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EFFECT OF SOME BIOLOGICAL FACTORS ON SOIL VARIABILITY IN THE TROPICS

II. EFFECT OF OIL PALM TREE (*ELAEIS GUINENSIS* JACQ.)

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SUMMARY

Soil heterogeneity induced by oil palm trees was investigated in the forest zone of western Nigeria. Surface and subsoil samples taken from adjacent to the palm tree showed lower bulk density, higher soil moisture retention, higher organic matter content and nutrient status than the surrounding soil. Maize plants grown on the palm site soil showed better growth, nutrient status and yield. The palm tree effect on soil productivity could not be blanketed with addition of N, P and K fertilizers because of the effect also of better soil physical conditions. The implication of the palm tree effect on field experimentation in the area was discussed.

INTRODUCTION

Soil variability, particularly on recently cleared land is a major problem in conducting field experimentation in the tropics[3]. In the forested zone of western Nigeria, soil variability on an Alfisol is also shown to be affected by the pre-clearing vegetation[5]. After secondary forest, the soil shows a higher degree of variability in their chemical properties than after thicket or cropping.

One of the major factors which significantly contribute to the chemical variability of the soil under secondary forest vegetation is the presence of oil palm trees (*Elaeis guinensis* Jacq.)[5]. The soil from the oil palm tree sites show higher organic matter and nutrient contents than the adjacent soil. The importance of certain trees in affecting soil variability is also reported in the case of Acacia trees in the dry tropics of Africa[1 2]. Oil palm trees are however, of more importance in the humid tropics where they are found in fertile valleys, in secondary forest and on old farms. In West Africa, the palm trees are most abundant in the zone between the dense evergreen and decidious forest and the open grass savanna. However, when the forest has been cut and is regenerating, the palm trees do not develop well. A survey in western Ghana shows an average of 240 trees/ha in the forest and only 40 trees/ha when the forest had been cut and fallowed[4].

In order to obtain more information on the soil variability due to the palm tree sites and its effect on crop growth and yield, some investigations were carried out, the results of which are reported in this paper.

MATERIALS AND METHODS

Investigation I

This was carried out to determine the physical and chemical soil variability at various distances from the oil palm tree trunk. For this study, four palm trees grown in a secondary forest on a sandy loam Egbeda soil series (Oxic Paleustalf) in the forest zone of western Nigeria were selected. The trees were of unknown age and have an average height of approximately 9 m. From around each tree, composite surface soil (0–15 cm) and subsoil (15–30 cm) samples were collected at distances of 0.25, 0.50, 1.0, 2.0, 3.0 and 4.0 m from the tree trunk. Each of the composite samples consist of four subsamples, all collected in the same way except in four different directions from the tree. The corresponding composite samples from each of the four trees were composited again for soil analysis. For bulk density measurement, undisturbed samples were taken with a core sampler. Soil moisture retention measurements were done using a pressure plate method at 1/3 and 15 atmosphere pressures. Soil pH was measured using glass electrode from a 1:1 soil-water paste. Organic matter content of the soil was determined by wet digestion. Total N was measured using the Kjeldahl method. Extractable P was extracted with Bray No. 1 and measured colorimetrically by molybdenum blue method. Exchangeable K, Ca and Mg were extracted with $1N$ ammonium acetate at pH 7.00. K and Ca were measured with a flame photometer and Mg with atomic absorption spectrophotometer. Soil CEC was measured by summation of the amount of exchangeable cations including exchangeable H and Al.

Investigation II

Greenhouse experiments were carried out to determine the N, P and K responses of maize plants grown on surface soils (0–15 cm) collected from 15 cm wide strips at distances of about 0.5 m and 3 m from around the tree. Two soils were used, Egbeda soil series and Apomu soil series (Psammentic Usthorthent). For each soil series, the experiment was conducted in a complete randomized block design with four replications. Five treatments as shown in Table 3 were compared. N, P and K were applied at rates of 100 ppm N, 100 ppm P and 50 ppm K respectively. One kilogram soil was used per pot. Four maize plants of cultivar TZA × TZB were planted per pot. The plants were harvested at 28 days after planting, and the dry weight determined after drying at 65°C. Soil analysis was conducted using the method described in investigation I. Mechanical soil analysis was done using the the hydrometer method.

Investigation III

To test the effect of the palm tree sites on crop growth, a plot of 32 × 36 m^2 was cleared from secondary forest. The plot was located on an Egbeda soil

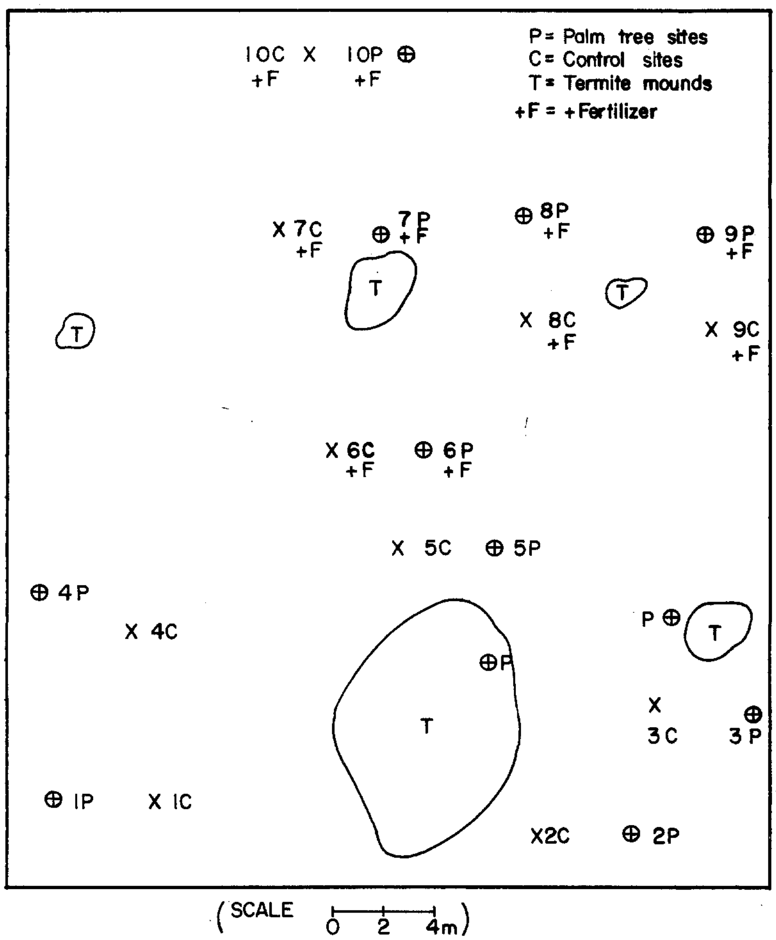

Fig. 1. Distribution of palm tree sites in experimental field plot.

series in the forest zone of western Nigeria. Clearing was done by hand and the vegetation removed from the plot after clearing. The palm tree sites were marked after clearing. Twelve oil palm trees were found inside the cleared area (Fig. 1). Tree heights ranged from approximately 8 to 12 m. After clearing, the land was rototilled and planted with maize cultivar TZA × TZB at a spacing of 75 cm × 25 cm. Three seeds were planted per hill and thinned to one plant at 2 weeks after planting. As shown in Figure 1, ten of the palm tree sites were selected for observation. Five of the sites received fertilizer application at a rate of 120 N– 40 P– 30 K in kg/ha. Ten control sites were also selected at random, 4 m away from the palm tree sites. Five of the control sites were also selected for fertilization at the above mentioned rate. At thinning, five maize plants each were collected from the palm tree and control with and without fertilizer application sites for nutrient analysis. For growth and yield observations five plants each were also selected from the palm and control sites. Plant analysis was carried out after digestion of the plant samples with a mixture of 1 : 1 $HClO_4$:HNO_3. P was measured with a technicon auto-analyzer. K and Ca in solution were measured with a flame photometer. Mg. Fe, Zn and Mn were measured with an atomic absorption spectrophotometer. The tissue N content of a subsample was measured by the micro Kjeldahl digestion method.

Soil moisture measurement of surface samples (0–10 cm depth) collected from the palm tree and control sites were done at 3 or 4 days interval starting from planting to harvesting. Soil moisture content was determined after drying the soil at 105°C. Soil bulk density was measured as in Investigation I.

RESULTS

Investigation I

Results of measurements of some of the physical properties of the surface soil surrounding the palm tree are shown in Table 1. The soil bulk density shows an increase with increasing distance from the tree. At 0.25 m distance from the tree, the soil bulk density is low at 0.61 g/cc, while it more than doubled at 4 m distance from the tree.

TABLE 1

Some physical properties of surface soil (0–15 cm) samples collected at various distances from the palm trees (mean values)

	Distance in m					
	0.25	0.50	1.0	2.0	3.0	4.0
Moisture content 1/3 atm (%)	21.0	16.5	13.3	10.7	10.5	10.6
Moisture content 15 atm (%)	18.5	13.5	9.4	8.0	7.9	7.7
Bulk density (g/cc)	0.61	0.67	1.01	1.00	1.16	1.28

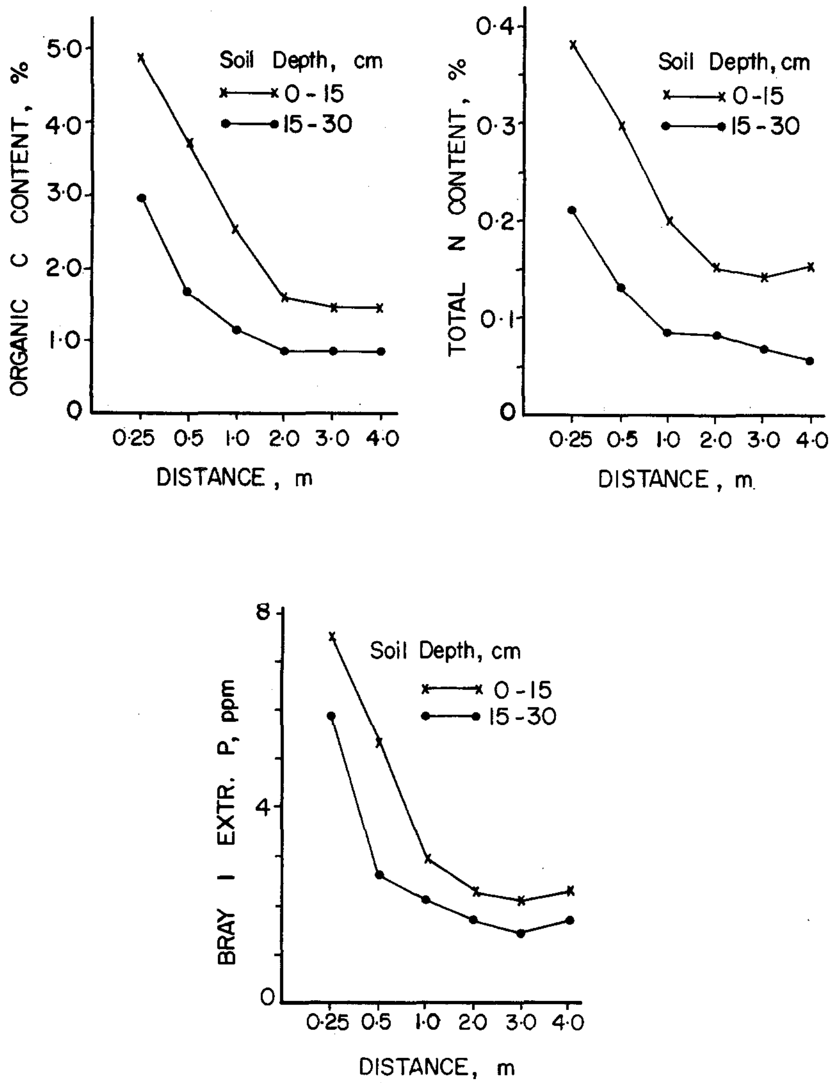

Fig. 2. Organic C, total N and extractable P contents in surface and subsoils at various distances from palm tree.

The bulk density value of 1.28 g/cc observed at 4 m distance from the tree, equals the usual value observed in Egbeda soil under secondary forest conditions. The low bulk density of the soil immediately adjacent to the tree is primarily due to the presence of large amounts of plant debris, mainly consisting of roots and decomposing palm leaf, influorescences and palm nut shells. Associated with the presence of the high amount of organic matter (Figure 2) the soil immediately adjacent to the palm tree up to a distance of 1 m also shows higher water retention both at field capacity and permanent wilting percentage (Table 1) as compared to the soil sampled further away from the tree. Despite the large differences in soil water retention, there are little differences in the amount of available water content.

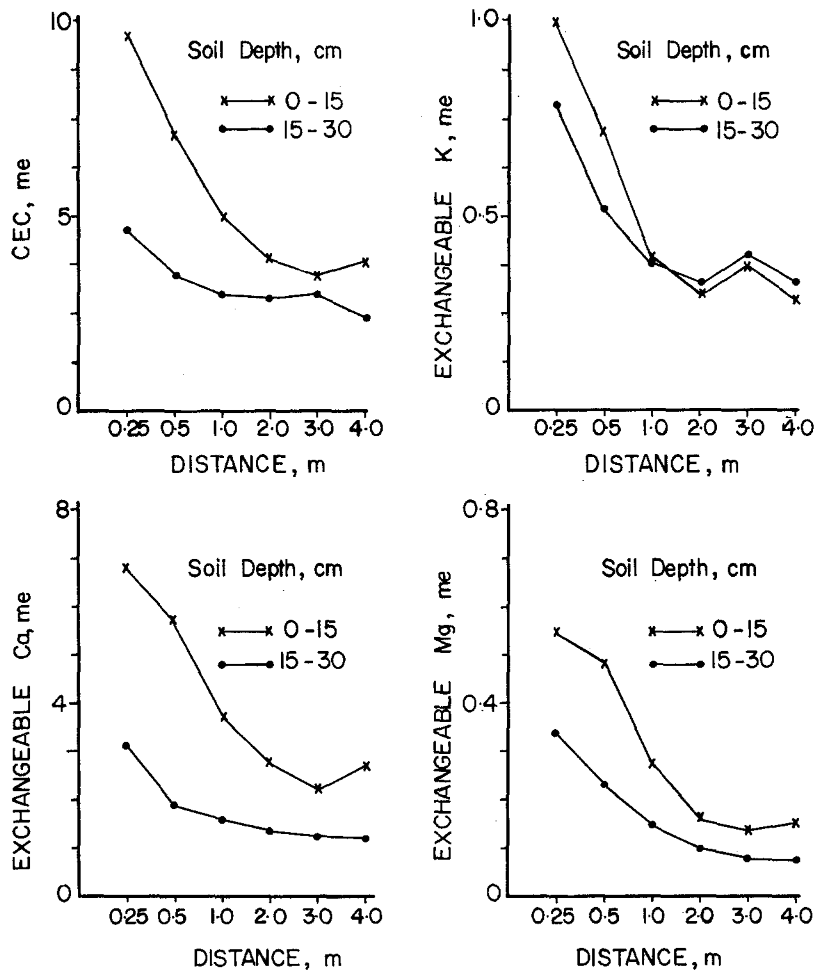

Fig. 3. Soil CEC, exchangeable K, Ca and Mg contents in surface and subsoils at various distances from palm tree.

Data presented in Figure 2, shows the high organic matter content of the soil adjacent to the palm tree. The surface soil at 0.25 m distance from the tree shows an organic C content of 4.8%. The organic C content decreases with increasing distance from the tree and levels off at about 2 m distance to 1.6% C. Despite the generally lower organic C content of the subsoil, the palm tree effect in increasing the organic matter is also noticeable in the subsoil immediately adjacent to the tree. Data on the total N and extractable P contents in the surface and subsoils at various sampling distances from the tree (Fig. 2) also show the same trend as that observed with the soil organic C content.

The palm tree effect on soil CEC is more pronounced on the surface than on the subsoil (Fig. 3). The surface soil at a distance of 0.25 m from the tree shows a CEC of about 10 meq/100 g. The effect on the subsoil CEC is less obvious and is only noticeable within a distance of 0.5 m from the tree. Very significant is the palm tree effect on the amount of exchangeable K in the surface and subsoils immediately adjacent to the tree (Fig. 3). At a distance of 0.25 m from the tree, the amount of exchangeable K in the surface and subsoils are respectively 1.0 meq and 0.85 meq/100 g, these values than level off to about 0.4 meq/100 g at 1 m distance both in the surface and subsoils. The palm tree effects on the exchangeable Ca and Mg in the surface soil are also observed up to a distance of 2 m from the tree (Fig. 3). At 0.25 m distance from the tree, the amounts of exchangeable Ca and Mg are respectively 0.78 and 0.55 meq/100 g, and they level off to respectively 0.30 and 0.15 meq/100 g at a distance of 3 m from the tree. The palm tree effect on the exchangeable Ca and Mg in the subsoil is however less obvious.

Investigation II

The properties of the soils used in investigation II, are shown in Table 2. For convenience of discussion, the soil sampled at 0.5 m distance from the tree is designated as palm site soil. Since beyond the 2 m distance from the tree as seen from the results of Investigation I, there is no distinct palm tree effect, the soil sampled at 3 m distance from the tree can be safely assumed to represent that of the surrounding soil. For this reason, the soil sampled at 3 m distance from the tree is designated as surrounding soil.

Comparing the chemical properties of the sandy loam Egbeda soil

TABLE 2

Characteristics of Egbeda and Apomu surface soil (0–15 cm) sampled at 0.5 m and 3 m distances from palm tree

Mechanical analysis %			pH H_2O	Organic C %	CEC meq/100 g	Exchangeable (meq/100 g					Available P (Bray I) ppm
Sand	Silt	Clay				Ca	Mg	K	Na	Mn	
Egbeda soil 0.5 m strip											
68	18	14	6.2	2.43	13.2	8.7	3.3	0.49	0.10	0.29	2.5
Egbeda soil 3.0 m strip											
72	14	14	6.5	1.33	5.9	4.0	1.3	0.27	0.07	0.13	1.8
Apomu soil 0.5 m strip											
76	12	12	5.7	1.45	6.6	3.2	2.1	0.23	0.06	0.51	17.8
Apomu soil 3.0 m strip											
80	10	10	5.9	0.90	3.9	2.3	0.9	0.15	0.06	0.35	6.3

with that of the loamy sandy Apomu soil, it is apparent that except for the amount of extractable P the Egbeda soil shows a higher nutrient status. Irrespective of the soil series, it is also apparent that the palm soils have higher organic matter contents and are better supplied with nutrients than the surrounding soil. The higher amount of extractable P in the Apomu soil, particularly in the palm site soil may be attributed to the following two factors: (1) the lower P sorption capacity of the Apomu soil, and (2) the traditional custom of land clearing in the area whereby during land preparation for cropping old palm leaves are usually gathered and burned around the tree trunk, thereby enriching the soil with P and other nutrients.

The effects of N, P and K application on the dry matter yield of maize grown on the above soils are shown in Table 3. Maize yield was generally better on the more fertile Egbeda soil. On both soils, maize yields were better on the palm site soils than on the surrounding soils. Relative yield response of fertilizer application were also less on the palm site soils, indicating the better fertility of these soils compared to surrounding soil. On the Apomu soil which shows low contents of organic matter and exchangeable K, the maize grown on both the palm site and surrounding soils responded to applications of N and K. The K response on the low K status Apomu soil is to be expected, since oil palm trees are known to deplete the soil of K[7]. The maize grown on the Egbeda palm site and surrounding soil show only responses to applications of N and P. The response to K application was not significant on the high K status Egbeda soil.

TABLE 3

Effect of NKP application and palm site on dry matter yield of maize (g)

	Apomu soil		Egbeda soil	
	1 m strip	4 m strip	1 m strip	4 m strip
O	4.57 a	2.29 a	7.26 a	5.03 a
NK	6.98 bc	5.39 b	9.80 b	5.48 a
PK	4.03 a	2.15 a	11.55 bc	7.98 b
NP	5.64 b	2.84 a	13.33 c	10.43 c
NPK	7.99 c	6.02 b	14.69 c	11.15 c

* Values within columns followed by the same letter are not significantly different at 5% level according to Duncan's Multiple Range Test

Investigation III

As shown in Figure 1, only ten of the twelve oil palm trees in the cleared plot were used in this investigation. This was due to the fact that two of the palm trees were located close to termite mounds, making them unsuitable for the study.

Data on the nutrient status of two weeks old maize plants from the field trial on the Egbeda soil is shown in Table 4. From the nutrient composition, it is clear that the plants grown on the palm site have significantly higher contents of N, P, K and Mg. However, their contents of Ca, Mn and Fe were significantly lower than those of plants grown in the control treatments with and without fertilizer application. Except for the rather low P content of the maize plants from the control and control +NPK treatments, all other nutrients appear to be adequate. The data also indicate that nutrient effect of the palm site could not be erased by addition of high N, P and K rates.

TABLE 4

Chemical composition of two weeks old maize plants from field trial*

Treatment	%					ppm		
	N	P	K	Ca	Mg	Mn	Fe	Zn
Control	3.67 a	0.29 a	6.42 a	1.10 b	0.32 a	206 b	440 a	50
NPK	3.89 b	0.26 a	6.41 a	1.04 b	0.33 a	205 b	571 b	53
Palm site	4.32 c	0.46 b	9.39 b	0.83 a	0.39 b	118 a	398 a	50
Palm site + NPK	4.79 d	0.47 b	8.70 b	0.73 a	0.41 b	118 a	426 a	57

* Values within column followed by the same letter or no letter are not significantly different at 5% level according to Duncan's Multiple Range Test.

TABLE 5

Effect of palm site and fertilizer application on maize growth and yield per plant

	Control		Palm site	
	No Fert.	+ NPK	No Fert.	+ NPK
Plant height/cm	304 ± 14.0	329 ± 11.2	319 ± 6.5	346 ± 19.3
Grain yield/g	187 ± 45.9	253 ± 58.6	325.7 ± 43.4	371.3 ± 64.1
Stover yield/g	445.3 ± 122.4	633.7 ± 74.3	668 ± 93.5	653.3 ± 2.9

The palm site and fertilizer application effects on maize plant height and yields are shown in Table 5. On the control sites, fertilizer application increased plant height, stover and grain yields. On the palm sites, plant height and yields are higher than those on the control sites without fertilizer application. Addition of fertilizer on the palm sites further increased maize plant height and grain yield.

Data on the surface soil moisture measurement at the palm and control sites during the maize growing period are shown in Figure 4. As expected, the palm site soil shows higher soil moisture retention than the control site soil. This may result in a better soil moisture supply to the plant and also less leaching of the native and applied nutrients. Measurement of soil bulk density at the end of cropping showed an average value of 0.92 g/cc for the palm site and 1.49 g/cc for the control site. Despite the increase in soil bulk density as compared to the values presented in Table 1, the palm site still maintains a low soil bulk density which favours better root development.

DISCUSSION

The experimental results obtained confirm earlier observations[5] on the importance of the oil palm tree sites as a source of soil heterogeneity after clearing secondary forest vegetation in the humid tropics of West Africa.

The enrichment of the surface and subsoils adjacent to the palm site with organic matter and plant nutrients besides being due to the presence of large amounts of decomposing palm tree litter and the traditional practices of concentrated burning as mentioned earlier, occasional addition of some organic matter (usually present in the axil between the tree trunk and the leaf petiole base) when leaves excised, may also take place. Investigation of this organic material

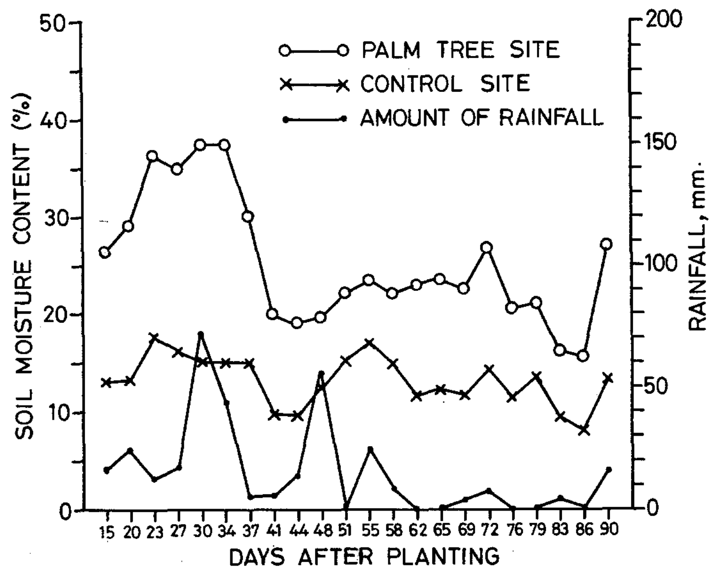

Fig. 4. Total soil moisture content at palm and control sites and total amount of rainfall received during maize cropping period.

also shows a high degree of nitrogenase activity (Ayanaba, personal communication). Since under traditional farming systems in the forest zone of West Africa, palm trees are usually not removed during land clearing for cultivation, as can be seen it plays an important role in nutrient recycling.

However, in agricultural systems where full land clearing is practised, the effect of palm tree sites in field experimentation, particularly on newly cleared land should be considered. Because of the large number of oil palm trees that can be found in certain areas of the humid tropics which may range from 40 to 240 trees per hectare [4 6], the palm site effects cannot be ignored in field experimentation with annual crops in the area. From the observation plot shown in Figure 1, the number of palm trees in the area is estimated at about 100 trees/ha. Assuming that the palm site effect extends to a radius of 2 m around the tree as shown from the results of investigation I, about 7% of the land area will thus be affected. As observed, the palm site effect on soil productivity cannot be blanketed even with the addition of high rates of N, P and K (Table 5), because of the influence also of better soil physical conditions and moisture retention (Figure 4). This can pose some difficulty in obtaining uniform land for breeding and agronomic experiments in the area. Moreover, the palm site effect may persist for a number of seasons of cropping. Ballaux (personal communication) indicated that the palm site effect can still be observed after four maize croppings. It should however also be kept in mind that the degree of soil heterogeneity created by the palm sites will vary with soil types and the age of the oil palm trees.

It also appears that Macrotermes tend to build their mounds adjacent to palm trees (Fig. 1), which only serves to increase soil variability.

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