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Full Length Research Paper

Optimum tillage system for pepper production in an alfisol of South-western Nigeria

T. M. Samuel[1*] and E. A. Ajav[2]

[1]Department of Agricultural Engineering, Olabisi Onabanjo University, Ibogun Campus. Nigeria.
[2]Department of Agricultural and Environmental Engineering, University of Ibadan. Ibadan. Nigeria.

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Optimum soil tillage for different crops in different regions needs be established for good yield. For pepper production on an alfisol with soil texture on the surface soil, this paper investigated three tillage systems (Plough-Plough Till – PPT, Plough-Harrow Till – PHT and Plough-Ridge Till – PRT) and two compaction levels induced by a 50 kW MF tractor (5 and 10 tractor passes – 5P and 10P) with No Tillage (NT) and zero tractor passes (ZP) as control. The experimental design was a randomized complete block design with three replications. The analysis of variance (ANOVA) showed significant difference ($p \leq 0.05$) on soil moisture content, bulk density, porosity and soil strength, investigated. Results showed that moisture content decreased with compaction level and was highest in NT plots (10.56%). Bulk density was highest in tilled plots (1.49 Mgm^{-3}) and increased with compaction level. Furthermore, porosity decreased with compaction and tillage intensity. In NT plots, soil strength was 1.12 Mpa, while 0.73 Mpa was recorded in tilled plots and increased with compaction level. Significant difference was observed in growth parameters and yield in tilled plots (5 t/ha), compared to 1.5 t/ha recorded in NT plots. This study has established that soil tillage is necessary for pepper production on an alfisol of southwestern Nigeria and is optimal at 5 tractor passes with PRT tillage system.

Key word: Tillage, compaction, pepper, alfisol, soil porosity.

INTRODUCTION

Tillage practice is an old art – as old as man himself. Successful crop farming basically depends on the provision of suitable climatic and soil conditions, the former being predominantly controlled by nature, while the latter is solely man's responsibility. At its inception, tillage practice thrived with simple tools. From using simple tools (expending a great deal of energy) to using sophisticated equipment (supplying direct energy), today's tillage method is the sequence of mechanical manipulation of the topsoil in which operations are dovetailed and adapted to the overall production technology. The rapid development in this direction in recent times culminates in greater expanse of land coming under cultivation, with its attendant bountiful harvest to feed the teeming population. However, whereas, tillage is set to pulverize the soil and create a refined soil condition for crops, intensive mechanization of farmland does result in soil compaction due to the passes of agricultural machinery on the soil. This had negligible effects on crop yield at inception. But the long-term effects of soil disturbance, coupled with the sophisticated heavy equipment now in use and the wide range of crops that require different tillage and compaction treatments (and these must be determined for each crop, and for a particular region for optimum production), have made tillage research rather indispensable.

Generally, plants require an environment in which nutrients, water and air are in abundance for their development, growth and reproduction. They develop best where they are able to extract these necessary elements from the soil through their roots. In their natural environment, plant species are able to survive in a balanced ecological system (competition) without any human interference. The introduction of a specific plant does, however, inevitably disturbs the balance; planting or sowing becomes necessary and the soil has to be opened up and, even in the most primitive stage, be

*Corresponding author. E-mail:samuel_taiwo1966@yahoo.com.

trodden (Krause et al., 1984). And since a natural condition suitable for all crops does not exist, the soil must be manipulated to produce the desired result.

Tillage is the basic operation in farming. It is generally done to create a favourable condition for seed placement and plant growth. These include ploughing, harrowing, mechanical destruction of weeds and soil crust, etc. Hence any physical manipulation of soil in order to get the desired condition of the seedbed for sowing and for good growth of plant may be termed as tillage operation. It is the mechanical manipulation of soil, which is used to maintain, modify or promote changes in soil structure in an effort to produce more desirable soil environment for plant growth.

Experience indicates that a certain amount of tillage is required on most soils to promote growth of plants. Throughout history, considerable development has taken place in the improvement of tillage tools. The progress of a country parallels the developments of tillage tools used in the cultivation of its soil. Tillage operations performed to sow or plant the same crops in different soils and regions are not the same. It varies considerably for different crops. Sowing of wheat seeds, transplanting paddy seedlings and placing sugarcane setts demand different types of soil manipulations. Hence tillage is an art rather than science (OJHA and Michael, 2005).

In crop production system prior to seedling, the seedbed preparation or tillage is an important field operation. About 20% of the energy required for crop production is utilized in tillage operation. Due to repeated use of tillage implements, subsoil layer are compacted leading to poor percolation and difficult condition for root penetration. Thus fields are adversely affected.

According to OJHA and Michael (2005), agricultural scientists and engineers working on improved tillage systems have made two important observations in the new tillage system:

1. In certain areas, soil conditions are such that if the tillage systems commonly followed in other areas are adopted, then it does not adequately prepare the soil needed for planting. The tilth is often impaired due to excessive manipulation of the soil. For such situations specialized systems of tillage have to be developed.
2. Of all the operations in the production of crops, primary tillage still requires more energy per unit area or per unit of crop production than any other operation.

Research on suitable requirement of the farming areas have developed some of the new tillage systems, which have been introduced in the world of agriculture. These include tillage systems for dry climates, minimum tillage system, zero tillage, ridge planting, rotary strip tillage system, alternative agriculture, conservation tillage, broad-based seedbed, and combination tillage. Tillage is generally categorized into three namely, primary, secondary and conventional.

Nwagu and Oluka (2006) studied the effects of five tillage treatments including zero-tillage, ploughing alone, harrowing alone, ploughing and harrowing, ploughing, harrowing and bedding on soil physical properties and yield of Okra in an ultisol of southeastern Nigeria and recommended harrowing alone as best for adoption based on yield.

An open question of which machinery management and tillage practice or combination of them are the best for each soil type, climate and crop, as observed by Mckyes et al. (1979), is one that has been of interest continuously, since man began to cultivate the land. The answer, according to them is very difficult to obtain because of the complexity of soil-water-plant system, not to mention the variability of soil and climate in the world. Lal (1979), while also corroborating this view, observed that no single tillage system could be used for all soils, crops and agro-ecological environments. He maintained that tillage is local-specific and should be developed for all conditions to solve specific problems of soil and water management, crop system and energy needs of the region.

But essentially, the tillage intensity adopted for a given crop in a particular area is vitally important in crop and soil management. This refers to the combination of tillage practices carried out on a particular piece of land. Itodo (1989) noted that if the appropriate level of tillage intensity is known for any crop for the prevailing soil and climatic conditions, the economic of tillage will be improved and the returns accruing will be quite more impressive.

Soil compaction is the pressing of soil together to make it denser or more succinctly stated, it is the increase of soil bulk density by the reduction of pore spaces. Modern agricultural soil now knows a great deal of compaction than it had ever been in the past. The soil, apart from being an environment for nurturing young sensitive seeds and seedlings, now serves as a surface for carrying many tons of weight in the form of tractors, trailers and other implements, thereby causing it to be structurally disorganized under the traffic of heavy implements.

Farming under this condition has short- and long-term effects that really spell doom for crop growth, and, of course, yield. The detrimental effects of soil compaction includes restriction of root development, nutrient movement, water and oxygen availability, which often result in reduced yield of both agronomic and horticultural crops (Threadgill, 1982). Soane et al. (1982) explained further that compaction will reduce soil permeability and the opportunity to remove excess water by drainage may diminish. Thus, compaction may both induce drainage problems and influenced the effectiveness of soil drainage. Oni (1991) also reported that repeat passes of agricultural tractors on farmland can lead to reduced infiltration rates, poor soil aeration, reduced root exploration, reduced crop yield and soil erosion, particularly for soils with low vegetative cover.

Even though soil compaction is undesirable for crop growth, Chamen et al. (1990) and Hunt (1973) argued that a complete absence of soil firming is undesirable. The former observed that this may lead to a reduction in crop performances due to nutrient deficiencies. Hence, a certain degree of compaction is required for maximum crop yield. The latter, on the other hand, cautioned that except for some soil firming around the plant seed, soil compaction should be avoided.

This paper, therefore, investigates the effect of different tillage systems and the levels of compaction on soil physical properties, plant growth characteristics and yield, so as to recommend the optimum on an alfisol for pepper production in southwestern Nigeria.

MATERIALS AND METHODS

The experimental field was cleared manually and was conducted at the University of Ibadan, Nigeria (7°20`N, 3°50`E). The experimental site was a well-drained soil. At the beginning of the experiment, composite soil samples were collected from each plot for chemical and particle-size analysis to determine the soil chemical and physical properties at the time of the experiment. Particle-size analysis was done following standard procedure (IITA, 1979) to determine the percentage of sand, silt and clay present in the soil sample. The experimental design was a randomized complete block design. Three tillage treatments were used namely Plough-Plough Till (PPT), Plough-Harrow Till (PHT) and Plough-Ridge Till (PRT) with No Till (NT) as control. The tillage treatment was done at 15 cm depth. Two compaction levels namely 5 and 10 tractor passes were used with zero tractor passes (ZP) as control. These treatments were achieved by the use of different implements coupled to a 50 kW Massey Ferguson agricultural tractor. The compaction level was obtained through wheel-to-wheel passes of the 50 kW MF tractor with front and rear inflation pressures of 15 and 30 bars, respectively, when driven over the field. Three replications were done in the experiment. Pepper seedlings were first raised in the nursery before they were transplanted onto each plot at a spacing of 70 cm along the row and 50 cm between, with two rows per plot.

Data were collected on soil physical and chemical properties and plant growth parameters throughout the period of the experiment. Height, fruiting/flowering pattern and yield were the plant parameters measured. Data on height were collected weekly from second week over seven weeks after transplanting. The percentage change in height was measured. Similarly, physical counting of the number of plants bearing fruits and flowers per plot were done for five weeks from the third week after transplanting. Ripe fruits were harvested manually per plot and weighed accordingly from the fourth month after planting.

100 cm^3 of core samples were taken from the plots for the first week after transplanting for the determination of moisture content. Oven dry method was used to determine the moisture of the soil per plot. Cylinder core method was used. A cylinder of known diameter and height was driven into the soil until it was almost buried, with another core of the same diameter placed directly on it. The core, brimful of soil, was then exhumed and emptied into a can of known weight. Soil samples collected from the plots were then weighed wet and dry and the percent change was calculated as the moisture content of the soil. From this result, bulk density and porosity were also calculated.

However, for soil strength, cone penetrometer was exerted into the soil and readings corresponding to the soil resistance to penetration were read off the penetrometer at five different depths – 2, 7, 15, 20 and 32 cm – per plot, at two locations on the same plot and the average was taken. Statistical analysis was performed to determine level of significance ($p \leq 0.05$) in the means of the different effects on the parameter of interest.

RESULTS AND DISCUSSION

Results of the particle size distribution of the surface horizon were 73% sand, 18% silt and 9% clay. The texture was sandy loam, classified as alfisol (Soil Taxonomy, 1975) with a pH of 6. Table 1 presents the details of the results. ZP gave the highest average moisture content (10.048%) followed by 5P (9.618%) and 10P (9.460%). This implies that moisture content decreased with increase in compaction level. This agrees with Oni and Adeoti's (1986) findings where moisture content decreases with increase in compaction level for cotton yield. Average bulk density consistently increased with increase in the number of tractor passes (1.43, 1.44 and 1.46 Mgm^{-3}). Increase in compaction results, due to reduction in the volume of voids with a tendency to leave a solid mass of soil. This is unfavourable for plant growth, as aeration and microbial activities are impeded. Hence minimum soil tillage is required to provide a favourable soil bulk density for pepper growth.

There was no difference in porosity between ZP and 5P, whereas, there was reduction at 10P. This implies that increase compaction reduces soil pores or void, hence its porosity. This is similar to the findings of Asoegwu (2005). Mean resistance of the soil to penetrometer gave 0.845, 0.928 and 0.973 MPa increasing with depth and compaction level. High mechanical impedance is unfavourable to crop growth and calls for reduction of soil strength, that is, the least, the better.

Average cumulative percent change in height decreased with compaction level (7.84, 6.57 and 6.22%) for the period of the experiment. However, 5P had the highest average flowering/fruiting development among the treatments. Highest yield (mean) was also recorded on the 5P plots (3.635 t/ha), 10P (2.768 t/ha) and ZP (2.836 t/ha).

Results of statistical analysis (ANOVA) showed that tillage and compaction treatments significantly ($p \leq 0.05$) affected soil physical properties (soil strength, moisture content, bulk density and porosity) as well as plant growth parameters (height, fruiting pattern and yield) during the period of the experiment as summarized in Table 2.

From Table 1, the average moisture content recorded are PHT 10.023%, NT 9.77%, PRT 9.613% and PPT 9.32%. Higher value of moisture content is desirable because it helps in the dissolution of soil minerals in the form needed by the plant. Average bulk density was constant for PPT and PRT (≈1.447 Mgm^{-3}), but lowest in NT (1.42 Mgm^{-3}). Machine traffic on the tilled plots might have been responsible for the high soil bulk density recorded. High value is least desirable because it

Table 1. Tillage effect on soil physical properties (0 - 15 cm depth) and growth parameters.

Properties		Level of compaction	Treatment				
			PHT	PPT	PRT	NT	Mean
Soil physical characteristics (0-15 cm depth)	Moisture content (%)	0	10.120	9.750	9.760	10.560	10.048
		5	10.000	9.750	9.630	9.090	9.618
		10	9.950	8.460	9.450	9.980	9.460
		Mean	10.023	9.320	9.613	9.877	
	Bulk density (Mgm^{-3})	0	1.460	1.440	1.420	1.400	1.430
		5	1.420	1.410	1.450	1.460	1.435
		10	1.470	1.490	1.470	1.400	1.458
		Mean	1.450	1.447	1.447	1.420	
	Porosity (%)	0	44.960	45.950	46.130	47.740	46.195
		5	46.400	46.870	45.540	45.270	46.020
		10	44.700	43.890	44.670	42.860	44.030
		Mean	45.353	45.570	45.447	45.290	
	Soil strength (MPa)	0	0.730	0.830	0.820	1.000	0.845
		5	0.890	0.880	0.840	1.100	0.928
		10	0.880	0.950	0.940	1.120	0.973
		Mean	0.833	0.887	0.867	1.073	
Growth parameters	Height ($mx10^{-2}$)	0	7.450	7.550	10.780	5.570	7.838
		5	7.540	8.220	6.590	3.930	6.570
		10	5.820	7.240	7.990	3.830	6.220
		Mean	6.937	7.670	8.453	4.443	
	Fruiting/flowering pattern	0	16.800	14.600	12.400	12.600	14.100
		5	16.000	19.400	17.400	17.000	17.450
		10	13.200	13.000	14.000	12.200	13.100
		Mean	15.333	15.667	14.600	13.933	
	Yield (t/ha)	0	3.227	2.612	3.992	1.511	2.836
		5	3.271	5.203	4.034	2.032	3.635
		10	3.358	2.401	3.419	1.892	2.768
		Total	9.855	10.217	11.444	5.436	
		%	26.670	27.650	30.970	14.710	

increases the cost of tillage since aeration and microbial activities are impeded. However, Porosity was the highest in PPT plot (45.57%). NT plot recorded 45.29%, PHT 45.353% and PRT 45.447%. This also follows the result of bulk density; hence porosity and bulk density are proportional in their effects on the treatments.

Analysis showed that soil strength increased with depth and is higher for NT plots (1.073 MPa) than tilled plots. This result agrees with Oni's (1991) findings from a similar research on Maize. It does confirm the fact that tillage reduces soil strength, especially primary tillage. High soil strength must be reduced tremendously before any meaningful farming can take place. Plant growth characteristics namely mean height and flowering/fruiting development were higher in tilled than untilled plots and was a replica of the yield. Yield gave 30.97, 26.67, 27.65 and 14.71% of total yield (36.952 t/ha) for PRT, PHT, PPT and NT, respectively. The cumulative change in height gives a vivid description of how the plants fared against the treatments. Moreover, PRT was picked up from the second week through the last week of collecting data than other treatments. NT showed retarded growth for the same period. This amplifies the essence of tillage for crop growth. This observation agrees with the practice of local farmers who make seedbed for peppers and other vegetables to enhance good soil environment for

Table 2. ANOVA Table for soil physical properties and pepper growth parameters.

	Moisture content			Bulk density			Porosity			Soil strength			Height			Fruiting pattern		
Source	**Total**	**Residual**	**Treatment**	**Total**	**Residual**	**Treatment**	**Total**	**Residual**	**Treatment**	**Total**	**Residual**	**Treatment**	**Total**	**Residual**	**Treatment**	**Total**	**Residual**	**Treatment**
df	143	132	11	143	132	11	143	132	11	59	48	11	83	72	11	59	48	11
SSD	1292.2	1254.7	37.45	1.88	1.77	0.11	2636.9	2499.1	137.87	16.69	15.97	0.72	2684	2399.4	284.6	2824.2	2514.4	309.8
MSD	9.04	9.51	3.4	0.01	0.013	0.01	18.44	18.93	12.53	0.28	0.33	0.07	32.3	33.32	25.87	47.87	52.38	28.16
F_{cal}		0.36			0.75			0.66			0.2			0.78			0.54	
F_{tab}		1.79			1.79			1.79			2.01			1.96			2.01	

their early development. PRT has the highest number of flowers (and, of course, fruiting) during the growth period. This is a replica of plant yield. Yield from NT were generally low for all tillage treatments. This indicates that PRT is the best based on yield.

Conclusion

The effect of tillage and compaction on soil physical property and plant growth parameters has been investigated. NT had the highest mechanical impedance, lowest bulk density and highest porosity. However, it consistently exhibited the lowest indicator of good plant growth (height, and fruiting/flowering development) among the tillage systems investigated. Consequently, the yield was the lowest – 14.71% of the total yield (36.952 t/ha) in the four tillage systems investigated. PHT had the highest moisture content, and close mean porosity and bulk density with PPT and PRT. PHT also recorded the lowest soil strength, closely followed by PRT and PPT. The yield was highest for PRT, having about 31% of the total yield for the tillage treatments. PPT and PRT maintained comparatively similar constant soil properties as well as good plant growth characteristics. The least yield in any tillage treatment was about 27% of the total yield. This implies that tillage is necessary for providing good soil environment for pepper production and is optimum with plough followed by ridging PRT, which gives the highest yield and, of course, highest economic returns desired in any farming operation. PRT, therefore, is recommended for pepper (*Capsicum annum*) production on an Alfisol of southwestern Nigeria.

For compaction moisture content and porosity consistently decreased with increase in compaction level, while bulk density and soil strength increased consistently with increase in compaction level. Except for the height, which consistently decreased with compaction level, fruiting/flowering and yield are highest at 5P, lower at ZP and 10P.

From this study, it has been established that tillage and compaction are necessary: PRT at 5 tractor passes is optimum. This is recommended for adoption in pepper production on an alfisol of southwestern Nigeria.

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