EFFECTS OF TILEAGE SYSTEM ON PROPERTIES OF AN ALFISOL IN SOUTH-WEST NIGERIA. 1

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Abstract

The effects of seven years of no-tillage with crop residue mulch on soil physical and chemical properties was compared with that of the conventional seedbed preparation involving ploughing and harrowing for an Alfisol in Southwest Nigeria. These observations were made on soil samples obtained from the longterm tillage plots established at the experimental farm of the International Institute of Tropical Agriculture since 1971. Soil bulk density, total porosity, resistance to penetrometer, and saturated hydrautic concretivity were more favourable in no-tillage than in ploughed plots. The water runoff was 11 and 74 mm with corresponding solitoss of 320 and 2800 kg/ha season for no-tillage and conventionally ploughted plots, respectively. Higher infiltration rate, and therefore less runoff and erosion, on no-tillage plots was partly attributed to favourable soil structure created by high earthworm activity. Earthworm casts amounted to 2020/m2 and 860/m2 in 80 days for no-tillage and convencionally ploughed plots, respectively. The surface layer of untilled plots contained higher concentration of organic carbon, total nitrogen, and exchangeable cations than that of the ploughed plots.

Introduction

The choice of an appropriate method of seedbed preparation depends on soil characteristics, cropping systems, climatic environments, and socio—economic conditions. In the humid and sub—humid tropics, where soil erosion by water is a serious hazard, mechanical methods of seedbed preparation may further accentuate the problem of soil erosion (Rhind, 1949:

Abeyratne, 1956; Pereira, 1962; Lal, 1976). Under these conditions, no-tillage system with crop residue mulches and with chemical weed control has been shown to be promising for erosion control (Greenland and Lal, 1977), and for sustained productivity (Greenland, 1975).

Rapid decline in productivity of soils in the humid tropics following deforestation for arable landuse is related to a multitude of interacting factors, including deterioration in soil physical, chemical, nutritional, and biological properties. Removal of a protective forest cover brings about a drastic change in ecological parameters that may lead to degradation of soil's productivity (Lal and Cummings, 1979; Lal, 1980). Maintenance of a protective ground cover through crop residue mulches and with least soil disturbance may dampen this rate of decline in soil properties. The objective of this report is to describe the effects of long term adoption of no—tillage and conventional tillage methods on physical and chemical properties and crop yield of an Alfisol in South—West Nigeria.

Material and Methods

These experiments were conducted at the International Institute of Tropical Agriculture (IITA), near Ibadan, Nigeria. The IITA is located approximately 30 km south of the northern limit of the zone of tropical rainforest. The average annual rainfall varies from 1000 to 1350 mm, and has a bimodal distribution. The first rainy season begins towards the end of March and terminates in July, and the shorter second season beings in August and ends in November. These two rainy seasons are separated by a short dry spell in August and a long dry season from November to March.

The soil analyses reported here pertain to samples obtained in 1977–78 from the long term tillage plots established since 1971. The soil belongs to Egbeda association and is classified as a clayey skeletal, kaolinitic, isohyperthermic, Oxic Paleustalf. Under the cover of natural vegetation, the surface soil is sandy loam with strongly developed fine crumb structure. There exists a well defined gravel horizon that lies approximately between 25 to 60 cm depths.

The effects of tillage systems on soil properties was investigated under maize—maize crop rotation. Maize (var TZPB) was seeded around 15th April in the first and 15th August in the second season. Conventionally tilled plots were ploughed with a moldboard plough to a depth of approximately 20cm and were disc harrowed twice.

No-tillage plots were sprayed with 2.5 1/ha of Paraquat (1.1-dime thyl-4, 4-bipyridinium ion) before seeding. Both tillage treatments received atrazine (2-chloro-4-ethylamino-6 isopropyl amino-1, 3,5-triazine) at 2 kg/ha as pre-emergence weed control.

All plots received a basal dose of muriate of potash at 30 kg/ha Nitrogen application was made at the rates of 0 (No), 40 (N1), 80 (N2), and 120 (N3) kg N/ha as urea applied 1/3rd at seeding and the remaining 4 weeks after. There were three levels of phosphorus: 0 (PO), 13 (P1), and 26 (P2) kg P/ha applied

as single super phosphate at seeding. Treatments were laid out as randomized split plot design with tillage methods as main plots. All treatments were replicated thrice with sub-plot size of 20x5m.

Soil physical properties were determined on six undisturbed cores (100 cm3) obtained from each sub-plot for 0-5, 5-10, 15-20, and 25-30 cm depths sampled before seeding and 4, 8, and 12 weeks. Soil physical properties monitored included bulk density, low and high energy moisture retention characteristics determined with tension table and moisture extractors, and saturated hydraulic conductivity monitored with a constant head permeameter. Pore size distribution was inferred from the moisture retention curves (Black, 1965). In addition, unconfined soil strength was monitored with a penetrometer, and aggregated stability was determined by Yoder's wet sieving technique (Yoder, 1936). The results of wet sieving analysis were computed to obtain a mean-weight diameter of aggregates (Van Bavel, 1949) Earthworm activity was monitored as the number of weekly fresh casts produced on a 25 x 25 cm quadrant in each sub-plots.

Soil erosion and water runoff was monitored in some treatments by establishing 10 x 1 m runoff plots. Estimates of water runoff and soil erosion were obtained after each rainstorm.

Chemical analyses of the soil was done on another set of samples similar to those obtained for soil physical analyses. These samples were air dried, ground gently and sieved through a 2-mm sieve. Soil samples were analysed for organic carbon (by dichromatic oxidation), total nitrogen (by Kjeldahl digestion), Bray-I phosphorus, and IN ammonium acetate extractable cations such as Ca++, Mg+, K+, and Na+ (Black, 1965).

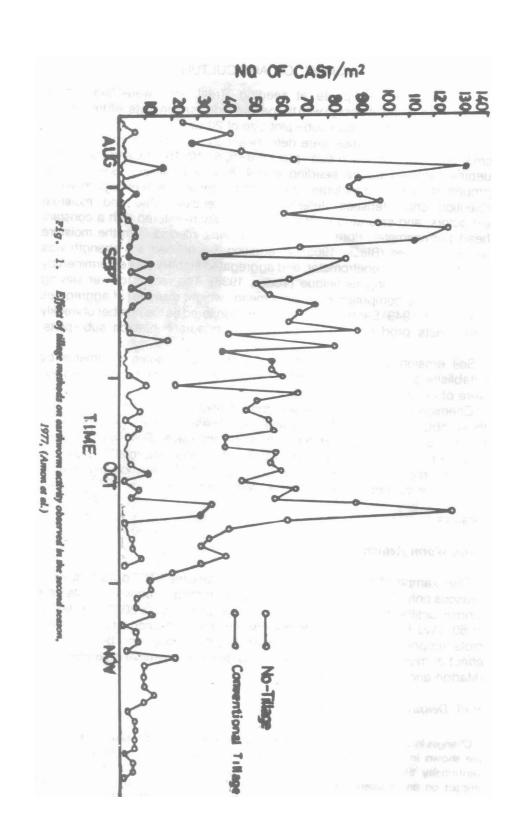
Results

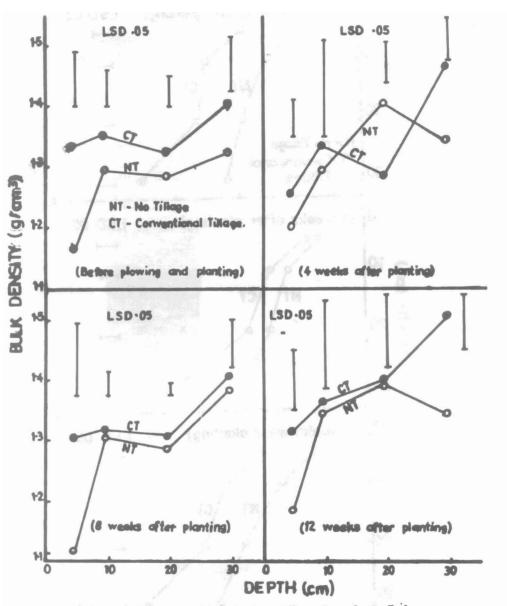
Earth Worm Activity:

The example of soil analyses are presented for either 1977 or 1978 growing seasons only. The results for two years were identical. Earthworm casts were more in untilled than in tilled plots (Fig. 1), and amounted to 2020 and 860/m2 in 80 days from August to October for no—tilled and conventionally tilled plots, respectively. Higher worm activity in untilled plots may be due to the effect of mulch (Lal, 1978), and to favourable soil chemical characteristics (Madge and Sharma, 1969).

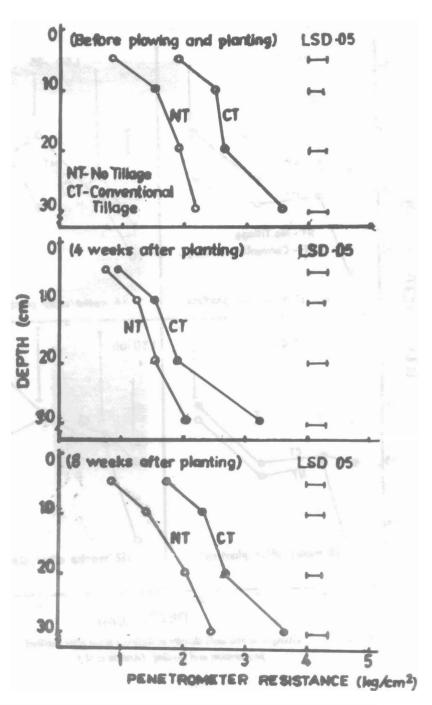
Bulk Density and Soil Strength:

Changes in soil bulk density at different times after seeding for both tillage systems are shown in Fig. 2. Higher bulk density observed before ploughing the conventionally tilled plots may be attributed to soil compaction caused by raindrop impact on an exposed unprotected soil. The loosening effect of mechanical seed-bed preparation lasted for about 4 to 6 weeks, and thereafter the surface soil





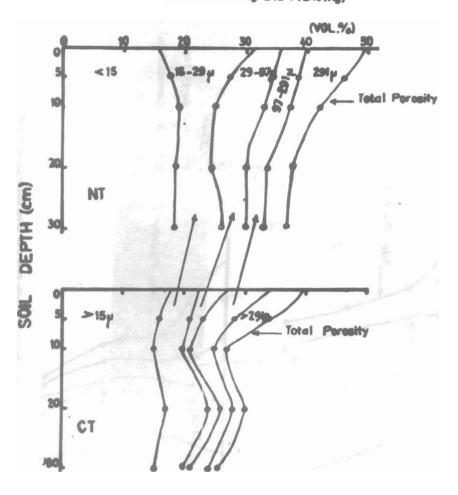
Pig. 2. Changes in soil bulk density at different times after seedbed preparation and seeding. (Armon et al.)



Pig. 3. Effect of tillage methods on the resistance to penetrometer.

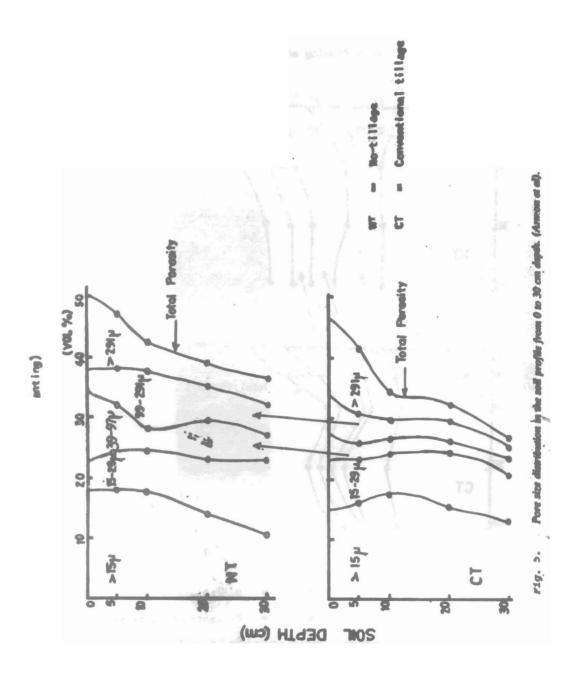
(Armon et al).

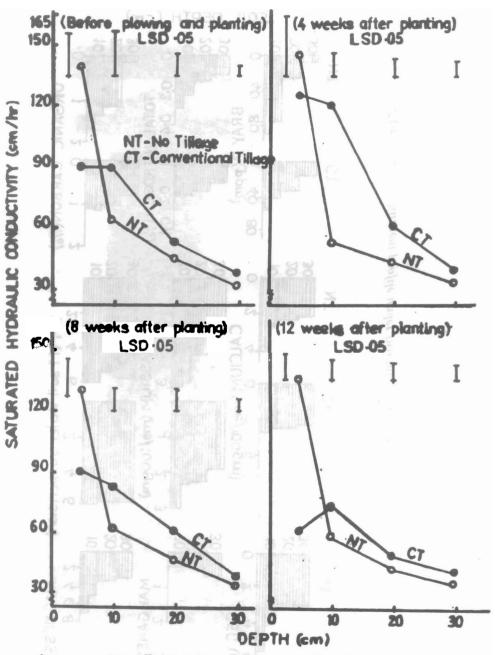
(Refore Plewing and Planting)



NY Mo-tillage
CT - Conventional tillage

Pig. 4. Pore size distribution in the soil profile from 0 to 30 cm depth. (Armon et al).





P1g. 6. Effect of tillage methods on saturated hydraulic conductivity of the surface layer monitored at different times after seedbed preparation and seeding. (Armon et al).

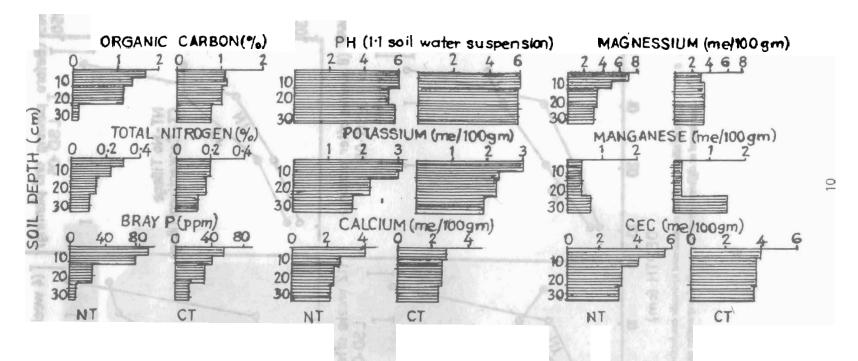


Fig. 7. Nutrient profile under two tillage systems.

settled to a higher bulk density than the untilled soil. Development of a compacted zone in the ploughed plots is observed between 20 to 30 cm depth.

Soil strength was related to changes in soil bulk density (Fig. 3). In conventionally tilled plots, the resistance to penetrometer of the surface soil changed from about 2 kg/cm² before ploughing to 1.2, 2.7, and 5.0 kg/cm² at 4, 8, and 12 weeks after. On the contrary, there were slight changes in resistance to penetrometer of the surface soil in the untilled plots (0.7 to 1.0 kg/cm²).

Structural Stability and Pore Size Distribution:

Mean weight diameter of the surface 0 to 5cm layer was 3.6 and 2.6mm for no-tillage and conventionally tilled plots, respectively. Porosite profiles measured before seeding and 4 weeks after are shown in Fig. 4 and 5 respectively. Before ploughing, there was higher total porosity and more macro-porosity in untilled than in tilled plots (Fig. 4). Increase in total porosity and in the relative proportion of macropores by ploughing was observed for 4 to 6 weeks. Ploughing resulted in 15 to 20 percent increase in total porosity of the surface layer. However, the effect of ploughing on porosity was negligible about 8 weeks after.

Saturated Hydraulic Conductivity;

Saturated hydraulic conductivity of the 0 to 5 cm layer was significantly more in no—tillage than in conventionally ploughed plots before ploughing, and reverse was the case immediately after and until 4 weeks after ploughing (Fig. 6). On the other hand, the hydraulic conductivity of the 5—10, 15—20, and 25—30 cm layers was more in ploughed than in unploughed treatments. Higher conductivity of the surface layer in no—tillage plots was related to a honey—comb like crumb structure created by biological activity of soil animals including earthworms, centipedes, and millipedes

Runoff and Soil Erosion:

Mechanical tillage incresed soil erosion. Cumulative runoff losses were 14 and 74 mm with corresponding soil loss of 320 and 2,800 kg/ha per season in no—tillage and conventionally ploughed plots, respectively. High infiltration in no—tillage treatment that decreased runoff losses is attributed to the lack of crust formation of the mulched soil surface, and to a high activity of soil fauna that improved macro porosity.

Nutrient Profiles:

Soil chemical characteristics under both tillage systems are shown in Fig 7. On weight basis for analyses conducted on sieved soil samples, the surface layer of untilled plots contained higher concentration of organic carbon, total nitrogen, and exchangeable cations than that of the ploughed

plots. However, there was a relatively uniform distribution of these elements with depth in ploughed than in unploughed plots.

Considering differences in soil bulk density due to tillage treatments, total nutrient contents of different layers was computed for both tillage methods (Table 1). Total nutrient contents in 0 to 5 and 5 to 10 cm layers were more in no—tillage than in ploughed plots, although reverse was the case for 15 to 20 and 25 to 30cm layers. The sum of N, P, Ca, Mg and K for 0 to 30 cm layer was 9.77 and 8.35 t/ha for no—tillage and ploughed plots, respectively. However, the total quantity of organic carbon in 0 to 30 cm layer was more in ploughed than in unploughed soil (39.2 vs. 41.2 t/ha), although a considerable amount of undecomposed crop residue remains on the surface of no—tillage plots.

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DISCUSSION A DISCUSSION A DISCUSSION A DISCUSSION DISCUSSION

Productive capacity of these Alfisols is related to the effective rooting depth, the soil depth above the gravel layer, and its water and nutrient retention capacity. Root development through the gravel layer is restricted (Babalola and Lal, 1977). Decline in the nutrient reserve of the ploughed plots may be attributed to soil erosion that preferentially removes colloid fraction with high "enrichment ratio" (Lal, 1976), resulting in a progressive depletion of its nutrient reserves.

There has also been, over a period of time, decline in physical and chemical properties of soil in no-tillage plots. Some weed species have developed resistance to paraquat and compete with crop growth. Weed species that persist in no-tillage plots include *Panicum maximum*, *Talinum triangulare*, and *Imperata cylindrica*. Besides, herbicides may be expensive and often not readily available to many small farmers in the tropics. The surface soil is also compacted wherever the crop residue mulch is inadequate. Mechanical tillage alleviates the adverse effects of soil compaction during seedling establishment, although crusting may inhibit seedling emergence.

The success of no-tillage system depends on the availability of crop residue mulch in quantity sufficient to prevent erosion, and to improve hydro-thermal regime of the soil. The mulch material may not be always available because of its alternate uses for fuel and fodder.

Both tillage systems have therefore their merits and demerits, and no single method can be universally applicable for all soils and crops. Though no-tillage system may maintain soil productivity over at long period, immediate returns are also of greater significance. Inspite of its high fertility status, no-tillage system may require additional N to off-set its immobilization by microbial activity. Crop yields in no-tillage plots may also be reduced by an increase in insect and pest incidence due to the infected residue left on the soil surface

The most serious problem with conventional tillage is soil erosion. Whereas contour cultivation, terraces, grass waterways, and buffer stripp can decrease soil erosion, those mechanical devices are expensive to install and

TABLE 1: TOTAL NUTRIENT CONTENTS IN SOIL UNDER PLOUGHING (+/As.).

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Depth	Org nic	Org nic Carbon	Total	NItro		Avail ble P	Ca		W.		¥	
(cm)	Ā	ե	Ā	_	z	CT NT	Ę	C1	È	b	Z	10
0 - 5	10.0	7.8-0.2	1.8-0.1	-1.1.05	0.06.01	0.04.01	3.6+0.4	0.44.3	0.094.03	0.0034.004	10.100.	0,084,11
2 - 10	8.95-0.6	7.6-0.23	1.524.09	1.0	0.04+.01	0,03+,003	0.4+.02	0.374.02	0.05+.004	0.03+,003 0.4+.07 0.37+.02 0.05+,004 0.03 +.07 0.07-008 .06 +0.00R	0.07-008	0.0- 90.
10 - 20	11.2 -0.5		2.0-0.1	2.1-0.1	.04+.07		3.6+0.4	0.65.04	0,054,01	0.04	0.174.1	0.11.0
20 - 30	9.1 -0.3	12.24.5	1.54.14	1.8.07	0.01 002	0.02+.001 0.6+0.6	3.6.0.6	0.6	0.64 5 0.054.0L	0.06 004 0.1 01 01	0.101	10.1
Total	39	41.2	8.9	5.9	0.15	0.14	2.2	1.83	1.83 0.24	0.13	0.78	0, 71,

maintain (Couper et al, 1979). Farmers may be releuctant to invest in such techniques whose returns are rather doubtful.

Whether no—tillage is a feasible alternative for tropical environments depends on its acceptance by the farmer. Its long term advantages in erosion control and maintenance of soil productivity have to be evaluated in view of its special requirements of herbicides, appropriate seeding and spray equipment, and development of specific farming systems. That is the real challenge to agronomists; extension workers, and farmers in the tropics.

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ation. Soil organic matter was positively correlated with leaf K, Ca an = 0.72**, 0.670** 0.72** respectively), whereas soil pH correlate city with leaf NO3-N and P (r=0.67**, 0.01**) respectively). A positivel listed between okru yield and teal Mg when 19*) and of the flowering (r = 0.72**) stages 0 92***) at the freeling stage of growth. It