Original Paper

Influence of tillage on soil physical properties and three varieties of sesame (*Sesamum indicum* L.) in Ogbomoso, southwestern Nigeria

Esther Abosede Ewetola*, Babalola Alaba Catherine, Idris Ayoade, Bamidele Omowumi Ayeni
Ladoke Akintola University of Technology Department of Crop Production and Soil Science, Ogbomoso, Nigeria

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A two year field experiment was conducted to investigate the effect of different tillage practices on soil physical properties and agronomic properties of three varieties of sesame (*Sesamum indicum* L.) in 2013 and 2014 cropping seasons. The study was a split plot in randomized complete block design (RCBD). Tillage was the main treatment having three types; manual clearing (MC), ploughed twice (PT) followed by ridged (RT) while the sub plot was sesame varieties; 03L+ Tithonia, Ex-Sudan and E8. The result showed that soil physical properties and sesame varieties were not generally affected by tillage practices during the two years of the experiment. However, there was significant interaction of tillage and sesame varieties on soil microporosity and available water content (AWC) in 2013. RT increased AWC in 2013 and 2014 compared to MC and PT although, the treatments were statistically similar. RT significantly increased stem girth, number of leaves, and number of branches of sesame in 2013. Ex- Sudan variety produced significantly higher number of leaves and branches in 2013. However, E8 produced higher number of capsules per plant and seed yield. In 2013, interaction between tillage practices and sesame variety were significant on microporosity, available water content and plant height. Ridge tillage and E8 variety gave the best result in terms of improved soil physical properties and yield, therefore it is recommended in this study area.

Keywords: tillage, soil physical properties, sesame variety, yield

1 Introduction

Soil tillage is among the important factors affecting soil physical properties and crop yield. Among the crop production factors, tillage contributes up to 20% (Khurshid et al., 2006). The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes, e.g. destruction of soil structure, accelerated erosion, depletion of organic matter and fertility, and disruption in cycles of water, organic carbon and plant nutrient (Lal, 1993). In humid tropics where most farmers are poor and fertilizer is expensive, soil working and tillage methods can temporarily serve as an alternative to fertilizer application (Adekiya and Ojeniyi, 2002).

There has been mixed reports from tillage research over the years. Many see the need to reduce the amount and intensity of tillage operations to reduce erosion, improve soil structure, and ease flooding by increasing the infiltration of water into the soil water system by quantitatively characterizing soil structural properties (Braudeau et al., 2004; Braudeau and Mohtar, 2008). Conventional tillage practices modify soil structure by changing its physical properties such as soil bulk density, soil penetration resistance and soil moisture content. Annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared with conservation and no-tillage method which leaves the soil intact (Rashidi and Keshavarzpour, 2007). This difference results in a change of number, shape, continuity and size distribution of the pores network, which controls the ability of soil to store and transmit air, water and agricultural chemicals. This in turn controls erosion, runoff and crop performance (Khan et al., 2001). Tillage practices profoundly affect soil physical properties. Therefore, it is essential to select a tillage practice that sustains the physical properties required for successful growth of agricultural crops (Jabro et al., 2009). The changes produced by tillage on soil physical properties differ among management practices and varies over a wide range of soils and climatic conditions (Elder and Lal, 2008).

Tillage practices are beneficial in Nigeria due to some land that have low clay activity, inherent low fertility,

***Corresponding Author:** Esther Abosede Ewetola, Ladoke Akintola University of Technology Department of Crop Production and *Soil Science,* Ogbomoso, Nigeria, e-mail: eaewetola@lautech.edu.ng

various nutrient imbalance, pure structural stability, low water holding capacity and susceptibility to erosion (Opara-Nadi, 1990).The proper use of tillage can improve soil related constrains, while improper tillage may cause a range of undesirable processes, e.g. destruction of soil structure, accelerated erosion, depletion of organic matter and fertility, and disruption in cycles of water, organic carbon and plant nutrient (Lal, 1993). Use of excessive and unnecessary tillage operations is often harmful to soil. It has been noted that soil tillage is among the important factors affecting soil physical properties and crop yield.

Sesame (*Sesame indicum* L.) production is an important component of Nigeria's food security strategy. It is quite extensively grown in Nigeria and according to Alegbejo et al. (2003), it is more widely grown in the northern states of Nigeria such as: Nasarawa, Jigawa, Benue, Yobe, Kano, Taraba, Kastina, Kogi, Gombe, Kebbi, Zamfara and Niger. The crop has the potential to generate employment for the teeming unemployed youths and also generate income from exports. The utilizations of sesame among others include human consumption, health treatments, beautification, livestock feeding and industrial uses (Sharma, 2005; El- Habbasha et al., 2007). Sesame as a vegetative crop has been introduced under different cropping systems and agro-ecology. Considering its importance, there is a need to bridge the gap in knowledge on appropriate tillage and variety of sesame that will thrive best in Ogbomoso, south west Nigeria. Therefore, the objective of this study was to determine the effect of tillage practices on physical properties of soil, growth and yield of three sesame varieties.

2 Material and methods

2.1 Description of study site

The field experiment was conducted between 2013 and 2014 at the Teaching and Research Farm, Ladoke Akintola University of Technology Ogbomoso, Nigeria on a soil which had been under continuous cultivation for more than 5 years. Ogbomoso lies between latitude 8° 10′ N and longitude 4° 10′ E in the Southern guinea savanna ecological zone of Nigeria. The site has an altitude of 340 m above sea level. The rainfall pattern is bimodal and averages 1,400 mm per annum. Rainfall peaks occur in June and September. There are two growing seasons; an early season runs from March/April to August and late season, from mid-August to October/November. Annual temperatures range from 29.8 to 19.7 °C. The soil of the area was Gambari series (Smith and Montgomery, 1962) derived from highly weathered metamorphic materials, typically referred to as basement complex rocks. The soil was classified as an Alfisol under the order Udic Paleustalf according to the USDA classification (Soil Survey Staff, 2006).

2.2 Field experiment

The experimental design was a split-plot laid out in a Randomized Complete Block Design. Tillage practice was the main treatment and sesame variety as sub plot treatment. Each treatment was replicated three times. The tillage practices were -Manual clearing (MC), Ploughed twice (PT) and Ridged (RT). The sesame varieties – 03L + Tithonia, Ex-Sudan and E8 were sourced from Institute of Agricultural Research & Training (IAR &T), Ibadan. The area of land used for the experiment measured 0.648 ha with a plot size of 54 × 12 m and sub-plot measuring 3 × 4 m (12 m^2) with 1 m border to separate each plot from another whereas the individual plots were separated by 0.5 m. Manual plots were cleared manually with cutlass and hoe while Ploughed plots were ploughed twice with a disc plough to a depth of 30 cm and Ridged plots were ploughed once and ridged with disc tractor mounted ridger. The same land preparation for tillage treatments were carried out in both 2013 and 2014. Sesame seeds were sown at the rate of three seeds per hole at a spacing of 60 × 10 cm. The seedlings were later thinned to one plant per stand at two weeks after sowing which gave 16,667 plants ha^{-1}. Data were collected at 2- week interval for 12 weeks on the following growth parameters; plant height, number of leaves, stem girth, number of branches. At harvest, data on number of capsules per plant and seed yield in kg ha^{-1} were determined.

The initial soil samples were taken at 0–15 cm depth for routine analysis to determine soil texture and chemical properties of the soil according to IITA 1982. Particle size analysis of the soil was determined by hydrometer method (Gee and Or, 2002). Soil pH was determined in water using 1 : 1, available P was determined in the soil using Bray P-1 method (Bray and Kurtz, 1945). Organic carbon was analyzed by dichromate wet oxidation method of Nelson and Sommers (1982). Exchangeable K, Na, Ca, and Mg were extracted with 1 M NH_4OAc at pH 7, and determined by atomic absorption spectrophotometer. Effective Cation Exchange Capacity (ECEC) was calculated by summing up the exchangeable bases plus the exchangeable acidity. Cation Exchangeable Capacity (CEC) was determined by neutral, 1 N Ammonium acetate method. Determination of Total Nitrogen was done by the Macro Kjeldahl method as described by Bremner and Mulvaney (1982).

Soil samples were taken after harvesting to determine physical properties of the soil at 14 weeks after sowing.

Bulk density was estimated by dividing the oven-dried mass of the soil by the volume of the soil as described by Grossman and Reinsch (2002). This was computed by dividing the oven-dried mass of the soil by the volume of the core.

$$bulk\ density\ (g\ cm^{-3}) = \frac{mass\ of\ soil\ (oven\ dried)}{total\ volume\ of\ soil} = \frac{Ms}{V_T} \quad (1)$$

Volume of soil sample = volume of core (cylinder) = πr^{2h}

where:
h – height of the cylinder
r – internal radius of the cylinder.

Total porosity (TP) was calculated from the parameters of bulk density and particle density using an assumed value of 2.65 g cm^{-3} for particle density in the formula:

$$TP = 1 - \left(\frac{Pb}{Ps}\right) \times 100 \quad (2)$$

where:
Pb – the bulk density
Ps – the particle density

Pore size distribution was calculated using the water retention data and capillary rise equation as described by Flint and Flint (2002). Macropores (pores >30 µm), taken as drain pores were estimated at 10 k Pa matric potential.

$$Ow = \frac{Ww}{Vw} \quad (3)$$

where:
Qw – macroporosity
Ww – the difference between wet and oven dry soil
Vw – volume of the soil

Microporosity of the soil was determined by subtracting macro porosity from the total porosity.

Soil available water was determined as described by Reynolds et al. (2002)

Data were subjected to analysis of variance (ANOVA) test based on Randomized Complete Block Design according to SAS (2002) version. Means were compared using Fisher's least significant difference at 5% level of probability.

3 Results and discussion

The soil physical and chemical properties of the field used for the experiment are presented in Table 1. Textural class of the soil was sandy loam, with neutral pH (6.9), very low in organic carbon, total nitrogen and available phosphorus. The exchangeable cations range from low (K and Ca) to medium (Mg and Ca) (Esu, 1991). The general low nutrient status of the soil might be due to continuous cultivation of the land prior to cropping.

Table 1 Initial soil physical and chemical properties of the field used for the experiment

Parameters	Values
Sand (g kg^{-1})	795.60
Silt (g kg^{-1})	87.80
Clay (g kg^{-1})	116.60
Textural class	sandy loam
pH H_20 (1 : 2)	6.90
Total N (g kg^{-1})	0.07
Organic carbon (g kg^{-1})	0.69
Available P (mg kg^{-1})	2.02
Exchangeable cations (cmol kg^{-1})	
K^{2+}	0.16
Ca^{2+}	1.47
Mg^{2+}	0.39
Na^{2+}	0.15
EA	0.14
ECEC	2.31
Micronutrients (mg kg^{-1})	
Zn	3.29
Cu	0.73
Fe	102.31
Mn	100.27

The effect of tillage practices and sesame variety on soil bulk density and total porosity for 2013 and 2014 cropping seasons are presented in Table 2.

Tillage practices had no significant influence on bulk density and total porosity in both years, the values ranged from 1.60 Mg m^{-3} Ridge tillage (RT) to 1.66 Mg m^{-3} Ploughed (PT) in 2013 and 1.45 Mg m^{-3} (RT) to 1.48 Mg m^{-3} (PT) in 2014. Also, total porosity was not affected by tillage practices in both years. The values ranged from 33.10% (PT) to 40.28% in 2013 and 34.06% (PT) to 40.48% (RT). In the same way, bulk density and total porosity had similar effect among sesame varieties in 2013 and 2014 cropping seasons.

Tillage practices influence on soil microporosity (MIC), macroporosity (MAC) and available water content (AWC) after 2013 and 2014 cropping seasons are shown in Table 3. Generally, there was no significant difference among tillage practices on these soil properties. Mean values over the two years ranged from 16.38–17.07%, 6.37–10.75% and 0.117–0.131 M^{-3} m^{-3}, respectively, for MIC, MAC and AWC. Similarly, these soil properties did not differ among sesame variety. The interaction between tillage practices and sesame variety treatments were significant (*P* <0.05)

Table 2 Influence of tillage and three sesame variety on bulk density and as total porosity at 0–15 depth after 2013 and 2014 cropping seasons

Treatment	Bulk density (Mg m^{-3})			Total porosity (%)		
	2013	2014	mean	2013	2014	mean
Tillage (T)						
Manual	1.64	1.47	1.55	33.10	35.50	34.3
Ploughed	1.66	1.48	1.57	30.39	34.06	32.23
Ridged	1.60	1.45	1.52	40.28	40.48	40.38
$LSD_{(0.05)}$	ns	ns		ns	ns	
Variety (V)						
03L + Tithonia	1.63	1.51	1.57	31.52	37.98	34.75
Ex-Sudan	1.67	1.49	1.58	38.49	35.54	37.02
E8	1.60	1.41	1.51	33.74	34.51	34.13
$LSD_{(0.05)}$	ns	ns		ns	ns	
Interaction						
T × V	ns	ns		ns	ns	

ns – not-significant, * significant at 5% probability level

on MC and AWC in 2013 cropping season. The result indicates that tillage effect on MC and SAW has led to the effect on sesame variety.

The lower bulk density of the tilled plots specifically ridge tillage though not significant has led to the increase in total porosity of the soil. This may be attributed to the repackaging of the soil that has improved the soil structure. For any given soil, the lower the bulk density, the less compacted the soil and the more the pore space as observed in this study. The observation of non-significance effect of tillage practices on soil physical properties may be due to the short duration of the study. This result is in line with the report of (Buschiazzo et al., 1998) that a period of 2–3 years was not enough for tillage to affect most properties of sandy loam and other soils in Argentinean Pampas. Also, Anikwe et al. (2007) noted that in an experiment under no-till and tilled with plastic mulch at 95 days after planting, no significant treatment differences in soil dry bulk density were found between various treatments. Non-significance of tillage effect on bulk density over time has also been reported by Osunbitan et al. (2005). Gomez et al. (2001) observed that it took five years before changes in some of the physical properties (structure and aggregate stability, which are indicators of bulk density) could be detected as a result of the soil management practices. The full effect of tillage can only be observed after four or five years and this could not be obtained in this short term study.

Also, the increase in microporosity, macroporosity and available water content of the ridged plots although not significant can be related to the improved soil structure. This might have provided ease of water movement into the soil and subsequently increased the available water content of the soil. The increase in MIC (water filled pores) under tilled plots has led to increase in available water content which invariably promoted growth of sesame. The result also implies that tillage has influenced water storage. The result of this study could be corroborated by Katsvairo et al. (2002) that macroporosity and total porosity of soil has no significant difference amongst moldboard, plow, chisel, and ridge tillage systems on a silt loam soil near Aurora.

Result of the effect of tillage practices on growth parameters of the three sesame varieties are presented in Table 4. In 2013 cropping season, all the growth parameters were significantly (P = 0.05) affected by tillage practices. Ridge tillage (RT) produced significantly taller plant by 65% and 68% than manual clearing (MC) and ploughed tillage (PT) respectively, while RT and PH were not statistically different from each other. No significant difference was observed among sesame variety. However, there was significant interaction between tillage practices and sesame variety on plant height. RT and PT produced significantly wider stem than MC by 53% and 42%, respectively. The order of number of leaves among tillage practices was RT > PT > MC. The result also indicates that, RT and PT significantly increased number of branches compared to MC while no significant difference was observed between RT and PT plots. Number of branches indicated significant difference among three varieties of sesame (Table 4). 03L + Tithonia and Ex-Sudan produced significantly

Table 3 Effect of tillage and three sesame varieties on microporosity, macroporosity and available water content after 2013 and 2014 cropping seasons

Treatment	Microporosity (%)			Macroporosity (%)			Available water content ($m^3 m^{-3}$)		
	2013	2014	mean	2013	2014	mean	2013	2014	mean
Tillage (T)									
Manual	6.37	27.14	16.51	26.14	6.37	16.55	0.108	0.127	0.118
Ploughed	7.08	25.47	16.38	23.39	6.59	14.99	0.109	0.124	0.117
Ridged	4.40	29.73	17.07	30.13	10.75	20.44	0.133	0.129	0.131
$LSD_{(0.05)}$	ns	ns		ns	ns		ns	ns	
Variety (V)									
03L + Tithonia	5.56	25.82	15.96	25.48	10.16	17.82	0.110	0.120	0.115
Ex-Sudan	6.12	28.70	17.41	27.13	6.68	16.91	0.122	0.156	0.139
E8	6.67	27.83	17.25	27.06	27.68	27.37	0.117	0.123	0.120
$LSD_{(0.05)}$	ns	ns		ns	ns		ns	ns	
Interaction									
T × V		*	ns		ns	ns		*	ns

ns – non-significance, * significant at 5% probability level

Table 4 Effect of tillage practices on growth parameters of three sesame varieties at 12 weeks after sowing

Treatment	Plant height (cm)			Stem girth (cm)			Number of leaves			Number of branches		
	2013	2014	mean	2013	2014	mean	2013	2014	mean	2013	2014	mean
Tillage												
MC	39.68	78.50	59.09	2.10	3.47	2.29	26.24	47.28	36.76	6.30	6.76	6.53
Ploughed	112.02	97.20	115.16	3.65	3.97	3.81	57.24	58.77	58.01	9.02	8.42	8.72
Ridged	126.07	118.30	122.19	4.53	4.54	4.54	76.76	74.96	75.8	10.00	11.80	10.9
$LSD_{(0.05)}$	28.67*	14.33*		0.62*	0.48*		35.93*	11.07*		1.77*	4.27*	
Variety (V)												
03L + Tithonia	29.90	98.54	64.22	3.22	4.06	3.64	52.60	59.74	56.17	8.71	8.27	8.49
Ex-Sudan	32.70	104.38	64.54	3.50	4.07	3.79	56.71	64.51	60.61	8.86	7.77	8.32
E8	33.44	91.19	62.32	3.54	3.86	3.70	50.93	56.77	58.69	7.76	10.93	9.35
$LSD_{(0.05)}$	ns	ns		ns	ns	5.72*	ns	ns	64*	ns		
T × V	*	ns		ns	ns		ns	ns		ns	ns	

ns – non- significance,

higher number of branches than E8, but 03L + Tithonia and Ex-Sudan had similar effect on number of branches.

In 2014 cropping season, tillage practices significantly influenced plant height, stem girth, number of leaves and number of branches of sesame (Table 4). Plant height was in order of RT > PT > MC among tillage practices. Similarly, RT (4.54 cm^2) recorded wider stem than MC (3.47cm^2). Also, PT plots (3.97 cm^2) recorded wider stem girth than MC plots. The result follow similar trend on number of leaves. It showed significantly higher number of leaves (between 59 and 75) in both RT and PT plots when compared to the corresponding MC plots.

No significant difference in number of branches was found among tillage practices. There was no significant difference on number of branches among varieties of sesame. However, the means over the two years revealed that E8 had higher number of branches than the other two varieties. Tillage practices significantly influenced number of capsules per plant (NCPP) in both years of study (Table 5).

In 2013 cropping season, RT and PT produced significantly higher NCPP than MC. The increase was in the order of RT > PT > MC. There was no significant difference in NCPP among sesame variety. RT plots significantly recorded

Table 5 Effect of Tillage practices on yield component and seed yield of sesame varieties at 14 weeks after sowing

Treatment	Number of capsules (Plant^{-1})			Seed yield (kg ha^{-1})		
	2013	2014	mean	2013	2014	mean
Tillage (T)						
Manual	14.10	18.99	16.56	199.42	663.50	431.46
Ploughed	56.46	25.48	40.97	450.12	567.30	508.71
Ridged	93.01	50.90	71.96	583.27	719.19	651.23
$LSD_{(0.05)}$	32.39*	8.08*		ns	ns	
Variety (V)						
03L + Tithonia	59.67	31.44	45.56	239.00	643.90	441.45
Ex-Sudan	51.93	32.72	42.33	187.43	508.80	348.12
E8	52.07	31.20	41.64	351.01	797.20	574.11
$LSD_{(0.05)}$	ns	ns		ns	210.00*	
Interaction						
T × V	ns	ns		ns	*	

ns – non- significance, * significant at 5% probability level

higher NCPP than MC plots by 62% in 2014 cropping season, while no significant difference in NCPP was found between PH and MC plots. The results also indicate no significant difference in seed yield among tillage practices in both years of study. However, RT and PT increased mean grain yield of sesame by 15 and 34% than MC, respectively, over the two years. In 2013 cropping season, variety has no influence on seed yield of sesame. Conversely in 2014, E8 variety produced significantly higher seed yield of 797.2 kg ha^{-1} and lower yield from 03L + Tithonia (643.9 kg ha^{-1}) and Ex-Sudan (508.8 kg ha^{-1}) which were not different from each other. Tillage practices and sesame variety has significant interaction on seed yield of sesame in 2014 cropping season. In all the tillage practices investigated, ridge tillage provided better enabling environment for superior growth than MC and PT plots. The improved soil structure and tilth afforded the plant for greater access to water and nutrients leading to taller plants, wider stems and higher number of branches that transformed to better crop growth. Similarly, Sarder and Rosario (1995) observed that tillage resulted in a higher plant height (14–20%) than no-till methods in sesame planted after wet land rice. In this study, increase in number of capsules of sesame obtained on RT and PH plots compared to MC plots could be explained from better growth recorded on tilled plots which produced better number of capsules. The values of obtained under RT and PH were higher than that of MC resulting in higher seed yield in the RT and PH. The higher seed yield on the tilled plots though statistically similar accrued from better soil condition that promoted growth and later led to production of more seed. Bennett et al. (1998) reported that no-till methods had a low seed yield compared to the other tillage methods. They found that sesame seed yield in conventional tillage plots increased approximately 2-fold in comparison to no-till plots. Yol et al. (2010) reported that number of capsules per plant and height are the most important characters that affect seed yield in sesame. In contrast, these two parameters did not follow a consistent trend among the three sesame varieties studied.

The benefit derived from improved soil physical properties accruing from tillage such as reduced bulk density, increased available soil water content brought about superior number of capsule per plant and grain yield under tilled plots. Generally, the significant (P <0.05) higher seed yield of E8 variety compared with and 03L + Tithonia and Ex-Sudan may be attributed to the adaptability of the study area. The two varieties E8 and 03L + Tithonia showed superior growth particularly in number of branches, which transformed to higher grain yield.

4 Conclusions

The study revealed that the physical constraint of soil can be responsible for the performance of crop to its optimum level. Ridge tillage gave the optimum soil condition among tillage practices for best sesame production. It was observed that E8 variety produced the highest grain yield than the other two varieties. In order to get optimum growth and yield of sesame, it is therefore recommended that ridge tillage and E8 variety should be adopted in Ogbomoso south-west, Nigeria.

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