressing of 100kg N/ha as urea, 40kg P/ha as triple-superphosphate and 30kg K/ha as muriate of potash. Maize yield was determined at dry grain stage. Total nitrogen in grain samples was determined by micro kjeldahl method. Sulphur in grain was determined turbidimetrically after wet digestion using a 1:1 mixture of HNO_3 and $HClO_4$.

Soil samples before cropping were air-dried and ground to pass through a 2mm screen for analysis. Available sulphur was determined turbidimetrically after soil samples were extracted with 0.01 M Ca $(H_2PO_4)_2$. Organic matter was determined using the method of Walkley and Black (1934). Total nitrogen was determined by kjeldahl digestion and estimated by using Technicon auto-analyser II. Phosphorous was extracted by Bray I procedure and determined colorimetrically using Molybdenum blue method. pH of the soils was measured in a 1:1 soil — water slurry with a glass electrode. The cation exchange capacity was determined by NH_4+ saturation and NaCl displacement. Exchangeable K, Ca, and Mg were determined in the 1 N NH_4OAC soil extract by flame photometry (K) and atomic absorption spectrophotometer (Ca and Mg).

Particle size analysis of the soils was determined by the hydrometer method (Bouyoucos, 1951) using sodium hexametaphosphate as a dispersing agent

The internal and the external critical levels of sulphur for optimium growth of maize were determined by the procedure described by Cate and Nelson (1965). In addition, the external critical level was confirmed by a mathematical procedure developed by Cate and Nelson (1971).

Results and discussion

Table 1 shows the properties of the experimental sites. The nitrogen content of the soils were low ranging from 0.1% at Okitipupa (Alagba series) to 0.14% at Ibodi (Itagunmodi series). In general, the available phosphorous varied from low to high. It ranged from 3.2 ppm at Ibodi to 21.2 ppm at Ede (Egbeda series). The soils were slightly acid with pH ranging from 5.3 at Okitipupa to 6.6 at Ede. They were light in texture with clay contents ranging from 12.8% to 34.6%. The organic matter contents of the soils were moderate, ranging from 1.6% at Ede to 2.93% at Ibodi with higher values in the forest zone than in the savana. The available sulphur of surface soil (0-15cm) were 3.8, 9.8, 5.4, 4.5 and 6.2 ppm at Ede, Ibodi, Ile-Ife, Aiyetoro and Okitipupa respectively. The surface adsorbed sulphur values were 0.8, 2.2, 0.6, 0.5, and 2.7 ppm at Ede, Ibodi, Ile-Ife, Aiyetoro and Okitipupa respectively.

Deficiency Symptoms In the greenhouse, sulphur deficiency symtoms were observed in the unfertilized Aiyetoro soil 25 days after transplating. A less promnent symptom was detected two days later in Ede soil. Inspite of the prominence of the deficiency symptom observed for Aiyetoro, growth retardation was not as pronounced as was observed for Ede. Sulphur deficiency symptom was not observed in the other soils.

Dry Matter Yield The results of dry matter yield per pot are presented in Table 2. These data suggest that the dry matter yield increased with an increased in level of added sulphur up to a certain level. The level of sulphur where dry matter yield was highest varies with soil. Analysis of variance of the data indicated a significant response to sulphur treatment at Ede (P 0.05), Aiyetoro (P 0.05), Ile-Ife (P 0.05) and Okitipupa (P 0.05), but the response was insignificant at Ibodi (P 0.05). Ibodi (Itagunmodi series) has high native sulphur level (Table 1) which seem to suggest sulphur sufficiency. The yield data were evaluated by plotting percent maximum yield against sulphur fertilization levels, (Fig. 1). The curves indicate that a quadratic relationship exists between dry matter yield and rate of suphur fertilizer application. The good correlation existing between dry matter yield and rate of fertilizer sulphur application is indicated by the high R^2 values (0.954^{**}, 0.855^{**} and 0.986^{**} at Ede, Ile-Ife, Okitipupa and Aiyetoro respectively). The optimum level of fertilizer sulphur to apply were derived from the yield curves (Fig.1) as the values of the sulphur application rate corresponding to 90 percent maximum yield. The optimum fertilizer requirement were found to be 23, 25, 15 and 19kgs/ha at Ede, Aiyetoro, Ile-Ife and Okitipupa respectively. The fertilizer needs appear to be influenced by the native sulphur levels in the soils (see table 1).

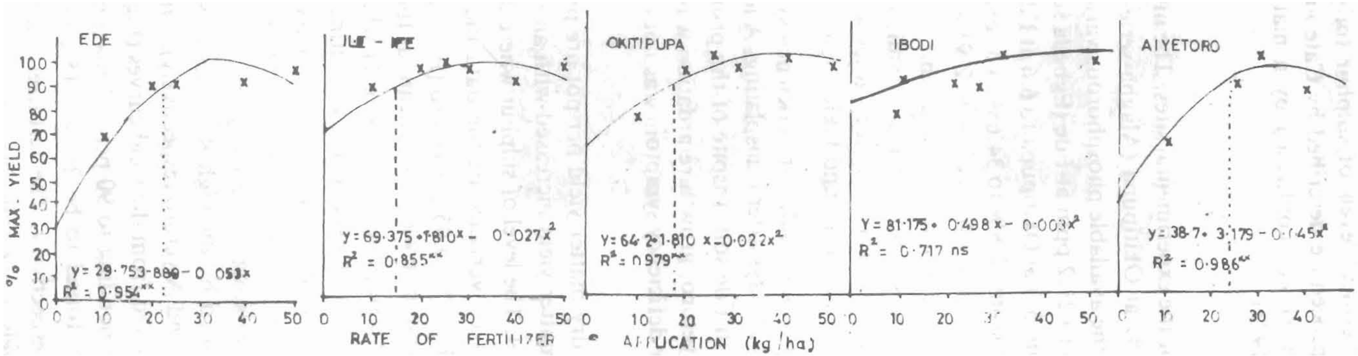


Fig. 1 Relationship between percent maximum yield and rate of fertilizer sulphur application.

TABLE 2: EFFECT OF DIFFERENT LEVELS OF SULPHUR ON DRY MATTER YIELD OF MAIZE PLANT TOP (G/POT) (MEAN OF 3 REPLICATES

RATE	EDE	AIYETORO	ILE-IFE	IBODI	OKITIPUPA
R_0 - 0 (kg/ha)	1.30a	2.62a	3.12a	3.74a	30.02a
R_1 - 10 (kg/ha)	31.51b	4.44b	4.21b	3.99a	3.39a
R_2 - 20 (kg/ha)	34.59c	5.79c	4.56b	4.03ab	4.26b
R_3 - 25 (kg/ha)	4.65c	604cd	4.71b	3.95ab	4.49b
R_4 - 30 (kg/ha)	5.10cd	6.82cd	4.59b	4.59b	4.36b
R_5 - 40 (kg/ha)	.4.67cd	5.87cd	4.27b	4.47b	4.51b
R_6 - 50 (kg/ha)	4.95cd	6.02cd	4.55b	4.47b	4.45b

* Values within columns followed by the same letter are not significantly different at 5% level.

Because fertilizer sulphur substantially improved yields in some of the soils, an increase in the sulphur concentration in the plant tissues resulting from the application of fertilizer sulphur would be expected. This was so in all the soils with the exception of Ibodi (Table 3). It seems that as the rate of sulphur application increases, a point would be reached whereby sulphur will be absorbed by plant in quantities greater than actually needed for plant growth. Sulphur enters plants as sulphate and undergoes metabolic conversion into protein sulphur (Freney *et al.*, 1977). Thus any quantity above that needed to supply sulphate to the metabolic process is stored provisionally as non-protein sulphur (sulphate sulphur). Because the accumulation of sulphate sulphur occurs after sulphur demands for protein have been satisfied, several investigators have proposed that sulphate sulphur is a good indicator of the plant sulphur status (Ulrich, 1943; Jones 1962; Freney *et al.*, 1978).

TABLE 3: EFFECT OF DIFFERENT LEVELS OF SULPHUR ON MEAN SULPHUR CONCENTRATION (%) IN MAIZE (KG/HA.)

Sulphur Rate	EDE	AIYETORO	ILE-IFE	IBODI	OKITIPUPA
R_0 - 0 (kg/ha)	0.093	0.085	0.162	0.202	0.152
R_1 - 10 (kg/ha)	0.105	0.127	0.177	0.205	0.172
R_2 - 20 (kg/ha)	0.112	0.153	0.180	0.205	0.173
R_3 - 25 (kg/ha)	0.130	0.172	0.205	0.212	0.188
R_4 - 30 (kg(ha)	0.137	0.183	0.207	0.213	0.190
R_5 - 40 (kg/ha)	0.143	0.197	0.212	0.213	0.192
R_6 - 50 (kg/ha)	0.144	0.202	0.211	0.217	0.193

The relationship between protein sulphur, non-protein sulphur and total sulphur in maize plant is indicated in Fig. 2. The points at which the sulphur demands for protein synthesis were satisfied are taken as the points of interception of the non-protein sulphur curve and the protein sulphur curve. These points were derived from Fig. 2 as 23.0. 26.0, 20.0 and 21.5 kg/ha of applied sulphur at Ede, Aiyetoro, Ile-Ife

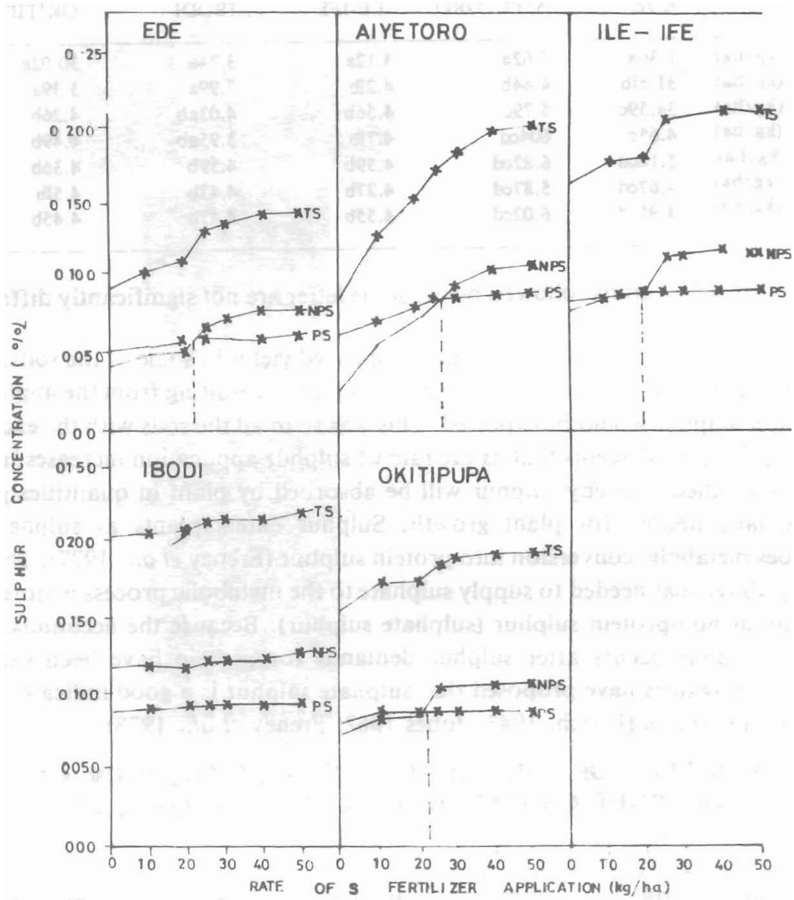


Fig. 2. Effect of different levels of sulphur on the mean sulphur fractions of maize top.

TS – Total sulphur.

PS – Protein sulphur

NPS – Non protein sulphur

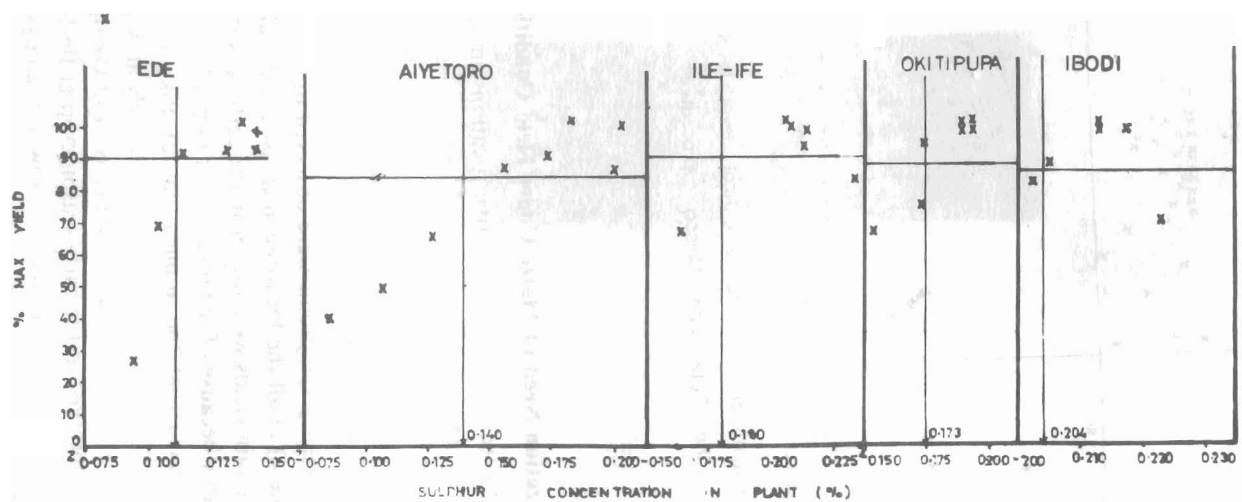


Fig. 3. **Determination of critical level by the Cate and Nelson procedure. Data showing percent maximum yield of maize in relation to sulphur concentration in maize tissue.**

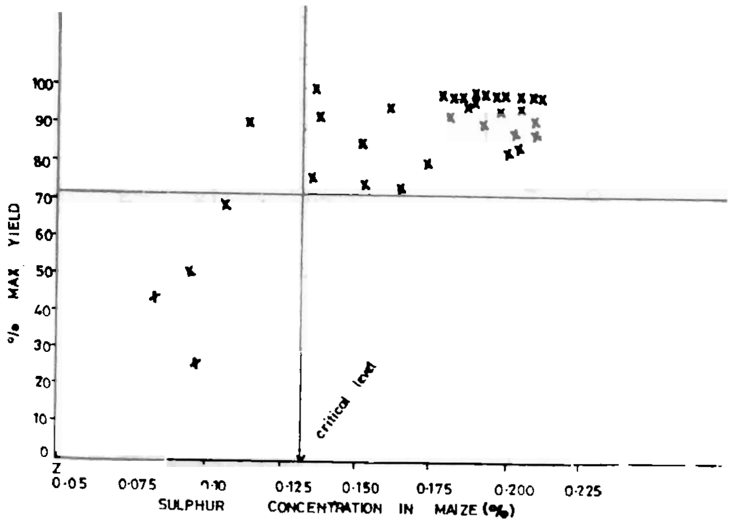


Fig. 4. Detemination of internal critical level level by the Cate and Nelson procedure.

Sulphur Fertilization Need of Maize Under Field Condition:

Field studies were conducted in three of the five locations investigated in the greenhouse viz - Aiyetoro (Agege series), Ile-ife (Egbeda series), and Okitipupa (Alagba series) to determine the nature of sulphur responses of maize that would obtain under field conditions on these different ecologies; and to determine the external critical requirement of sulphur in the field.

Grain Yield No sulpur deficiency symptoms were observed in the three locations. However, grain yield (Table 4) in all the locations increased with sulphur addition for the early season crops. Grain yields were higher in the early season crops than in the late season crops probably because of the insufficient rainfall in the late season. From Table 4, it was estimated that the applications of 10kg/ha and 20kg/ha sulphur resulted in 61 and 91 percent yield increases respectively at Aiyetoro (Agege series); and oly 16 and 23 percent yield increases respectively at Okitipupa. A yield response up to 20kg/ha was observed in the early season crop at Ile-Ife, but only a very slight response was show in the late season crop. However, analysis of variance showed that difference in treatments was only significant for the early season crop ($P \ngtr 0.05$) and not significant in the late season ($P \nless 0.05$). A residual effect of applied sulphur fertilizer was suspected. A third crop at Ile-Ife (Fig. 5) resulted in relatively high grain yield (higher than the yield obtained in the second crop) even though no sulphur fertilizer was applied to this third crop, thus confirming the suspected residual effect.

At Aiyetoro (Agege series) the analysis of variance on yield data indicated significant increase in yield with sulphur addition, up to about 20kg/ha, for the two crops. This may be expected because of the low level of plant available sulphur (4.5 ppm) at Aiyetoro. At Okitipupa (Alagba series), although an increase in yield was observed with sulphur addition, analysis of variance showed this to be insignificant ($P > 0.05$) in both early and late season crops. The non-significant response of maize to fertilizer sulphur at Okitipupa could be due to its relatively high level of available sulphur (6.2 ppm) in the soil.

TABLE 4 — EFFECT OF SULPHUR APPLICATION ON GRAIN YIELD OF MAIZE (kg/ha)

Fertilizer Rate	ILE-IFE			AIYETORO			OKITIPUPA		
	Ist Crop	2nd Crop	Mean	1st Crop	2nd Crop	Mean	1st Crop	2nd Crop	Mean
0 kgS/ha	3206.5a	1517.0a	2361.8a	1740.0a	1716.3a	1728.1a	2203.3a	1771.8	1987.5a
10 kgS/ha	5155.3b	1626.5a	3390.9b	3266.5b	2934.5b	3100.5b	2523.3	1769.5	2146.4a
20 kgS/ha	6124.3c	1447.5a	3785.8c	3364.5c	3164.8b	3264.6c	2709.0	1801.5	2255.3a
30 kgS/ha	5453.8bc	1437.5a	3444.5bc	3498.3c	3112.5b	3305.4d	2454.8	2042.8	2248.8a
40 kgS/ha	5562.0bc	1486.3a	3252.8bc	3444.3c	3212.5b	3328.4d	3485.5	1809.5	2147.5a

* Values followed by the same letter are not significantly different at 5% level.

TABLE 5: CALCULATION OF COEFFICIENT OF DETERMINATION (R^2) AND CRITICAL LEVEL FOR BEST TWO POPULATION SPLIT USING THE 2-MEAN DISCONTINUOUS MODEL.

Last Value of soil S included in population 1	Population 1 Mean Relative yield	Population 1 Corrected sum of squares of deviation from mean (CSS^1)	Population 2 Mean Relative yield	Population 2 Corrected sum of squares of deviation from mean (CSS^2)	Postulated critical level between values	R^2 for postulated critical level
4	48	0	61	1182	4 and 5	0.142
5	53	140	70	354	5 and 6	0.641
6	59	1199	70	9	6 and 7	0,123
7	60	1208	—	—		

Total corrected sum of squares — TCSS = 1377.

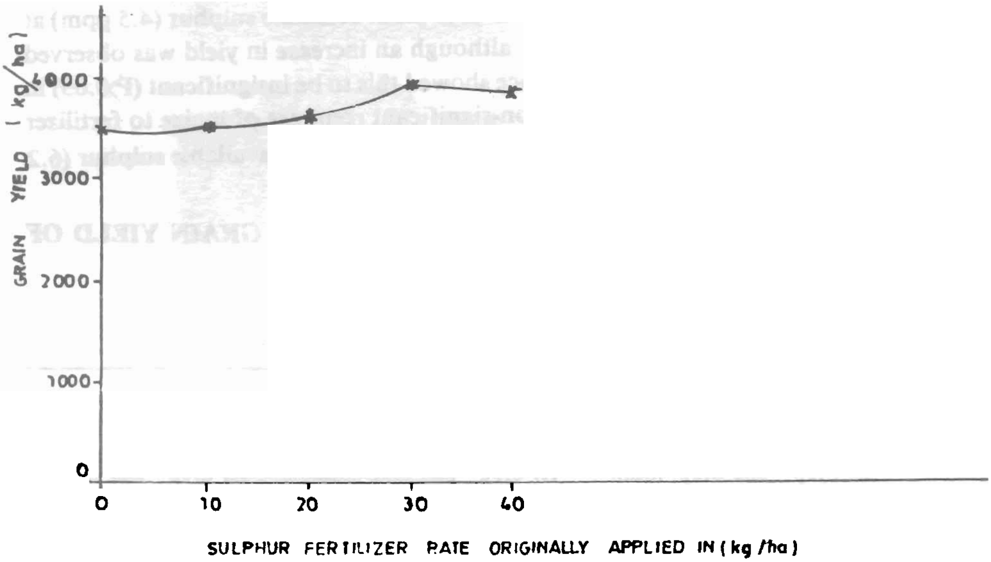
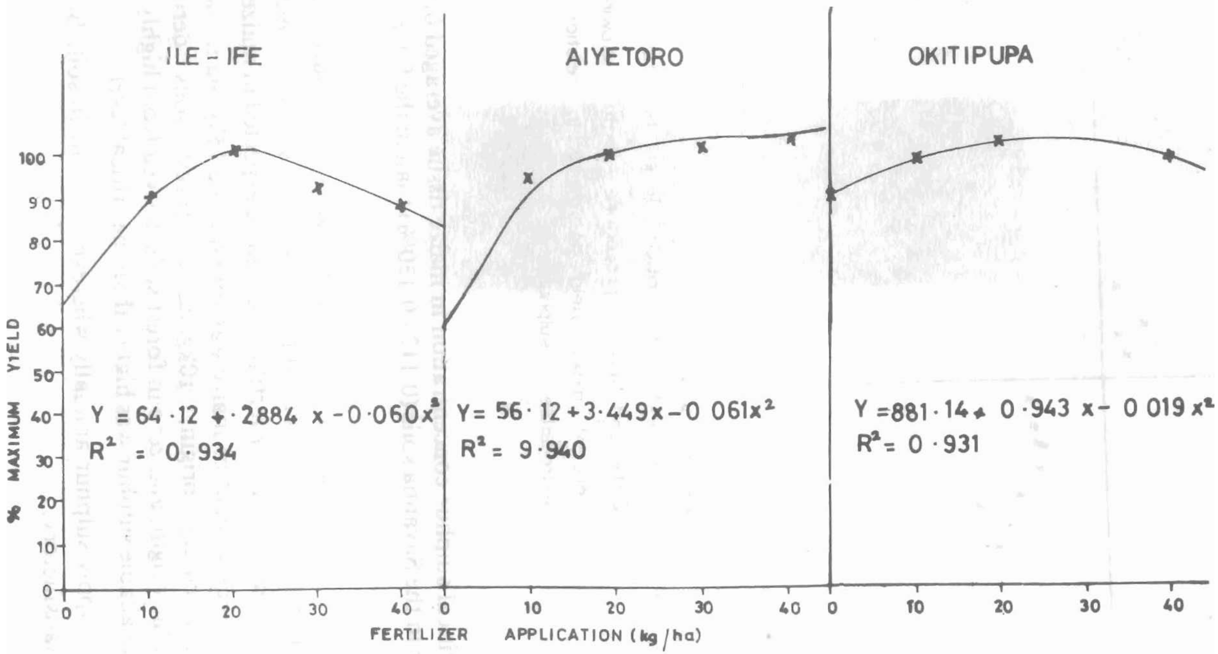


Fig 5. Effect of previous application of sulphur on grain yield of maize at Ile - Ife.

The results from this study show that the extent of response of maize to sulphur fertilizer application depends on the native sulphur levels in the soil.

The level of fertilizer to apply for optimum yield of maize in the three locations were derived from the yield curves as the application rate that achieved 90 percent maximum yield (Fig. 6). The mean of two harvests was used in the construction of the yield curves. The optimum yields were achieved at sulphur applications rates of 10kg/ha at Ile-Ife, and 15kg/ha at Aiyetoro; no sulphur application would be needed at Okitipupa. The external critical sulphur requirement of maize was determined according to the method of Cate and Nelson (1965). The critical level was determined to be 5.9 ppm $Ca(H_2PO_4)_2$ - extractable sulphur (Fig. 7). The critical level was also evaluated by the mathematical method developed by Cate and Nelson (1971). This procedure amounts to splitting the data into two groups using successive tentative critical levels to determine the particular critical level which will maximise the overall predictability (R^2). In this study maximum R^2 was observed between 5 and 6 ppm (Table 5). Therefore, the critical level lies between 5 and 6 ppm. This agrees with the graphical method which placed the critical level at 5.9 ppm. The value is lower than 8.5 ppm reported as critical by Kang and Osiname (1976).



Fig· 6 . Effect of sulphur application on grain yield of maize.

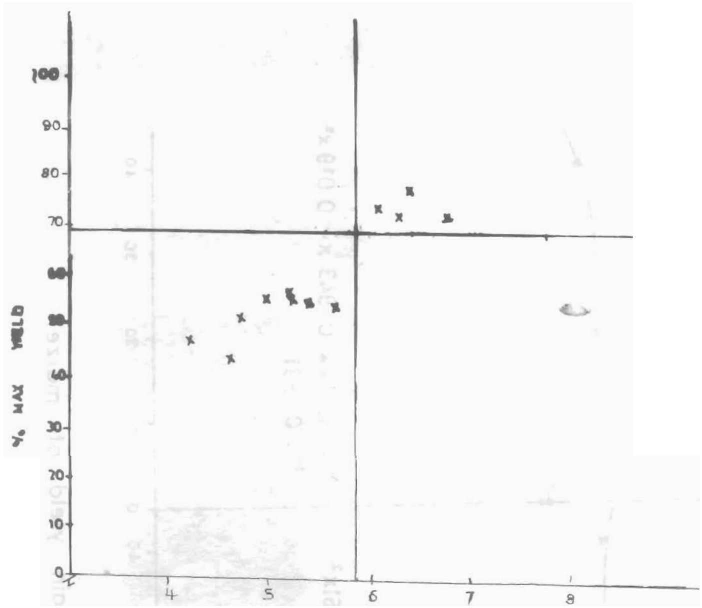


Fig- 7 Determination of critical level by the Cate and Nelson procedure. Data showing percent max. yield of maize in relation to extractable sulphur.

Conclusion

The internal critical sulphur concentration in maize tissue averaged 0.130%. The values were lower in the Savanna soils (0.112 - 0.130%) than in the forest soils (0.173 — 0.204%).

The external critical level of sulphur for optimum growth of maize was found to be 5.9 ppm Ca $(H_2PO_4)_2$ - extractable sulphur. Thus for soil test value above 5.9 ppm, little or no response to sulphur fertilization can be expected in maize (Farz-34).

Sulphur fertilizer requirement of maize was found to be 15kg/ha in Savanna soil derived from sedimentary origin, 10kg/ha in forest soils derived from igneous/metamorphic origin; and zero in forest soils derived from highly weathered sandstone, where available sulphur was higher than the critical level.

not be necessary to apply sulphur annually wherever it is low in soil. Biannual application may be satisfactory.

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