Tillage, seed bed configuration and mulching: effects on soil physical properties, and responses of cassava, cowpea and maize

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Abstract

The influence of tillage, and 2 seed bed configurations on soil physical properties and responses of cassava *(Manihot esculenta)*, cowpea *(Vignia unguiculata* L. Walp), and maize *(Zea mays* L.) was studied for two cropping seasons in 1978 under mulch and no-mulch conditions. The study was conducted on an Alfisol at the Ife (Nigeria) University teaching and Research Farm.

Tillage reduced soil bulk density at planting (1.43 g/cc) by 23%. Six weeks after seeding, the bulk density of ridges and mounds had increased by 24% compared to 3.5% increase for no-tillage plots under bare condition. Mulching reduced soil compaction of tilled plots by 50% while compaction was negligible on the mulched no-tillage plots.

Soil moisture reserve, 3 weeks after planting was higher by 5 and 8 per cent (of cummulative rainfall) respectively for no-tillage and ridged plots compared to mounds under unmulched conditions. In the same correspondent order soil temperature was, respectively, lower by 3°C and 1°C sthan in mounds during the period. Mulch effect on soil moisture and temperature was more significant with no-tillage compared to ridges and mounds.

Yield of cassava was reduced by only 13% when grown with no-tillage plus mulch, compared to 40% with no-tillage without mulch. There was no significant effect of tillage on cowpea yield. Yield results reflected differences in soil moisture and temperature regimes which influenced seedling germination, stand and subsequent plant development.

Introduction

In recent years, a number of comparative tillage studies has shown an increasing trend toward less tillage in seed bed preparation due to its numerous merits over the conventional tillage involving plowing and harrowing. Some of the advantages claimed for zero- or mulch-tillage for example, include protection of the soil by a mulch cover, decreased soil erosion, improved plant available water, nutrients and crop yields and savings in labor (Baumer and Bakermans, 1973). Although most of the information have resulted from tillage studies in the temperature regions (Jones *et al,* 1968; Shear and Moschler, 1969; Van Doren, 1973; Van Doren *et al,* 1976), mulch tillage may have similar merits under tropical conditions (Kannegieter, 1968; Lal, 1974a; Lal,1974b), considering the high susceptibility of tropical soils to erosion and rapid deterioration under continuous conventional cultivation (FAO, 1974; Lal, 1976). In Nigeria, planting on ridges, mounds and occasionally on flat cultivated land are used uncritically by farmers as standard procedures in annual crop husbandry. Information on the influence of tillage and the traditional practices on Nigerian soils and crops is very limited. Although some attempts have been made to establish the information on few soils and crops (Ezedinma, 1964; Kowal and Stockinger, 1963; Lal, 1973; Nangju, 1977), comparisons of such studies have shown much variability from study to study.

This study was conducted to determine the effects of no-tillage, ridge and mound bed configurations, with and without crop residue mulch on soil and responses of cassava, cowpea and maize on an Oba soil in Western Nigeria.

Materials and methods

The study was conducted over two cropping seasons in 1978 at the Ife (Nigeria) University Teaching and Research Farm. "FARZ 27". maize *(Zea mays* L.), "Ife Brown" cowpea *(Vignia unguiculata* L. Walp) and cassava *(Manihot esculenta)* "Isunikankiyan" were grown under mulched and unmulched conditions, with the following treatments:

(i) No-tillage in which seeds were planted in unplowed flat land;
(ii) Traditional tillage with manually prepared ridges, 40 cm high, 45 cm wide with a l-m row spacing, and
(iii) Tillage with manually prepared mounds (hills) 40 cm high, with 45 cm base width and 100- and 50-cm between- and within-row spacings, respectively.

Soil of the study area was Oba soil which is classified as an Alfisol (Harpstead, 1973). It is a well drained soil derived from biotite gneiss with a sandy loam texture in the surface, a sandy clay subsoil (15-30 cm) and a gravel horizon at about 25 cm depth. The soil was on 8% slope and previously in a 15-year bush fallow.

TABLE 1: SOME PHYSICAL AND CHEMICAL PROPERTIES OF OBA SOIL (0-15 cm)[1]

Property	Start of rotation	End of rotation						LSD (0.05)
		Mulch			No-mulch			
		NT	R	M	NT	R	M[2]	
Sand-%	64.9	66.2	66.8	67.2	67.3	70.7	69.4	6.8
Clay-%	17.5	17.0	17.6	16.6	17.7	15.8	16.5	3.6
Silt-%	17.6	16.8	15.6	16.2	15.0	13.5	14.1	3.4
Available water (gg^{-1})	.102	.098	.095	.092	.093	.087	.088	.016
Water stable aggregates 2.36 mm (%)	92	89	79	76	71	62	67	6.0
Aggregate instability-N^{-1}	.037	.040	.051	.049	.050	.058	.056	.005
p^H (Cacl$_2$)	6.0	5.8	5.4	5.3	5.2	5.1	5.2	0.6
Organic carbon-%	2.16	1.96	1.70	1.68	1.75	1.62	1.59	0.12

1 Each value is the average of values obtained under the three different crops of each treatment

2 No-tillage (NT), Ridge (R), Mound (M).

Plots were 5m by 10m and arranged in a randomized complete block design with three replications. The mulched plots received about 25 kg plant residue each as surface mulch at planting.

First season planting was done on 26 April for cassava, cowpea and maize. The same cultivars of cowpea and maize were again planted on 7 September for the second season. Being perennial, only one annual crop of cassava was grown. The previous season ridges and mounds were loosened with a hand hoe for the second season planting. Plant spacings of 1 x 1m for cassava and 1m x 50cm for maize and cowpea reflected inevitably those of the mounds. Fertilizer was applied by side-banding, four weeks after planting at rates of 120 kg N, 30 kg P and 40 kg K per ha for maize plots and 40 kg N, 30 kg K per ha for cowpea plots. Cassava plots did not receive any fertilizer. Weeds and insect pests were adequately controlled during the growing periods.

Soil bulk density and gravimetric moisture content were measured in the 0-15 cm depth layer at one week intervals, using a core sampler. Soil temperature was measured daily at 8 a.m., 12 noon and 3 p.m. using bent-stem soil thermometers installed at 5 cm depth. Periodic determinations of porosity from porosity - particle density relations, per cent aggregation by the wet sieving technique (Kemper, 1965) and aggregate stability (Bruce-Okine and Lal, 1975) were made. Composite samples from the 0-15 cm were taken at the beginning and end of each season and analysed for particle size distribution (Day, 1965), pH (potentiometrically in 0.01M $CaCl_2$), organic carbon by the Walkey-Black method (Allison, 1965), Bray-1 P, nitrate nitrogen and cation exchange capacity (Jackson, 1958).

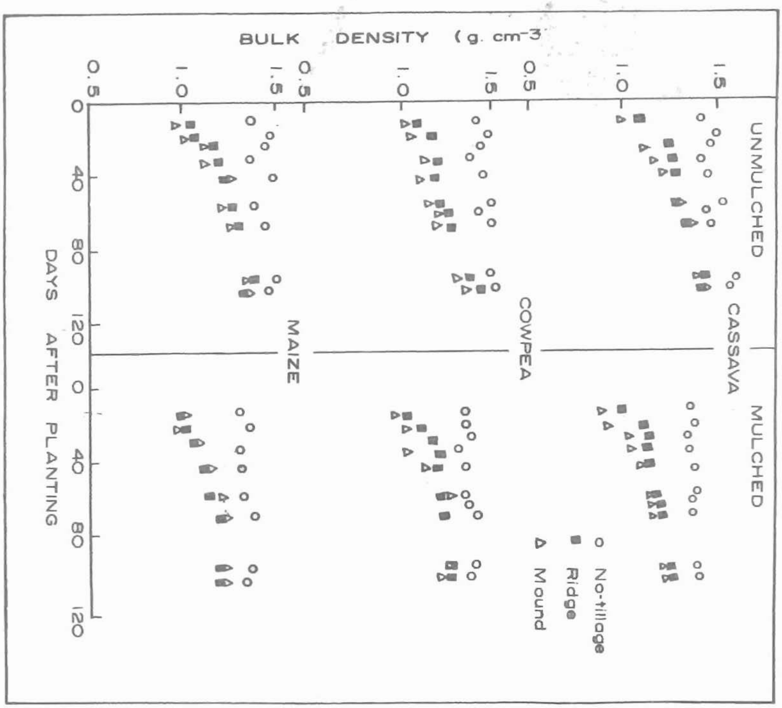
Observations on plant responses included determinations of seedling emergence and stand and weekly plant height until flowering.

Results

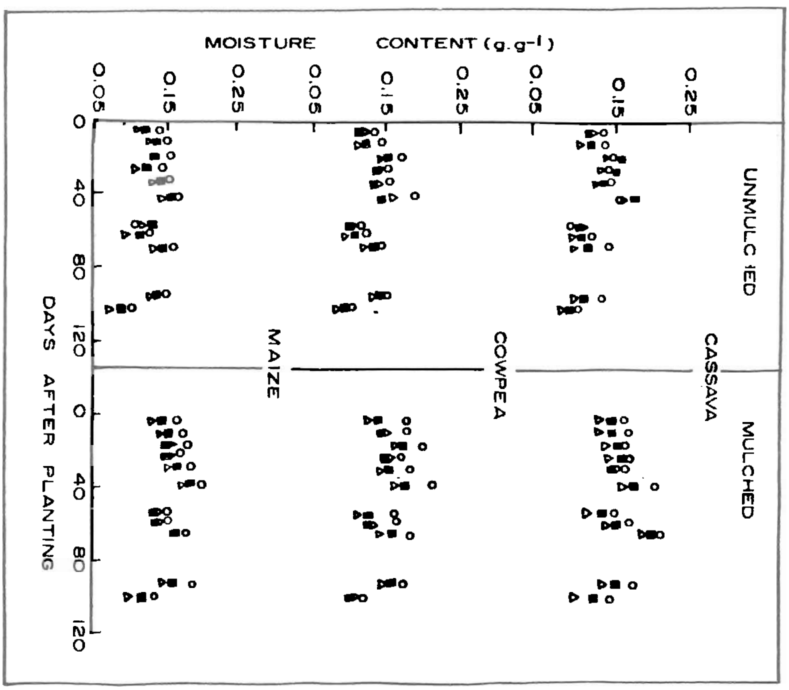
Soil bulk density

Changes in soil bulk density under the different treatments in the first season are illustrated in Fig. 1. Average bulk density at seeding was 1.43 g/cc for no-tillage plots, 1.14 and 1.12 g/cc for plots with ridge and mound configurations, respectively. Thereafter, all treatments showed appreciable increases in bulk density due to compaction. Rate of soil compaction was highest during a period of six weeks after planting in the first season (compared with other periods in the first and second seasons) when rainfall was highest both in amount and intensity. Bulk density of unmulched ridges and mounds increased respectively at the rates of about 0.0071 and 0.0093 g/cc per cm rain during this period. Soil compaction at the end of this period had increased the bulk density of unmulched ridges and mounds by 24% compared with 3.5% increase on unmulched no-tillage plots. Increases in bulk density at the end of the season were 0.08, 0.28 and 0.29 g/cc for no-tillage, ridges and mounds, respectively in the first season. The increases in the correspondent order were 0.04, 0.36 and 0.35 g/cc in the second season.

Mulching appeared to eliminate compaction on no-tillage plots and reduced the compaction of ridges and mounds by as much as 50% in the first season (Fig. 1) and 40% in the second season.



1. Soil bulk density (0 - 15cm) as influenced by tillage, seedbed configuration and mulch, under different crops.



2. Effects of tillage, seedbed configuration and mulching on soil moisture storage

A rotation of cowpea-cowpea was more effective in retarding the return of tilled soil to equilibrium bulk density condition compared to maize-maize and cassava rotations (Fig. 1). Soil bulk density values under cassava and maize, 6 weeks after planting, were respectively 4 and 9 per cent higher than that under cowpea for unmulched ridges and mounds.

Soil moisture storage

No-tillage plots had higher moisture storage in the 0-15 cm depth compared to ridges and mounds (Fig. 2). Under bare conditions, moisture reserve, three weeks after planting in the first season was 22, 17 and 14 per cent of the cummulative rainfall for no-tillage, ridges and mounds, respectively. The result was the reverse in the second season with lower precipitation amount, and lower and less fluctuating soil temperature than the first season. There was no significant difference in moisture reserve between ridges and mounds.

Mulching significantly improved soil moisture storage in all the treatments (Fig. 2). Differences in soil moisture content between mulched and unmulched plots were as high as 6% in the first season. The effect of mulch on soil moisture conservation was more significant with no-tillage than ridges and mounds. Soil moisture contents averaged 19.2, 16.6 and 14.5 percent for mulched no-tillage, ridge and mound treatments, respectively in the first season. In the second season the differences in soil moisture between mulched and unmulched treatments were only significant in the first 60 days after planting, that is, before a long rainless period. Soil moisture content in the 0-15 cm depth averaged 6.8% by the end of the second season.

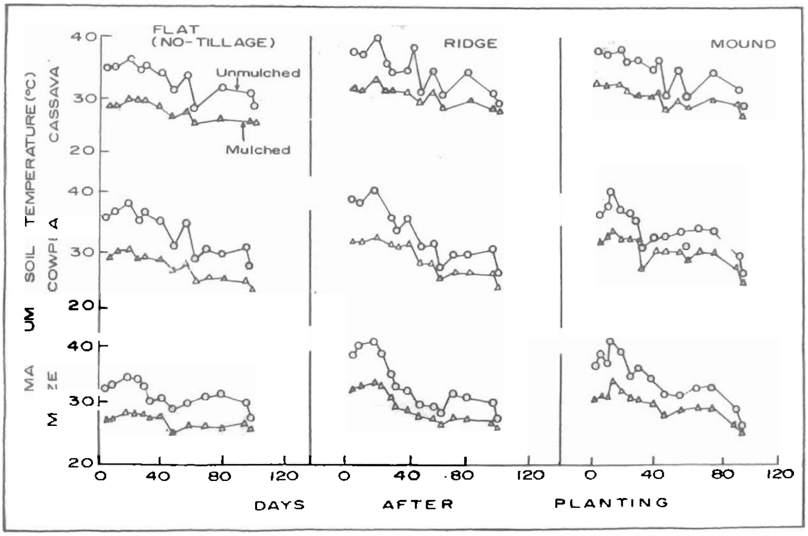
Soil moisture conservation under the different crop rotations reflected their relative amounts and rates of provision of canopy cover, and evapotranspirational losses. Moisture reserve was consistently highest under cowpea and lowest under cassava during the growing periods.

Soil Temperature

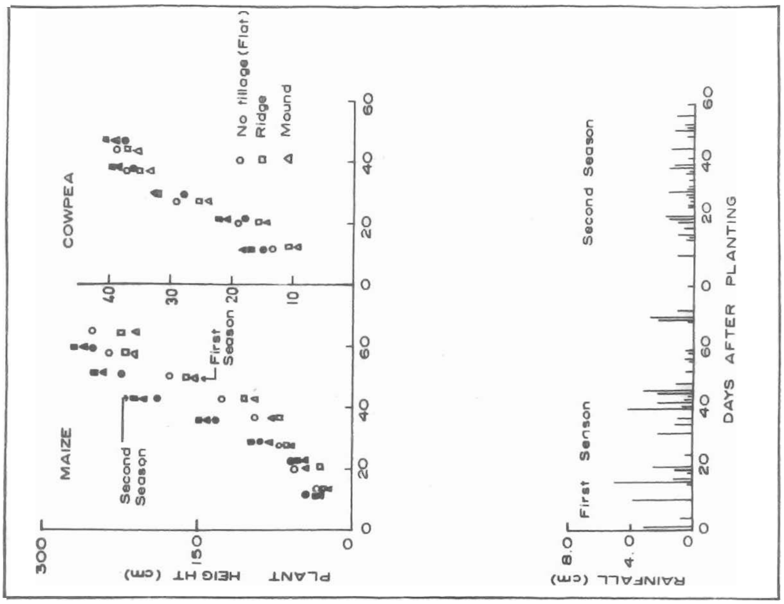
All treatments in the first season showed high maximum temperatures at planting which decreased subsequently from April to July (Fig. 3). In contrast, the temperature was lower at planting and increased thereafter in the second season. On the average, temperatures were lower in amount and amplitudes in the second season compared with the first season.

Tillage apparently increased surface soil temperature (Fig. 3); average temperatures in the first 4 weeks after planting were 34.2, 37.5 and 35.7°C for no-tillage, ridge and mound treatments, respectively, under unmulched conditions. In the second season, completely different results were obtained, no-tillage plots being at higher temperature than ridges and mounds by about 3°C under unmulched conditions. Minimum temperature was considerably less variable among treatments than the maximum temperature.

Soil temperature was consistently lower in mulched soil compared to unmulched soil (Fig. 3). Differences in the maximum temperature between mulched and unmulched plots 3 weeks after planting were 6.3, 10.2 and 8.0°C for no-tillage, ridge and mound treatments, respectively. The effect of mulch on soil temperature was generally reduced by tillage. The effect also reduced progressively on all treatments as the respective crop



3. **Soil temperature under different crops as influenced by tillage, seedbed configuration and mulching treatments.**



4. **Effects of tillage, seedbed configuration and mulching on the growth of maize and cowpea.**

foliage developed to intercept more incoming solar radiation during the season. By 75 days after planting maximum temperatures under mulch were only 1.8, 3.0 and 2.3°C lower than in bare soil under no-tillage, ridge and mound treatments, respectively.

Soil temperature, on the average, was lower under cowpea-cowpea rotation and highest under cassava in the first season but lowest under cassava in the second season.

Soil aggregation and porosity

The proportion of water stable aggregates greater than 2.36 mm was 92% at planting in the first season. Under unmulched tillage treatment, aggregation was subsequently reduced by 7 and 22 percent, at the end of first season and second season, respectively and the soil was about two-thirds as stable at the end of the second season as at the beginning of the first season (Table 1). Soil structural deterioration was lower with unmulched no-tillage treatments than the unmulched ridges and mounds. Mulching reduced soil structural deterioration of ridges and mounds and deterioration was negligible on mulched no-tillage plots. Changes in soil porosity during the season paralleled those of soil bulk density. Soil porosity was 57% for ridges and mounds and 48% for no-tillage at first planting but declined under unmulched conditions to 44 and 40 percent, respectively at the end of the second season. There was no significant change in soil porosity under mulched no-tillage treatment.

Crop response

Tillage, when not accompanied by mulch, delayed seedling emergence and reduced seedling stand in the first season but these results were the reverse in the second season. Maize and cowpea emergence was about 80% complete 6 days earlier in the second season than in the first season. Seedling emergence was 16% higher on no-tillage plots than on ridges and mounds in the first season. Mulching improved seedling emergence in all treatments; by about 34% under maize and cassava and 25% under cowpea. Mulching was, however, found to make cowpea more susceptible to insect damage than maize and cassava.

Plant growth was affected by tillage and seed bed configuration (Fig.4). At 45 days after planting, in the first season, the height of maize plants from no-tillage and ridged plots were 33 and 11 percent higher than plants on mounds under unmulched conditions. The values in correspondent order were 20 and 13 percent for cowpea. These results were in contrast to those of the second season, greater growth rate being recorded for ridges and mounds. The greatest increases in growth rate which occurred 20-30 days after planting for cowpea, 30-50 days for maize and 80-100 days for cassava in the first season, came 5 to 12 days earlier in the second season.

Yields of cassava, cowpea and maize are given in Table 2. The generally low crop yields reflected the wide-spacing limitation of mound treatment. Tillage, without mulch, increased cassava and maize yields in the second season by 40 and 20 percent, respecively, but did not produce any significant increase in cowpea yield. Mulching resulted in more significant increases in crop yield than did tillage. Mulching also had a higher significant effect under no-tillage than ridge and mound treatments (Table 2). Cassava yield was only about 13% lower when grown with no-tillage and mulch compared with growing on mulched ridges or mounds.

TABLE 2: CROP YIELDS AS INFLUENCED BY TILLAGE, SEED BED CONFIGURATION AND MULCH

Crop	Treatment	First Season		Second Season	
		Mulch	No-mulch	Mulch	No-mulch
			Tons/ha		
Maize	No-tillage	3.95 a[1]	3.04 b	3.87 a	2.62 bc
	Ridge	2.96 b	2.45 c	3.50 cd	3.06 b
	Mound	2.88 b	2.21 c	3.45cd	3.18 b
Cowpea	No-tillage	55.4[2]	52.3[2]	0.52 a	0.36 c
	Ridge	48.6	44.3	0.46 b	0.40 c
	Mound	47.9	44.8	0.45 b	0.39 c
Cassava	No-tillage	—	—	10.5 a	7.2 c
	Ridge	—	—	12.6 b	9.7 a
	Mound	—	—	11.7 b	10.3 a

1. Means for each treatment followed by the same letter are not significant at $P = 0.05$

2. Total dry weight in kg/plot.

Discussion and conclusion

Results presented in Fig. 1 indicate that soil compaction was due to post-seeding rainfall as earlier reported elsewhere by Jones and Wild (1975) and Millington (1961). The fact that there were significant increases in bulk density of tilled soil even with surface mulch suggests that soil compaction from the gravitational settling of soil particles upon wetting could be as significant as the direct compaction due to rainfall impacts on unprotected soil. This observation was apparently due to the low water stability and consequent high rate of deterioration of soil structure.

The lower moisture reserve of the tilled plots (compared to no-tillage plots) was due to compaction and resultant increased runoff (from the ridges or mounds to the furrows as observed on the field) which reduces the water input. The initial increases in porosity due to tillage also increase evaporative losses of water. In contrast, the unmulched tilled plots, because of re-preparation of the ridges and mounds in the second season probably had higher infiltration rates and hence higher moisture reserve than the bare no-tillage plots that had been compacted during the previous season. Differences in temperature among the treatments can be explained by the inverse relationship between soil moisture and temperature, given an amount of net radiation. Results on soil temperature similar to those in the first season have been reported by Lal (1973).

The effect of mulching in increasing soil moisture storage was however generally not as large as the effect on temperature reduction due to the low water holding capacity in the soil. This, couple with the fact that higher crop yields were obtained in the second season at lower soil moisture storage and lower temperature, suggests that high temperatures may be a major factor limiting crop production under tropical conditions. It is evident from the comparison of the crop responses in the two seasons (Fig. 4) that a combined effect of high soil temperatures (34°C) and high soil moisture storage (as in the first season) could be more deleterious to crop yields than that of low temperatures and low moisture. Maize crop was more sensitive to soil compaction than cowpea. A no-tillage system with inadequate surface mulch might cause more significant reductions in yield of maize than cowpea. A soil density of 1.46 g/cc was probably only a little higher than the critical bulk density of the soil for cassava since it resulted in only 13% reduction in yield compared with about 30% reduction under unmulched no-tillage condition with a 1.55 g/cc density. Contrary to the common knowledge, growing cassava with no-tillage and surface mulch may therefore be advantageous on the Oba soil (in terms of crop yields).

A no-tillage system with mulch would be desirable under the conditions of this study. Ridges and mounds should be adequately mulched if they have to be used for cassava for economic reasons. Such a system of mulch tillage would limit soil deterioration and enhance crop yields.

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