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Effects of row arrangement of maize and groundnut intercrop on selected soil properties in Ife area, Nigeria.

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Abstract

Maize and groundnut intercrop is considered necessary as a form of management practice to improve soil properties and to guarantee a return on-farm investment. The soil pore system, among other soil hydraulic properties, accounts for the quantum of soil water and soil air made available for plant use as well as other living fauna and flora in the soil and may be subjected to deformation arising from compaction. This study evaluated the effects of row arrangement of maize and groundnut intercrop on soil micro and macro porosities, bulk density, hydraulic conductivity, soil strength, particle size and organic carbon. The experiment was a factorial design laid out in randomized complete block design, with two factors and three replicates at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria. The treatments on each plot were carried out in row arrangement (1:1, 1:2, 2:1, 2:2 and sole cropping of groundnut as control) and local varieties of the groundnut (Boro, Gbada and Kampala). Data obtained were subjected to analysis of variance, and the means were separated using Duncan's Multiple Range Test at $p \leq 0.05$ using SAS 9.0 and Microsoft excel. Results showed that row arrangement with 50% or more maize population relatively increased soil organic carbon content but reduced unsaturated hydraulic conductivity at 2 cm suction compared to the case with groundnut. Except for soil strength close to the soil surface where Boro groundnut variety was higher in strength, groundnut varieties did not affect most soil properties investigated at the end of the second cropping season. Foot traffic during harvesting significantly increased soil strength near the soil surface, which may have resulted in 17.59% drop in macro-porosity. Although multiple cropping systems assessed within the short-term study have limited influence on some soil physical properties, consideration need be given to organic carbon content, hydraulic conductivity and surface soil strength in row arrangement and intensity of foot traffic by farm workers during harvesting.

Keywords: Groundnut varieties, Row arrangement, Foot traffic, Soil hydraulic conductivity, Soil strength.

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1.0. Introduction

Soil is comprised of minerals, soil organic matter, water, and air. The composition and proportion of these components greatly influence soil physical properties, including texture, structure, and porosity (McCauley *et al.,* 2005). Soil porosity is the void portion of the soils that are not occupied by solids, also an integral property of soil and has a strong influence on all soil processes. The soil pore characteristics do determine not only the flow of water, gases and solutes but also the chemical reaction of exchangeable cations, pH, biological composition and activity of soil fauna and flora (Lal and Shukla, 2004; Nimmo, 2004).

Soil strength is the resistance that has to be overcome to obtain a known soil deformation. It refers to the capacity of a soil to resists, withstands or endures applied stress without experiencing failure (Lal and Shukla, 2004). In agriculture, soil strength has applications to root growth, seedling emergence, aggregate stability, erodibility and erosion, compaction and compatibility and the draft requirement for ploughing (Lal and Shukla, 2004).

Intercropping systems according to Ibeawuchi and Ofoh (2003) limits soil losses and run-off and provides a nearly continuous cover thus preventing soil from the direct impact of the rains, and produces a dense and diversified root system which reduces leaching of nutrients. Intercropping of diversified crops controls soil disintegration by checking precipitation drops from directly hitting the soil surface, and possible sealing of surface pores increases the water infiltration and reduces the run-off volume (Seran and Brintha, 2010).

The spatial arrangement of crops helps in the effective utilization of land, soil moisture, nutrients and solar radiation. This is brought about by choosing appropriate crops of varying morpho-physiological nature and planning their planting geometry to reduce mutual competition for resources and enhance complementarities to increase overall productivity which is achieved by intercropping systems (Gurigbal, 2010).

The knowledge of soil pore classes and distribution is therefore essential in characterizing mass flow, transport processes and their application in soil water and solute management. In cultivated agricultural soils, functional classification of pores is of particular importance because of the role they play in storing and supplying water for plant growth (Mengistu *et al*., 2018). Management practices in agriculture as well as meteorological factors, amelioration, and root and earthworm activity, induce changes in soil porosity (Bryk *et al.* 2000; Pagliai and Vignozzi, 2002).

Associated with management practices in an intercropping system, is foot trafficking of farmworkers. The question arises if foot trafficking during harvesting in an intercropped system involving different varieties of groundnut implies soil pore system and associated soil physical properties? The study aimed to characterize the soil pore system and some soil properties as affected by the row arrangement and varieties of groundnut.

2.0. Materials and Methods

2.1. Study Area

The field experiment was conducted at the Teaching and Research Farm of Obafemi Awolowo University (OAU), Ile-Ife, situated within the tropical rainforest belt area of Southwest Nigeria. The area lies in the coordinates of latitude 07˚32` N and 07˚34` N and longitude 04˚33' E and 04˚ 35` E with an altitude of about 244 m above sea level. The soil at the study sites is an Iwo series and is classified as Typic Paleustult (USDA) or Ferric Acrisols (FAO) and is derived from coarse-grained granite and gneiss (Okusami and Oyediran, 1985). The climate of the area was characterized by bimodal rainfall regime with peaks in July and September of each year within the range of 1000 mm – 1240 mm, high temperature and relative humidity. Tuber crops, mainly cassava were planted on the land in the previous two cropping season, and no particular fallow plant was planted apart from common weeds like siam weed and sunflower were found growing on the field.

2.2. Experimental Design and Field Study

The experiment was a factorial design laid out in Randomized Complete Block Design having three replicates. The experiment includes two factors which were row arrangement of the crops (1:1, 1:2, 2:1, 2:2 and sole cropping of groundnut as control) and varieties of the groundnut (Boro, Gbada and Kampala). The dimension of the experimental plot was 3 m by 3 m. The groundnut varieties obtained from the Department of Crop Production and Protection have intercropped with Quality Protein Maize bred in the Institute of Agriculture Research and Training. 30 kg N/ha of booster fertilizer was applied as compound NPK 15:15:15, and 30 kg of single super phosphate was also applied to each plot. Chemical weed control was deployed using a systemic, non-selective, post-emergence herbicide which has no soil activity or residual effect.

The fieldwork involved collection of soil samples for laboratory analyses (pH and particle size distribution) using a sampling tube, collection of undisturbed core sample that was retained in the sampler for determination of bulk density, porosity and field moisture capacity (FMC), use of tension infiltrometer for K determination in-situ and assessment of soil strength using dynamic cone penetrometer The procedure was carried out before and after harvesting of the crops.

2.3. Soil analysis

2.3.1. Soil chemical analysis

The soil pH was determined using the glass electrode (Walklab) pH meter using 1:1 soil-water and 1:2 soil in 0.01 M $CaCl_2$ solution (Thomas, 1996). The pH meter was buffered at pH 4 and 7 before reading it in soil suspension. Soil organic carbon was determined by chromic acid digestion (Nelson and Sommers, 1996).

2.4. Determination of soil physical properties

The particles size analysis was determined using the modified hydrometer method (Buoyoucous, 1962; Gee and Or, 2002).

The bulk density was determined using undisturbed cylindrical core method. A core sample of a known volume was driven into the soil to collect the undisturbed samples. The soil samples were taken into the laboratory and were transferred into a moisture can of a known weight and were oven dried in the oven at 105˚C until the weight of the samples was constant (Blake and Hartage, 1986). The following formulae used to calculate the bulk density of the sample:

$$\rho_b = \frac{Weight\ of\ dried\ soil}{Volume\ of\ Soil} \quad \text{---------(1)}$$

The field moisture capacity and total porosity were determined by saturating soil sample in a core sampler in the laboratory as described by Flint and Flint (2002). This was saturated by progressively raising the level of the water to the core height, and the set up was left to stand overnight before submergence. The volumetric moisture content of the saturated soil at this point was the total porosity. The soil was covered with a perforated black polythene bag to prevent evaporation during drainage. The water was then allowed to drain from the covered soil by gravity until gravitational drainage ceased after 72 hours. The volumetric moisture content at this point was the FMC. That is,

Total porosity = volumetric moisture content at saturation ($C_{v\ sat}$)

The macroporosity and microporosity are expressed as,

Macroporosity = Cv sat - Cv FMC---------------------(2)

Where C_{vsat} is the volumetric moisture content at saturation representing total porosity and C_{vFMC} is the volumetric moisture content after gravitational drainage representing field moisture capacity

Microporosity = Total porosity – Macroporosity------(3)

Both macroporosity and microporosity are then expressed as a percent of total porosity

The soil strength was determined using dynamic cone penetrometer (DCP). The strength of the soil was taken twice on each experimental plot. In each test, a series of blows were made until the lower shaft of the DCP reached 500 mm. From this, the strength at 15 cm, 30 cm, 45 cm and 50 cm depths was estimated

Unsaturated hydraulic conductivity of the soil was determined using tension or disc-infiltrometer. The unsaturated hydraulic conductivity was estimated using Zhang (1997**)**

2.5. Statistical analysis

Data generated were subjected to analysis of variance, and the means were separated using Duncan's Multiple Range Test at the 0.05 probability level. Microsoft excel 2007 was used to plot the bar charts.

3.0. Results and Discussion

3.1. Antecedent properties of the soil

Result in Table 1 shows the physical and chemical properties of the soil before planting. The soil was categorized into sandy loam textural class with a high amount of sand but a low amount of clay and silt, which is the common in tropics soil (Soil Survey Division Staff, 1993). The soil pH was slightly acidic with a pH value of 5.55 and 4.73 using water and $CaCl_2$, respectively. The soil organic carbon (1.01%) was in the medium range (Adepetu *et al.,*2014).

3.2. Effects of row arrangement of maize and groundnut intercrop on selected soil properties.

Results in Table 2 shows the effects of a row arrangement of maize and groundnut intercrop on selected soil properties. Row arrangement did not significantly ($p \leq 0.05$) affect soil bulk density, soil strength at various depths and on macro-and micro- porosities. However, there was a significant ($p \leq 0.05$) different on organic carbon among the row arrangements which increase with the increase in several maize rows. The higher root biomass from maize compared to groundnut may have contributed to particulate soil organic matter after maturity and harvesting. The extensive system of maize has been recognized (Belel *et al.*, 2014). This is also in line with the finding of Gosh *et al.,* (2006) that stated that intercropping is an agroecosystems management practice which may help to increase the level of soil organic matter and thus soil quality, by increasing the crop residue returned to the soil and increasing the C/N ratio of these residues. The more the groundnut rows the significantly higher ($p \leq 0.05$) the unsaturated hydraulic conductivity at 2 cm suction. Two rows of maize to one of groundnut had the least water-conducting soil (1.20 cm/hr). The significant difference ($p \leq 0.05$) on sand contents among the row arrangements appeared a reason for the significant difference in unsaturated hydraulic conductivity, however, a row of maize to a row of groundnut with significantly lowest sand content, though numerically lower (1.55 cm/hr) was not significantly different in hydraulic conductivity compared to sole groundnut (2.26 cm/hr) with the highest sand content. Further, the micro-and macro- porosities were not significantly different.

Table 1: Antecedent properties of the soil

Soil properties	**Values**
Sand (g/kg)	770
Clay (g/kg)	130
Silt (g/kg)	100
Textural class	Sandy loam
pH (H_2O)	5.55
pH ($CaCl_2$)	4.73
Organic carbon (%)	1.01

Table 2: Effects of Row Arrangement of Maize and Groundnut Intercrop on Selected Soil Properties

RA	**Sand**	**Clay**	**Silt**	**OC (%)**	**BD (g/cm^3)**	**Macpor (%)**	**Micpor (%)**	**K_2**	**SSTOP**	**SS15**	**SS30**	**SS45**
		(g/kg)						**(cm/hr)**			**(kg/m^2)**	
1:1	75.55^b	14.21^a	10.24^a	1.06^a	1.36^a	13.19^a	86.81^a	1.55^{ab}	2.35^a	7.89^a	11.34^a	6.22^a
1:2	77.12^{ab}	12.81^a	10.07^a	0.98^{ab}	1.32^a	16.17^a	83.83^a	1.73^{ab}	2.32^a	7.80^a	12.86^a	5.07^a
2:1	75.79^b	13.73^a	10.48^a	1.06^a	1.36^a	13.71^a	86.29^a	1.20^b	2.42^a	7.07^a	11.46^a	5.98^a
2:2	76.92^{ab}	12.35^a	10.74^a	0.96^{ab}	1.48^a	14.84^a	85.16^a	1.60^{ab}	2.49^a	8.01^a	12.15^a	6.46^a
Sole	78.21^a	12.68^a	9.11^a	0.86^b	1.45^a	16.59^a	83.41^a	2.26^a	2.38^a	7.90^a	12.54^a	5.83^a

NB: OC – Organic Carbon; BD – Bulk Density; Macpor – Macroporosity; Micpor – Microporosity
K_2 - Hydraulic Conductivity; SSTOP – Soil Strength at 0 – 15 cm; SS15 – Soil Strength at 15 – 30 cm
SS30 – Soil Strength at 30 – 45 cm; SS45 – Soil Strength at 45 – 50 cm.
Macroporosity and microporosity are presented as a percent of total porosity
RA – Row Arrangement;
1:1- One row of maize followed by One row of groundnut;
1:2- One row of maize followed by Two rows of groundnut;
2:1 – Two rows of maize followed by One row of groundnut;
2:2 – Two rows of maize followed by Two rows of groundnut;
Sole – Groundnut only

3.3. Effects of row arrangement of maize and groundnut intercrop on soil porosity and strength in a maize and groundnut intercrop

Results in Figure 1 and 2 show the effects of row arrangement of maize and groundnut intercrop on the soil macro and micro porosities. There was no significant ($p \leq 0.05$) different on soil macro and micro porosities before and after harvest of the crops among the row arrangements. The reason could be attributed to limited soil disturbance and also short term duration of the legumes which have not exerted their full influences on the soil. Groundnut was planted on the plot for two seasons before soil assessments. This was in line with the finding of Gomez *et al.* (2001) that stated that it takes five years before changes in some of the soil physical properties could be detected as a result of the soil management practices. Karuma *et al.* (2014) also reported a non-significant different tillage and cropping system on total porosity. Although not significant, there was 17.59% drop in macroporosity and 4% drop in unsaturated hydraulic conductivity at 2 cm suction due to foot traffic during harvesting. However, the signifi-

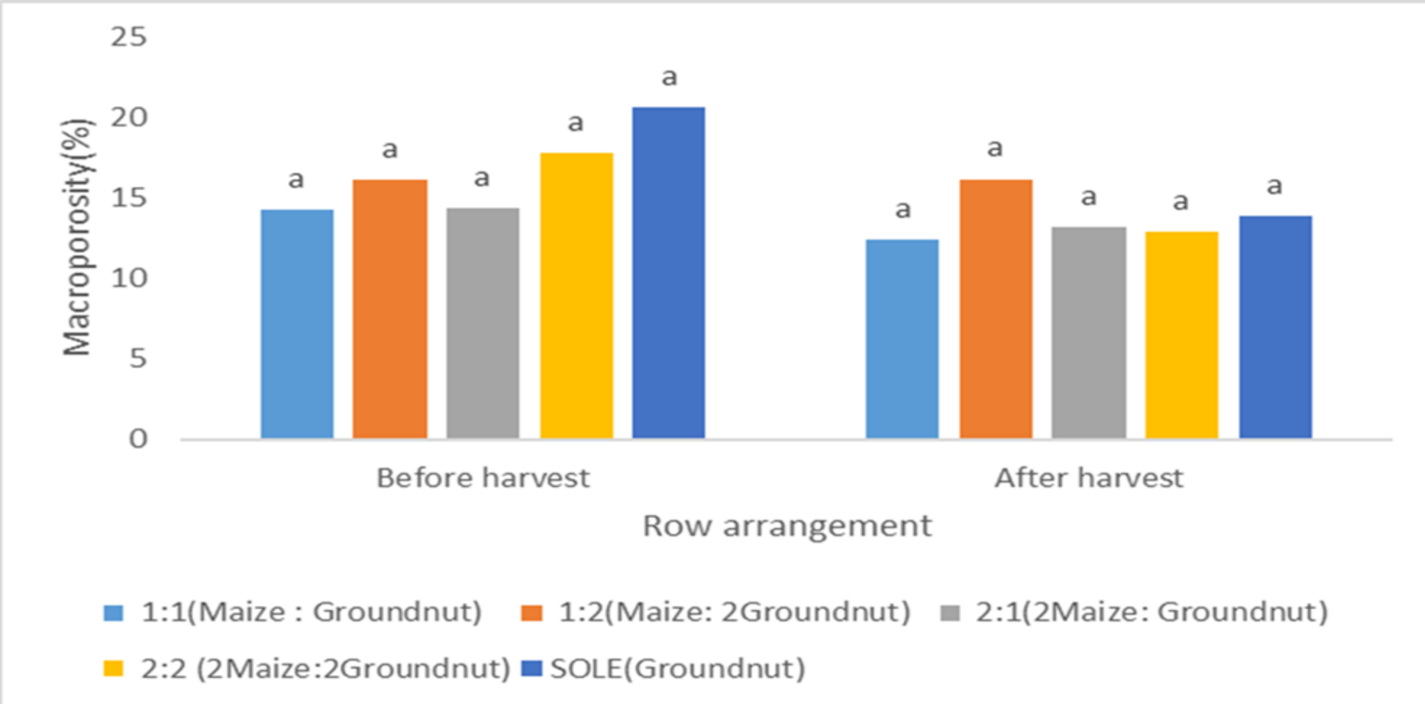

Figure 1: The effects of maize and groundnut intercrop and foot traffic during harvesting on soil macroporosity.
Means with the same letters are not significantly different from one another at the 0.05 probability level, using Duncan's multiple range test.
Macroporosity and microporosity are presented as a percent of total porosity

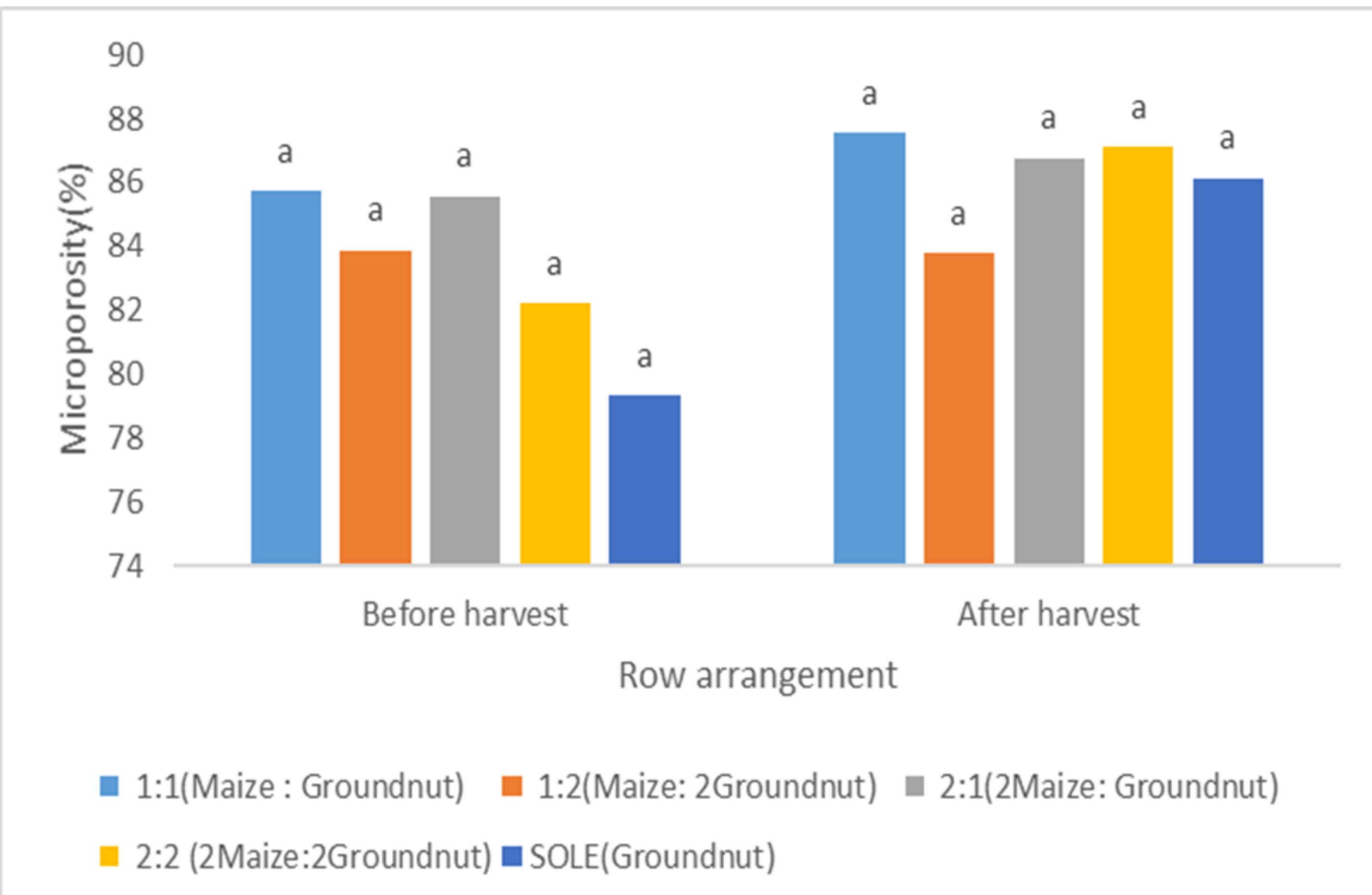

Figure 2: The effects of maize and groundnut intercrop and foot traffic during harvesting on soil microporosity
Means with the same letters are not significantly different from one another at the 0.05 probability level, using Duncan's multiple range test.
Macroporosity and microporosity are presented as a percent of total porosity

Table 3: Effects of Groundnut Varieties on Selected Soil Properties.

Varieties	Sand	Clay (g/kg)	Silt	OC (%)	BD (g/cm^3)	Macpor (%)	Micpor (%)	K_2 (cm/hr)	SSTOP	SS15	SS30	SS45
										(kg/m^2)		
Boro	76.87^{a}	12.53^{a}	10.60^{a}	1.02^{a}	1.43^{a}	15.32^{a}	84.68^{a}	1.36^{a}	2.56^{a}	8.71^{a}	13.03^{a}	6.34^{a}
Gbada	76.83^{a}	13.39^{a}	10.17^{a}	0.98^{a}	1.36^{a}	15.81^{a}	84.19^{a}	1.77^{a}	2.42^{ab}	7.92^{ab}	12.79^{a}	5.89^{a}
Kmapala	76.44^{a}	13.55^{a}	9.62^{a}	0.95^{a}	1.41^{a}	13.77^{a}	86.23^{a}	1.72^{a}	2.28^{b}	7.06^{b}	10.86^{a}	5.72^{a}

NB: OC – Organic Carbon; BD – Bulk Density;
Macpor – Macroporosity; Micpor – Microporosity
Macroporosity and microporosity are presented as a percent of total porosity
K2 - Hydraulic Conductivity;
SSTOP – Soil Strength at 0 – 15 cm;
SS15 – Soil Strength at 15 – 30 cm
SS30 – Soil Strength at 30 – 45 cm;
SS45 – Soil Strength at 45 – 50 cm.

Table 4: Effects of groundnut and maize intercrop before and after harvest on soil physical properties.

Harvest Period	Bulk Density (g/cm^3)	Macpor (%)	Micpor (%)	K_2 (cm/hr)	SSTOP	SS15	SS30	SS45
						(kg/m^2)		
Before harvest	1.36^{a}	16.66^{a}	83.34^{a}	1.71^{a}	2.14^{b}	7.25^{a}	11.47^{a}	5.25^{a}
After harvest	1.42^{a}	13.73^{a}	86.27^{a}	1.64^{a}	2.56^{a}	8.06^{a}	12.47^{a}	6.35^{a}

NB: OC – Organic Carbon; BD – Bulk Density;
Macpor – Macroporosity; Micpor – Microporosity
Macroporosity and microporosity are presented as the percent of total porosity
K2 - Hydraulic Conductivity;
SSTOP – Soil Strength at 0 – 15 cm;
SS15 – Soil Strength at 15 – 30 cm
SS30 – Soil Strength at 30 – 45 cm;
SS45 – Soil Strength at 45 – 50 cm.

cant increase in strength at 0 – 15 cm depth after harvesting could be linked to structural crust due to foot traffic during harvesting (Table 4).

3.4. Effects of groundnut varieties on selected soil properties.

The effects of groundnut varieties on selected soil properties were presented in Table 3. There was no significant ($p \leq 0.05$) different on most selected soil properties such as particle size analyses, organic carbon, bulk density, unsaturated hydraulic conductivity, soil strength at 30 – 45 cm, soil strength at 45 - 50 cm, soil macro and micro porosities among the varieties. However, there was a significant ($p \leq 0.05$) different on soil strength at 0 - 15 cm and 15 - 30 cm among the varieties. Boro variety had the highest strength, whereas Kampala was the least ($p \leq 0.05$).

4.0. Conclusion

The study considered the influence of row arrangement in maize-groundnut intercrop and groundnut varieties, and associated farm operations in multiple cropping systems on soil properties. The more the rows of maize in the intercrop, the higher the soil organic carbon content. However, the unsaturated hydraulic conductivity at 2 cm suction decrease when maize was more in rows compared to the intercrop with more rows of groundnut. Except for soil strength close to the soil surface where Boro groundnut variety was higher in strength, groundnut varieties did not affect most soil properties investigated at the end of the second cropping season. Foot traffic during harvesting significantly increased soil strength near the soil surface, which may have resulted in 17.59% drop in macroporosity. This study adds to the growing body of research that indicates that multiple cropping systems assessed, within a short-term frame, have limited influence on some soil physical properties. Nonetheless, soil organic carbon con-

Table 3: Effects of Groundnut Varieties on Selected Soil Properties.

Varieties	Sand	Clay (g/kg)	Silt	OC (%)	BD (g/cm^3)	Macpor (%)	Micpor (%)	K_2 (cm/hr)	SSTOP	SS15 (kg/m^2)	SS30	SS45
Boro	76.87^{a}	12.53^{a}	10.60^{a}	1.02^{a}	1.43^{a}	15.32^{a}	84.68^{a}	1.36^{a}	2.56^{a}	8.71^{a}	13.03^{a}	6.34^{a}
Gbada	76.83^{a}	13.39^{a}	10.17^{a}	0.98^{a}	1.36^{a}	15.81^{a}	84.19^{a}	1.77^{a}	2.42^{ab}	7.92^{ab}	12.79^{a}	5.89^{a}
Kmapala	76.44^{a}	13.55^{a}	9.62^{a}	0.95^{a}	1.41^{a}	13.77^{a}	86.23^{a}	1.72^{a}	2.28^{b}	7.06^{b}	10.86^{a}	5.72^{a}

NB: OC – Organic Carbon; BD – Bulk Density;
Macpor – Macroporosity; Micpor – Microporosity
Macroporosity and microporosity are presented as a percent of total porosity
K2 - Hydraulic Conductivity;
SSTOP – Soil Strength at 0 – 15 cm;
SS15 – Soil Strength at 15 – 30 cm
SS30 – Soil Strength at 30 – 45 cm;
SS45 – Soil Strength at 45 – 50 cm.

Table 4: Effects of groundnut and maize intercrop before and after harvest on soil physical properties.

Harvest Period	Bulk Density (g/cm^3)	Macpor (%)	Micpor (%)	K_2 (cm/ hr)	SSTOP SS45	SS15	SS30	
					.	(kg/m^2)		
Before harvest	1.36^{a}	16.66^{a}	83.34^{a}	1.71^{a}	2.14^{b}	7.25^{a}	11.47^{a}	5.25^{a}
After harvest	1.42^{a}	13.73^{a}	86.27^{a}	1.64^{a}	2.56^{a}	8.06^{a}	12.47^{a}	6.35^{a}

NB: OC – Organic Carbon; BD – Bulk Density;
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SS15 – Soil Strength at 15 – 30 cm
SS30 – Soil Strength at 30 – 45 cm;
SS45 – Soil Strength at 45 – 50 cm.

tent, hydraulic conductivity and surface soil strength emerged as properties that are quickly influenced by maize-groundnut intercrop and intensity of foot traffic by farm workers during harvesting.

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