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RESPONSE OF PLANTAIN TO MULCH ON A TROPICAL ULTISOL. PART I. EFFECT OF DIFFERENT MULCHING MATERIALS ON SOIL PHYSICAL AND CHEMICAL PROPERTIES*

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A b s t r a c t. Field experiments were conducted on an Ultisol near Port Harcourt in south-east Nigeria. The broad objective was to evaluate the response of plantain to mulch. Medium false horn plantain (Musa sp. cv AAB) known locally as 'Agbagba' was used in the trial. The treatments were: elephant grass (Pennisetum purpureum), opaque plastic (black underneath and white at the top) adequately perforated, elephant grass on plastic, plastic on elephant grass, wood shavings, unmulched control. In this paper, we present the effect of the different mulch materials on soil physical (bulk density, temperature, thermal efficiency) and chemical (pH, organic carbon, total nitrogen, Bray-P, cation exchange capacity) properties.

In general, organic mulches (elephant grass and wood shavings) or plastic on elephant grass maintained more favourable soil physical and chemical properties than inert synthetic (plastic) mulch or unmulched control. Comparison between plastic and organic mulches suggests that effect of mulch on soil was both physical and chemical. The results emphasize the beneficial effects of mulching on soil properties under plantain.

INTRODUCTION

Plantains (*Musa sp. cv* AAB) provide an important source of food in many parts of the humid tropics. In addition, plantain production is fast becoming highly commercialised as a result of the new awareness of the potential importance of plantains, both as a cheap food and high income-yielding crops [9,14,31]. The economic and industrial importance of the crop in Nigeria have been highlighted [1,23].

One major constraint in commercial plantain production in tropical Africa is the rapid decline in vigour and yield in the ratoon crops in field-grown plantains [3]. On the other hand, the closely related banana remains productive through many ratoons, even under field conditions [7,34]. Compound-grown plantains also remain productive over many ratoons. The high productivity and longevity of compound-grown plantains compared with their field-grown counterparts have been attributed to regular application of kitchen and other compound wastes, close cultural attention given by the farmers, and to nutrient recycling to the benefit of the compound plantains from deep rooted perennial tree crops inter-

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planted [7,16]. Consequently, compound plantains are grown under more favourable soil conditions than the field-grown crops.

Mulching has been reported to improve soil environment for crop production through its influence on soil physical, chemical and biological properties [2,4,8,11,21,24,25]. Over the years research in various parts of West and Central Africa has shown that plantain responds postively to mulch [6,13,15,17-20,29,30,32-34].

In most of these studies, however, the effects of different mulching materials on properties of the soil under plantain have not been quantified over a long period. In addition, it still remains unclear whether the response of plantain to mulch is due to nutrient or physical changes in the soil induced by mulching.

As part of a detailed study of the response of plantain to mulch on a tropical Ultisol, efffects of different mulching materials on soil physical and chemical properties are evaluated. In an attempt to separate nutrient and physical effects, inert synthetic (plastic) mulch and biological materials (elephant grass and wood shavings) are compared with an unmulched control treatment.

MATERIALS AND METHODS

Location

The experiment was conducted at the International Institute of Tropical Agriculture (IITA) substation at Onne, near Port Harcourt in the high rainfall region of south-east Nigeria (4°51'N, 7°03'E). The climate of this region is humid and supports lowland tropical rainforest vegetation. The mean annual rainfall is about 2 500 mm, generally falling between the beginning of March and November. Rainfall distribution is bimodal (March-July and late August-November). The highest mean monthly temperature occurs between November and April and ranges between 30 to 35°C. The soil of the experimental site is an Ultisol, derived from coastal sediments, and is classified as loamy, siliceous, isohyperthermic, oxic paleudult. Some chemical and physical properties of the 0 to 15 cm depth of the soil are shown in Table 1. The soil consists of 70.1% sand, 5.1% silt and 24.8% clay and has a bulk density of 1.44 g cm^{-3}. The soil is acidic and has a pH (in water) of 4.72. Total acidity and cation exchange capacity are 0.75 and 2.46 meq/100 g, respectively. Organic carbon is 1.21%, total nitrogen is 0.12% and available phosphorus is 125.54 mg kg^{-1}.

Table 1. Some chemical and physical properties of 0-15 cm layer of the experimental soil

Soil property	Value
pH (1:1 H_2O)	4.72
Organic carbon (%)	1.21
Total nitrogen (%)	0.12
Bray-1 phosphorus (mg kg^{-1})	125.54
Cation exchange capacity (meq/100g)	2.46
Total acidity (meq/100 g)	0.75
Exchangeable cations (meq/100 g)	
Calcium	0.62
Magnesium	0.48
Potassium	0.53
Manganese	0.02
Sodium	0.09
Particle size distribution (%)	
Sand	70.1
Silt	5.1
Clay	24.8
Bulk density (g cm^{-3})	1.44

Exchangeable cations range from 0.62 meq/100 g for calcium to 0.02 meq/100 g for manganese. Prior to the present study, which started in August 1986, the field had been left fallow for two years with *Peuraria phaseoloides*. On the 14th of August, the entire field was mowed with a rotary mower. This was done to kill the *Peuraria phaseoloides*. The mowed fallow crop was left as mulch on the field. The dry matter yield of the *Peuraria phaseoloides* was 7.8 t ha^{-1}.

Experimental layout

The experimental layout was a complete randomized block with four replications. Each replicate consisted of six plots, each 19 m by 14 m in area. Treatments were five different mulching materials and a weeded control:

Treatment 1. Unmulched control, the plot was clean weeded with regular spraying with paraquat (1-1^1, dimethyl 4.4^1 bipyridilium ion).

Treatment 2. Elephant grass (*Pennisetum purpureum*) shoot at the rate of 80 t ha^{-1} yr^{-1} fresh weight, giving a layer of 15.5 cm thickness.

Treatment 3. Opaque plastic (black underneath and white at the top) which was adequately perforated.

Treatment 4. Elephant grass shoot (same as in treatment 2) on plastic (same as in treatment 3).

Treatment 5. Plastic (same as in treatment 3) on elephant grass (same as in treatment 2).

Treatment 6. Wood shavings at the rate of 100 t ha^{-1} yr^{-1} giving a layer of 11 cm thickness.

High rates of the organic mulches (elephant grass and wood shavings) were used in order to provide effective ground cover and to stimulate better root and sucker development [30, 34]. Mulch rate of 80 t ha^{-1} yr^{-1} of fresh shoot of *Eupatorium odorantum* or *Pennisetum purpureum* has been used in plantain studies in south-east Nigeria [34]. Some chemical properties of the organic mulches are given in Table 2. Treatments 2 to 6 did not require any weed control. On each plot, 20 clean sword suckers of medium false horn plantain (*Musa op. cv* AAB) called 'Agbagba' locally and 'Libanga Likale' in Central Africa were planted for observation while another 20 suckers were planted as guards. The planting distance was 3 by 2 m. Another 200 suckers were planted as guards for the entire field. Total number of suckers planted for the entire field was 1 208. Fertilizers (N and K) were applied by broadcasting six times at regular intervals over 10-month growing period to give an annual total of 300 kg N ha^{-1} and 550 kg K_2O ha^{-1}. Plastic mulch was removed before fertilizers were applied. Furadan (2,3-dihydro-2,3-dimethyl-7-benzo-furamyl m-methyl carbamate) was applied at six months interval at 3 g active ingredient per plant crop. Cercospora or sigatoka leaf spot attacked the field during the experiment and was controlled by spraying the field with tilt (piopiconazole-1-(2-(2,4 dichlorophenyl)-4-propyl-1,3-dioxalan-2-yl methyl)-1H-1,2,4-triazole). A single follower system was adopted for ratoon crop with only the biggest sucker per mat being allowed to replace the plant or mother crop.

Soil properties measurement

Soil bulk density was measured at 16 and 24 months after planting (MAP) using undisturbed cores (5 cm long and 5 cm internal diameter). Three cores were taken at random from each plot but approximately 1 m from the plants. Samples were taken from 0-10 cm depth at 16 MAP and from 0-10 and 10-20 cm depths at 24 MAP. Soil temperature was measured with bent-stem

Table 2. Some chemical properties of the organic mulches used in the study

Treatment	Total N (%)	Total P	Bases: Ca	Mg	K	Mn	Na
		(mg kg^{-1})					
Elephant grass	2.09	293	394	358	2 308	387	442
Wood shavings	0.33	28	358	76	1 698	102	631

mercury-in-glass soil thermometers installed at the centre of each plot for all replications within plant rows at depths of 5 and 10 cm relative to the soil surface. Diurnal variation of maximum and minimum soil temperature was measured for a period of 12 months (September 1986-August 1987). Soil samples for the determination of chemical properties were taken at 6, 18 and 24 MAP from 0-15 cm depth and from each replicate of each treatment and analyzed. These samples were air-dried and sieved through a 0.5 mm sieve. Soil pH was determined in a water suspension at a 1:1 ratio. Soil samples were analyzed for organic carbon (by Kjeldahl digestion), Bray-1 phosphorus, and for 1N ammonium acetate-extractable potassium, calcium and magnesium. The cation exchange capacity was calculated by the sum of ammonium acetate-exchangeable bases and potassium chloride exchangeable aluminium and hydrogen (acidity).

RESULTS AND DISCUSSION

Bulk density

Soil bulk density measured at 16 MAP was not significantly affected by mulch treatments (Table 3). At 24 MAP, bulk densities of 0-10 and 10-20 cm depths were significantly affected by mulching. In the 0-10 cm depth, bulk density was lowest for plastic on elephant grass treatment and highest for both plastic and elephant grass on plastic treatments. However, only plastic on elephant grass treatment had significantly lower bulk density than the unmulched control; bulk density under the other treatments was not significantly different from the control. Mulching effect on bulk density was not significantly different for elephant grass and plastic on elephant grass treatments (1.28 g cm^{-3} vs. 1.26 g cm^{-3}). In the 10-20 cm depth, bulk density was lowest for elephant grass mulch and highest for elephant grass on plastic mulch. All the other mulch treatments had bulk densities in between.

Soil temperature

Figs 1 and 2 show mean montly maximum soil temperatures (September 1986-August 1987) at 5 and 10 cm depths, respectively. Fig. 2 shows mean monthly minimum soil temperatures at 10 cm depth. For statistical comparison, average temperatures (September 1986-August 1987) at each depth were computed (Table 4). Data presented in Table 4 show that mean monthly maximum and minimum soil temperatures at both 5 and 10 cm depths were statistically affected by mulching. The differences due to mulch treatments were also observed in the month

Table 3. Effect of mulching materials on soil bulk density (g cm^{-3}) of 0-10 and 10-20 cm layers

Treatment	Months after planting (MAP)		
	16	24	24
	0 - 10 cm		10 - 20 cm
Control	1.41 a[1]	1.38 bc	1.50 ab
Elephant grass	1.33 a	1.28 ab	1.47 a
Plastic	1.42 a	1.47 c	1.59 bc
Elephant grass on plastic	1.40 a	1.47 c	1.59 bc
Plastic on elephant grass	1.36 a	1.26	1.52 abc
Wood shavings	1.36 a	1.42 c	1.52 abc

[1] Means followed by the same letter within the same column are not significantly different at the 5% level of Duncan's multiple range test.

Table 4. Mean monthly maximum and minimum soil temperature and thermal efficiency at 5 and 10 cm depths as affected by mulching

Treatment	Temperature* (°C)							
	Max.	Min.	Max.-Min. difference	Thermal efficiency	Max.	Min.	Max.-Min. difference	Thermal efficiency
	5 cm				10 cm			
Unmulched control	33.8 a[1]	28.8 a	5.0	2.57 a	30.3 a	27.0 b	3.3	1.66 ab
Elephant grass	30.3 bc	27.5 b	2.8	1.33 b	28.1 b	26.4 b	1.7	0.85 c
Plastic	31.5 b	27.5 b	4.0	2.01 a	32.4 c	28.3 a	3.7	2.21 a
Elephant grass on plastic	28.6 d	26.9 b	1.7	0.89 b	30.8 a	28.3 a	2.5	1.25 bc
Plastic on elephant grass	29.4 cd	27.3	2.1	1.05 b	30.6 a	28.4 a	2.2	1.18 bc
Wood shavings	28.3 d	27.0 b	1.3	0.73 b	29.6 a	28.5 a	1.1	0.05 c

[1] For explanation see Table 3.
* Average for September 1986 - August 1987.

of occurrence of peak in maximum temperatures at 5 cm depth (Fig. 1). Mean monthly maximum soil temperature at 5 cm depth was highest for the unmulched treatment and lowest for the wood shavings mulch during most of the months. All the other treatments had temperatures in between. The moderation effect of mulch on soil maximum temperatures has also been reported [4,5,10,12,22]. Sudden changes in soil temperature as in unmulched soil can affect the plant roots, especially uptake of water and essential nutrients and biological activities. The peak maximum temperature (38 °C) recorded at the 5 cm depth throughout the period of observation was measured in January 1987 in the unmulched treatment. On the other hand, the peak maximum soil temperature (33.5 °C) under plastic mulch was recorded in April. Compared with the unmulched treatment, elephant grass, plastic, elephant grass on plastic, plastic on elephant grass and wood shavings treatments decreased mean monthly maximum soil temperature at 5 cm depth by 3.5, 2.3, 5.2, 4.4 and 5.5 °C, respectively (Table 4). Throughout the period of observation, mean monthly maximum soil temperature at 10 cm depth was highest under plastic mulch treatment and lowest under elephant grass treatment. Among the mulched treatments, mean montly maximum soil temperatures at 5 and 10 cm depths were higher under plastic mulch than under the other mulches, confirming the lower thermal efficiency of plastic mulch.

Mean monthly minimum soil temperatures at 10 cm was lowest for elephant grass treatment (Fig. 2). Among the other treatments, minimum soil temperatures varied from month to month. Generally, variations in minimum soil temperatures from month to month among treatments were not marked.

Diurnal variations (maximum and minimum) at 5 cm depth among treatments were very marked (Table 4). Data based on average for the period of observation show that diurnal temperature ranges were 5°C for unmulched soil, 2.8 °C for elephant grass mulch, 4.0 °C for plastic, 1.7 °C for elephant grass on plastic, 2.1 °C for plastic on elephant grass and 1.3 °C for wood shavings mulch. At the 10 cm depth, diurnal temperature ranges were 3.3, 1.7, 3.7, 2.5, 2.2 and 1.1 °C for unmulched, elephant grass, plastic, elephant grass on plastic, plastic on elephant grass and wood shavings, respectively. Organic mulch treatments seem to dampen the diurnal wave of soil surface temperature only. Similar observations were

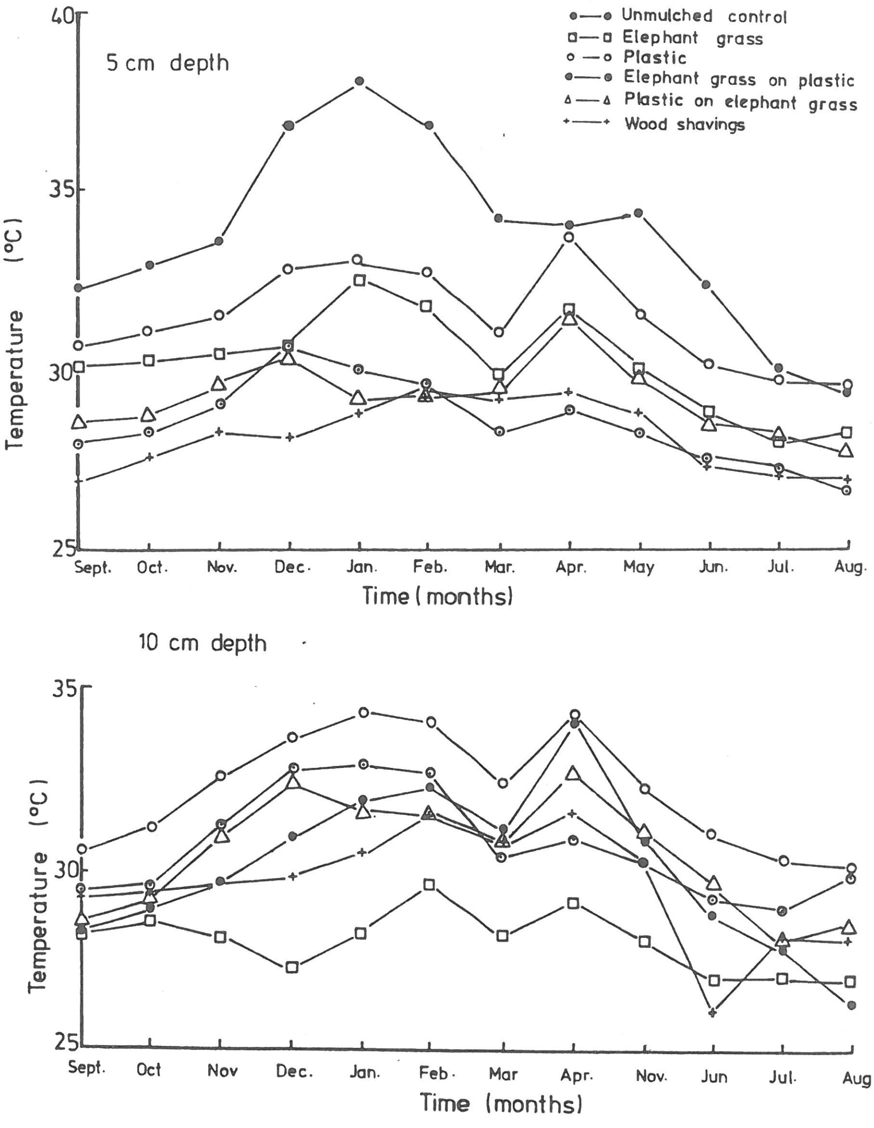

Fig. 1. Variation of mean monthly maximum soil temperature at 5 cm and 10 cm depths for different mulching treatments.

made by Hasson and Hussain under greenhouse condition in aridic region [5].

The effectiveness of a given mulch in reducing temperature fluctuation was evaluated using the 'Stigter's ratio' method [26-28]. Data presented in Table 4 show that mulching with wood shavings, plastic on elephant grass, elephant grass on plastic and elephant grass induced the same temperature fluctuation reduction which was different from that induced by control and plastic at the 5 cm depth. However, at the 10 cm depth, the thermal efficiency induced by elephant grass, wood shavings, elephant grass on plastic and plastic on elephant grass mulches was similar. On the other hand, mulching with elephant grass on plastic, plastic on elephant grass, and the unmulched control also

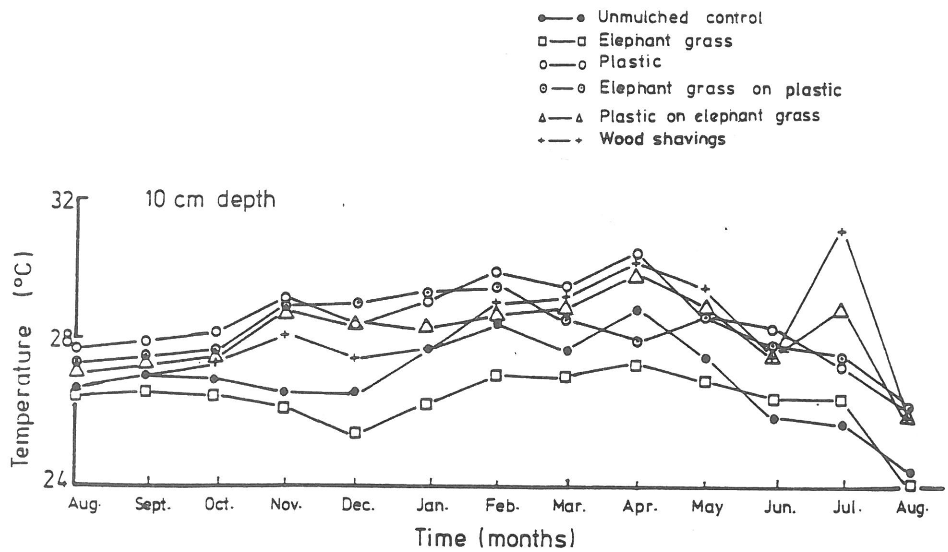

Fig. 2. Variation of mean monthly minimum soil temperature at 10 cm depth for different mulching treatments.

produced similar thermal efficiency, whereas, the temperature fluctuation reduction induced by plastic mulch and the unmulched control was significantly different from the other treatments.

Soil chemical properties

Chemical properties of 0-15 cm depth sampled at 6, 18 and 24 MAP for different treatments are shown in Tables 5, 6 and 7, respectively. At 6 MAP, soil pH was lowest under plastic mulch and highest under wood shavings mulch. However, differences in pH for elephant grass, plastic, elephant grass on plastic, plastic on elephant grass and unmulched treatments were not significant. Similarly, soil pH under unmulched control, elephant grass, elephant grass on plastic, plastic on elephant grass and wood shavings treatments was not significant. Mulch treatments did not affect organic carbon and total nitrogen sampled at 6 MAP. Bray-P, total acidity and cation exchange capacity were higher under elephant grass mulch in comparison with the other mulch treatments. Bray-P was lowest under plastic mulch, total acidity lowest under wood shavings mulch and CEC lowest under plastic on elephant grass treatment. Exchangeable potassium, calcium and magnesium were significantly affected by mulching treatments. Exchangeable K was highest under elephant grass on plastic and lowest under both plastic and unmulched treatments. There was no significant difference in exchangeable K content between elephant grass and elephant grass on plastic treatments (0.39 meq/100 g vs. 0.40 meq/100 g). Exchangeable Ca was highest under wood shavings mulch, while exchangeable Mg was highest under both elephant grass and wood shavings treatments. The high contents of Bray-P and exchangeable K, Ca and Mg as well as the fovourable CEC under elephant grass treatment may be attributed to the favourable nutrient dynamics under the mulch. For example on a kg ha^{-1} basis, elephant grass mulch showed an increase of 31, 70, 6 and 21 per cent in Bray-P, exchangeable K, Ca and Mg, respectively, in relation to the control.

Table 5. Effects of mulching materials on soil chemical properties of 0-15 cm layer sampled at 6 MAP

Treatment	pH	Organic C (%)	Total N (%)	Bray-1 P (mg kg^{-1})	Total acidity (meq/100 g)	CEC (meq/100 g)	Exchangeable cation K (meq/100 g)	Exchangeable cation Ca (meq/100 g)	Exchangeable cation Mg (meq/100 g)
Unmulched control	4.56 ab[1]	1.58 a	0.12 a	107.25 ab	2.10 ab	3.38 ab	0.23 a	0.50 ab	0.39 ab
Elephant grass	4.58 ab	1.43 a	0.12 a	140.43 a	3.95 a	3.95 a	0.39 b	0.53 ab	0.47 b
Plastic	4.15 a	1.48 a	0.11 a	92.80 b	2.94 b	2.94 b	0.23 a	0.44 ab	0.23 a
Elephant grass on plastic	4.45 ab	1.36 a	0.11 a	124.25 ab	3.37 ab	3.37 ab	0.40 b	0.42 a	0.39 ab
Plastic on elephant grass	4.33 ab	1.37 a	0.11 a	112.73 ab	2.89 b	2.89 b	0.28 a	0.37 a	0.34 ab
Wood shavings	4.73 b	1.72 a	0.13 a	114.68 ab	2.97 b	2.97 b	0.25 a	0.63 b	0.47 b

Table 6. Effects of mulching materials on soil chemical properties of 0-15 cm layer sampled at 18 MAP

Treatment	pH	Organic C (%)	Total N (%)	Bray-1 P (mg kg^{-1})	Total acidity (meq/100 g)	CEC (meq/100 g)	Exchangeable cation K (meq/100 g)	Exchangeable cation Ca (meq/100 g)	Exchangeable cation Mg (meq/100 g)
Unmulched control	4.30 ab[1]	1.56 ab	0.14 a	115.50 ab	1.98 ab	0.16 a	0.21 a	0.21 a	0.11 a
Elephant grass	4.43 b	1.83 b	0.15 a	89.73 a	1.98 ab	0.30 b	0.36 b	0.36 b	0.32 b
Plastic	4.20 a	1.40 a	0.12 a	115.03 ab	2.15 a	0.15 a	0.14 a	0.14 a	0.17 a
Elephant grass on plastic	4.45 b	1.61 ab	0.14 a	163.60 c	1.71 a	0.24 ab	0.19 a	0.19 a	0.18 a
Plastic on elephant grass	4.30 ab	1.45 a	0.12 a	119.50 bc	1.92 ab	0.24 ab	0.21 a	0.21 a	0.17 a
Wood shavings	4.50 b	1.66 ab	0.12 a	100.68 a	1.94 ab	0.24 ab	0.36 b	0.36 b	0.18 a

Table 7. Effects of mulching materials on soil chemical properties of 0-15 cm layer sampled at 24 MAP

Treatment	pH	Organic C (%)	Total N (%)	Bray-1 P (mg kg^{-1})	Total acidity (meq/110 g)	CEC (meq/110 g)	Exchangeable cation K (meq/110 g)	Exchangeable cation Ca (meq/110 g)	Exchangeable cation Mg (meq/110 g)	Exchangeable cation Mn (meq/110 g)	Exchangeable cation Na (meq/110 g)
Unmulched control	5.23 a[1]	1.32 a	0.15 ab	50.18 a	1.17 a	2.03 a	0.21 a	0.28 a	0.19 a	0.13 abc	0.22 ab
Elephant grass	5.33 ab	1.89 c	0.19 b	58.68 a	1.28 a	2.88 c	0.28 ab	0.47 bc	0.61 c	0.20 c	0.23 ab
Plastic	5.23 a	1.35 a	0.14 a	49.65 a	1.57 a	2.28 ab	0.16 a	0.19 a	0.15 a	0.01 a	0.21 a
Elephant grass on plastic	5.15 a	1.46 ab	0.14 a	63.95 a	1.48 a	3.02 c	0.37 b	0.34 ab	0.46 bc	0.18 bc	0.28 b
Plastic on elephant grass	5.43 bc	1.50 ab	0.14 a	70.03 a	0.92 a	2.11 a	0.21 a	0.33 a	0.41 b	0.13 bc	0.23 ab
Wood shavings	5.58 c	1.73 bc	0.16 ab	46.28 a	1.31 a	2.68 bc	0.19 a	0.55 c	0.40 b	0.10 ab	0.22 ab

[1] For explanation see Table 3.

At 18 MAP, mulch treatments significantly affected all soil chemical properties except total N content (Table 6). Soil pH decreased under all mulch treatments except for plastic and elephant grass on plastic, when compared with values obtained at 6 MAP. However, soil pH was highest under wood shavings mulch and lowest under plastic mulch. Organic C was highest under elephant grass treatment and lowest under plastic. Bray-P was highest under elephant grass on plastic treatment, while total acidity was highest under plastic treatment. Exchangeable K, Ca and Mg were highest under elephant grass treatment.

At 24 MAP, mulch treatments significantly affected all soil chemical properties measured (Table 7). Soil pH increased by 11, 13, 11, 9, 15 and 18 per cent under control, elephant grass, plastic, elephant grass on plastic, plastic on elephant grass and wood shavings, respectively, in relation to the initial pH of the experimental soil. Organic C and total N were higher under organic mulches (elephant grass and wood shavings), in comparison with the other treatments. Organic C and total N (on kg ha^{-1} basis) increased by 9 and 25 per cent for control, 56 and 58 per cent for elephant grass, 12 and 17 per cent for plastic, 21 and 17 per cent for elephant grass on plastic, 24 and 17 per cent for plastic on elephant grass, 43 and 33 per cent for wood shavings when compared with the initial organic C and total N contents of the experimental soil. The high contents of organic C and total N under wood shavings and elephant grass mulches may be attributed to nutrient addition from the mulches (Table 2). In comparison with values obtained at 18 MAP (Table 6), Bray-P and total acidity measured at 24 MAP decreased appreciably. Exchangeable Ca and K decreased under all treatments in relation to initial soil contents. Exchangeable Mg decreased under all treatments except under elephant grass mulch, when compared with the initial Mg content of the soil.

CONCLUSIONS

1. Elephant grass, plastic on elephant grass and wood shavings mulches significantly decreased soil bulk density in the 0-10 cm depth, measured at 24 MAP.
2. Mean monthly maximum and minimum soil temperatures were more favourable under elephant grass mulch than under all other mulch treatments and the control.
3. Diurnal variations of soil temperature were more pronounced at 5 cm than at 10 cm depth, especially for unmulched plots.
4. At 5 cm depth, wood shavings, plastic on elephant grass, elephant grass on plastic and elephant grass mulches induced similar thermal efficiency which was different from control and plastic mulch Thermal efficiency was best under wood shavings and elephant grass mulches at 5 and 10 cm depths respectively, in relation to the other treatments.
5. Soil pH, organic carbon, total nitrogen and exchangeable potassium, calcium and magnesium were generally more favourable under elephant grass and wood shavings mulches than under all the other types of mulch.
6. Increase in soil pH due to mulching was more pronounced at 24 MAP than at 6 and 18 MAP.
7. In general, organic mulches (elephant grass and wood shavings) maintained more favourable soil physical and chemical properties than inert synthetic (plastic) mulch.
8. Comparison between plastic and organic mulches suggests that effects of mulch are both physical and chemical.

REFERENCES

1. **Adeyemi S.A.O., Ogazi P.O.**: Fruit and vegetable processing. Seminar on Agro-based Industrialization ASCON, Badagry, Lagos, 1983.
2. **Agboola A.A., Fayemi A.A.**: Effect of soil management on corn yield and soil nutrients in rain forest zone of Western Nigeria. Agron. J., 64, 641-644, 1972.
3. **Braide J., Wilson G.F.**: Plantain decline: a look at possible causes. Paradisiaca, 4, 3-7, 1980.

4. **Fasheun A.**: Soil temperature management for optimal seedling emergence in A. esculentus and C. olitorius. Int. Agrophysics, 4, 333-338, 1988.
5. **Hasson A.M., Hussain R.**: Effect of polyethylene mulch on soil temperature variation under planted green house in aridic region. Solar and Wind Technology, 4, 459-465, 1987.
6. IITA. (International Institute of Tropical Agriculture): Annual Report for 1980. Ibadan, Nigeria, 44-48, 1981.
7. IITA. (International Institute of Tropical Agriculture): Annual Report for 1982. Ibadan, Nigeria, 162-163, 1983.
8. **Juo A.S.R., Lal R.**: The effect of fallow and continuous cultivation on the chemical and physical properties of an Alfisol in Western Nigeria. Plant Soil, 47, 567-584, 1977.
9. **Karikari S.K., Amankwah K.A.**: The effect of sucker size on growth and development of banana (Musa ABB group). Acta Hortic., 53, 341-347, 1977.
10. **Lal R., Hahn S.K.**: Effects of methods of seedbed preparation, mulching and time of planting on yam in Western Nigeria. Sym. Proc. Int. Soc. Trop. Root Crops. IITA, Ibadan, Nigeria, 2-17 December, 1973.
11. **Lal R., Kang B.T.**: Management of organic matter in the tropics. 11th Cong. ISSS, New Delhi, 3, 152-178, 1982.
12. **Maduakor H.O., Lal R., Opara-Nadi O.A.**: Effects of methods of seedbed preparation and mulching on the growth and yield of white yam (Dioscorea rotundata) on an Ultisol in south-east Nigeria. Field Crops Res., 9, 119-130, 1984.
13. **Mbumba N.**: Mulching plantains with water hyacinth. Proc. Annual Meeting of West African Regional Cooperative for Research on Plantains. IITA, Ibadan, Nigeria, December 5-9, 1983.
14. **Ndubizu T.O.C., Obiefuna J.C.**: Upgrading inferior plantain propagation material through dry-season nursery. Scientia Hortic., 18, 31-37, 1982.
15. **Ndubizu T.O.C., Okafor E.I.**: Growth and yield patterns of Nigeria plantains. Fruits, 11, 672-677, 1976.
16. **Nweke F.L., Njoku J.E., Wilson G.F.**: Productivity and limitations of plantain (Musa AAB) production in compound gardens of south-east Nigeria. Fruits, 43, 161-166, 1988.
17. **Obiefuna J.C.**: Effect of propagule type and depth of planting on the yield decline of plantains (Musa AAB) in the rain forest belt of Nigeria. Trop. Agric. Trinidad, 60, 107-110, 1983 a.
18. **Obiefuna J.C.**: The effect of sawdust mulch and increasing levels of nitrogen on the growth and yield of plantain (Musa AAB). Proc. Annual Meeting of West African Regional Cooperative for Research on Plantains. IITA, Ibadan, December 5-9, 1983 b.
19. **Obiefuna J.C.**: The effect of monthly planting on yield pattern and yield decline of plantains (Musa AAB). Scientia Hortic., 29, 47-54, 1986 a.
20. **Obiefuna J.C.**: Crop wastes and plantain (Musa AAB) production in the tropical rain forest of Nigeria. 8th Ann. Conf. of Hortic. Soc. of Nigeria. NIHORT, Ibadan. November 9-15, 1986 b.
21. **Ojeniyi S., Agbede O.**: Soil organic matter and yield of forest and tree crops. Plant Soil, 57, 61-67, 1980.
22. **Okigbo B.N.**: Effects of pre-planting cultivation and mulching on the yield and performance of cassava (Manihot esculenta). In: Soil Tillage and Crop Production (ed. R. Lal). IITA Proc. Series 2, 75-92, 1979.
23. **Olayide S.O., Olatunbosun D., Idusogie E.O., Abiagom J.D.**: A quantitative analysis of food requirements, supplies and demand in Nigeria, 1965-1985. Federal Dept. Agric., Lagos, 1972.
24. **Opara-Nadi O.A., Lal R.**: Influence of method of mulch application on growth and yield of tropical root crops in southeastern Nigeria. Soil Tillage Res., 9, 217-230, 1987 a.
25. **Opara-Nadi O.A., Lal R.**: Effects of no-till and disc plowing with and without residue mulch on tropical root crops in southeastern Nigeria. Soil Tillage Res., 9, 231-230, 1987 b.
26. **Stigter C.J.**: Mulching as a traditional method of microclimate management. Arch. Met. Geoph. Biocl., Ser. B 35, 147-154, 1984 a.
27. **Stigter C.J.**: Examples of mulch use in microclimate management by traditional farmers in Tanzania. Agric. Ecosyst. Environ., 11, 173-176, 1984 b.
28. **Stigter C.J.**: Research methodology to quantify and understand the modification of the energy flux at soil/atmosphere interfaces. Int. Colloq. on Energy Flux at the Soil/Atmosphere Interface. ICTP, Trieste, 5-10 May, 1985.
29. **Swennen R.**: A physiological study of the sucker behaviour in plantain (Musa AAB). Agric. Dissert. KUL, Leuven, 1984.
30. **Swennen R., Wilson G.F.**: Flamingia congesta as a live cover plant for plantain. Banana News Letter, 8, 17, 1985.
31. **Wilson G.F.**: Research on plantain in the cropping systems of humid tropics. Fruits, 31, 517-519, 1976.
32. **Wilson G.F.**: Status of bananas and plantains in West Africa. Scientia Hortic., 28, 29-35, 1986.
33. **Wilson G.F., Swennen R.**: Effects of plastic mulch on plantain. IITA Resource and Crop Management Program. Annual Report , 108-109, 1986.
34. **Wilson G.F., Swennen R., De Lange E.**: Effects of mulch and fertilizer on yield and longevity of a medium and giant plantain and a banana cultivar. Int. Assoc. for Research on Plantains and Bananas. Proc. 3rd Meeting, Abidjan, 27-31 May, 1985.