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Research Paper

Assessment of Groundnut/Maize Intercropping System on Soil Bulk Density and Volumetric Moisture Content Grown in a Typic Paleudult Soils of Southeastern Nigeria

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This study was conducted in 2010 and 2011 at the Research and Training Farm of Abia State University Umuahia Campus in the humid tropical rain forest zone of Southeastern Nigeria to determine the effect of intercropping on soil bulk density (BD) and volumetric moisture content (VMC). Treatments comprised of a local groundnut genotype and an improved resistant red bulk (RRB), maize genotype DMR-L (Y) at 40,000 and 48,000 plants/ha. A density of 80,000 plants/ha was maintained for groundnut. Treatments were laid out on 5 m x 4 m plots in a Randomized Complete Block Design (RCBD) replicated three times. Pre-cropping soil samples were collected at 0–30 cm depth and analyzed for physico-chemical properties of the experimental site soil. Undisturbed soil samples were taken from 0-10, and 10-20 cm depth of each treatment and from each replication for the determination of soil bulk density (BD) and volumetric moisture content (VMC). The result showed that by intercropping RRB or the Local genotype and maize at 40,000 or 48,000 plants/ha the farmer has the capability of improving the bulk density (BD) of his soil by over 35% and volumetric moisture content (VMC) by over 75%.

Key words: Bulk density, groundnut, humid tropical, intercropping, maize, plant density, volumetric moisture.

INTRODUCTION

In the humid tropics, intercropping is a prominent feature of peasant farming which helps to minimize risks associated with monocultures and assures stable income and nutrition (Okigbo, 1980; Ikeorgu and Odurukwe, 1989; Konian *et al.,* 2013). Bulk density (BD), which is the degree of looseness or compactness of the soil is affected by soil structure (Nwosu *et al*., 2013). When soil is compacted, the BD is raised to the maximum limit because most of the pore spaces are destroyed which invariably account for the status of moisture content, soil aeration and ultimately to the plant growth (Ajayi, 2015).This means that BD and available volumetric moisture content are correlated. Bulk density is defined as the ratio of the weight of a given volume of dry soil (air spaces inclusive), to the weight of an equal volume of water (Opara-Nadi, 1997) which means that BD is needed for the determination of soil moisture content on volumetric basis. According to Bonarius (1975), BD under 1.0 g/cm^3 has higher proportion of organic matter at the top layer while soils above 1.0 g/cm^3 indicate sandy nonaggregated and compacted well-graded soils. Groundnut -maize intercropping is often practice under different tillage methods to produce food and obtain cash income from the same piece of land (Ikeorgu and Odurukwe, 1989, Ishaq *et al.,* 2001). Maize (*Zea mays* L.) is the largest cultivated crop in Nigeria in all the ecological zones of the country.

Groundnut (*Arachis hypogaea* L), also known as "peanut" or "earthnuts" is referred to a king of "oil seeds" and globally cultivated on an area of 24.62 million hectares of land (FAO, 2013). Yields obtained from the two crops when grown as sole crop or when they are intercropped are low due to poor soil fertility and inadequate field management by farmers (Videnovic *et al.,* 2011; Howell, 2011; Patil *et al.,* 2015). The reason for the low yields is because the humid tropics are characterized by highly erosive, erratic and poorly distributed rains (Lal, 1980; Osunbitan *et al.,* 2005; FAO, 2011). The rains generally lead to rapid deterioration of soil properties and declining fertility of these soils (Ishaq *et al.,* 2001, Osunbitan *et al.,* 2005). In intercropping, crops combination such as maize/legume intercrop has been recommended for complementarities in nutrient and water use (Francis, 1986; Patil *et al.,* 2015). In addition the stimulation of biotic activity for nutrient recycling of decomposed residues has been shown to sustain crop yield (Hill, 1990).

It had been noted that the soils of humid and sub-humid tropical rainforest zone of Southeastern Nigeria is predominantly associated with nutrient depletion (Chude *et al.,* 2004) due to high acidity, low activity clay, low organic matter content, low water holding capacity, low cation exchange capacity (CEC), poor structural stability (FPDD, 1989), and high susceptibility to soil erosion (Opara-Nadi, 2000). The soils are easily degraded by farming operations and in terms of productivity require high management investment (Bationo *et al*., 2006). To boost soil fertility and high crop yields in the zone many researchers (Opara-Nadi, 2000; Akpan *et al*., 2008 and Sureh, 2008) have suggested, among other soil management techniques, intercropping with legumes to build up the soil structure thereby promoting mineralization and root penetration.

The importance of soil moisture to groundnut+maize intercropping cannot be over emphasized. FAO (1986; 2012); Brouwer and Heibloem (1986); Chukwu, (1999) and Udom *et al.* (2010) have also advocated the importance of adequate soil moisture to groundnut in a sandy soil. Groundnut is important in Nigeria for its non-drying oil and cake which is rich in protein content and in farming systems as widely used traditional compatible intercrop with cereals (FPDD, 1989). Intercropping maize with groundnut has been observed by researchers to promote increased total output per area of land, increased yield under stress condition, greater gross monetary advantages at zero nitrogen (N), availability of more mineral N at the top soil of former plot grown with groundnut compared to that of cotton, sorghum or cowpea and land equivalent ratios (LERs) always larger than unity (Marshall and Willey, 1983; Schmidt and Frey, 1985). The aim of this study is to determine the effect of intercropping on soil bulk density (BD) and volumetric moisture content of Typic Paleudult soils of Southeastern Nigeria.

MATERIALS AND METHODS

Description of the experimental site

The study was conducted in 2010 and 2011 at the Research and Training Farm of Abia State University Umuahia Campus (latitude 05° 9'N and longitude 07° 33' E with an altitude of 122 m above sea level), in the humid tropical rainforest zone of Southeastern Nigeria. The soil is Typic of Obolo mapping unit classified Typic Paleudult (USDA) and correlated with Haphic-Acrisol (FAO–UNESCO) by Chukwu and Ifenkwe (1996). The area is a tropical climate characterized by distinct dry and wet seasons; the rainfall is seasonal with two peaks in July and September, with average annual rainfall varied between 2100 and 2300 mm. The monthly minimum and maximum temperatures ranges from 23 to 33°C, respectively. The monthly minimum and maximum temperatures ranges from 23 to 33°C respectively while, monthly relative humidity varies from 51 to of 87% (NRCRI, 2014). The dominant vegetation of the area is forest and the major land use types are arable crop production, cash crop production and other non-agricultural uses. The study area has been cultivated for maize, coco-yam, cassava, sweet potatoes and was left fallow for about two years before the commencement of the study.

Experimental design, field plan, and treatments

The field experiment was laid out in a Randomized Complete Block Design (RCBD) with eight treatments, replicated three times to give (8 x 3) 24 experimental plots. The experimental treatments comprised; (RRB + 48,000 maize plants/ha, RRB + 40,000 maize plants/ha, Local + 48,000 maize plants/ha, Local + 40,000 maize plants/ha, Sole RRB, Sole Local, 48,000 maize plants/ha and 40,000 maize plants/ha). The dimension of the area measured 17m x 40m ($680m^2$) while, each experimental plot was 5 m x 4 m (20 m^2), with inter-block and inter-plot spacing of 2.5 and 2.0 m, respectively. A 2-m wide pathway was maintained around the entire experimental area. Maize seeds were sown at the spacing of 60cm by 100 cm.

Soil sample collection and analysis

Composite undisturbed soil samples were collected at the

Table 1. Initial soil physical and chemical properties of the study site, Abia State, Nigeria.

Properties	Parameters
pH (water)	4.71
Organic carbon (%)	0.83
Total nitrogen (%)	0.04
Phosphorus ($mgkg^{-1}$)	11.77
Cation exchange capacity ($cmolkg^{-1}$)	5.0
Total acidity ($cmolkg^{-1}$)	1.63
Base saturation (%)	65.2
C/N ratio	20.8
Exchangeable cations (CEC)($cmolkg^{-1}$)	
Ca^{2+}	1.99
Mg^{2+}	0.65
K^{+}	0.07
Na^{+}	0.03
Particle size distribution (%)	
Sand	70.9
Silt	7.6
Clay	21.5
Texture	Sandy clay loam
Bulk density (kgm^{-3})	1.52

depths of 0 - 10 cm and 10 - 20 cm from the eight experimental treatments replicated three times, for the determination of soil bulk density and volumetric moisture content. The soil samples were dried at 65°C for 48 h to eliminate moisture. Pre-cropping soil samples were collected from 0-30 cm depth, air-dried at room temperature and analyzed. The collected soil samples were air-dried and sieved through a 2 mm mesh. Particle size analysis was carried out by hydrometer method (Akpan-Idiok, 2012) using sodium hexametaphosphate as dispersant. Soil pH was determined in soil-water ratio of 1:2.5 using a glass electrode pH meter (Thomas, 1996). Organic carbon was determined by the Walkley and Black method (Nelson and Sommers, 1996), while total nitrogen was determined by the Kjeldahl digestion method (Bremner, 1996). Available phosphorus was determined by the Bray and Kurtz No. 2 method (Kuo, 1996). Exchangeable bases (Ca, Mg, K and Na) were extracted in 1N NH4OAc at pH 7. Potassium and sodium were determined with a flame photometer, while Ca and Mg were determined by the EDTA titration method (Eteng *et al*., 2014). Exchangeable acidity was determined by titration method using IN KCl extract (McLean, 1982). Effective cation exchange capacity was a summation of exchangeable bases (Ca, Mg, K and Na) and exchangeable acidity (Sumner and Miller, 1996). Percent base saturation was obtained by dividing the total exchangeable bases (Ca, Mg, K and Na) by the ECEC (Eteng *et al*., 2014).

Statistical analysis

The data collected were analyzed using the procedure of Fisher's analysis of variance technique and least significant difference (LSD) test at 5% probability level was applied to compare the treatments' means (Steel *et al*., 1997) using general linear model of Genstat (2013).

RESULTS AND DISCUSSION

Soil properties

The pre-cropping soil properties of the experimental site at 0-30 cm depth are shown in (Table 1). The pH (4.71) of the soil indicates a strongly acid in reaction (Nwosu *et al*., 2013). This suggests that aluminum and/or manganese toxicity is likely to impair nutrient availability and crop yield since intercropping is reported to result in lowing soil pH thereby higher rates of gross Al and Mn mineralization than in sole cropping (Gattani *et al*., 1976; Friesen *et al*., 1980). The soil texture is sandy clay loam with bulk density (BD) of 1.52 kgm^{-3}. Soil with a low bulk density has lower penetration resistance than the high bulk density soil. The soil suffered multi-nutrient deficiency of N and K and is low in organic matter. Intercropping results in higher rates of gross nutrient mineralization than the sole crops. According to previous studies by Opara-Nadi (2000) and Akpan-Idiok (2012), the application of organic matter as manure or mulch as well as application of inorganic fertilizers and the use of legumes, are necessary to build up soil nutrient and increase the bulk density of the site.

Bulk density (BD)

There was significant difference in the BD of the 0-10 and 10-20 cm soil depths when groundnut and maize were intercropped (Table 2). The BD in 10-20 cm depth was generally higher than in the 0-10 cm depth for the same

Table 2. Soil physical characteristic as affected by intercropping at two years of cropping.

Treatment	Bulk density (kgm^{-3})		Volumetric moisture content (%)	
	Soil depth (cm)		Soil depth (cm)	
	0-10	10-20	0-10	10-20
RRB + 48,000 maize plants/ha	1.46	1.51	30.0	34.3
RRB + 40,000 maize plants/ha	1.47	1.53	30.4	34.7
Local + 48,000 maize plants/ha	1.49	1.56	31.9	35.1
Local + 40,000 maize plants/ha	1.50	1.51	32.4	34.5
Sole RRB	1.52	1.54	30.6	32.7
Sole Local	1.50	1.53	32.8	33.5
48,000 maize plants/ha	1.53	1.55	32.6	31.6
40,000 maize plants/ha	1.54	1.56	32.9	31.9
LSD	0.05	0.07	3.4	3.1

LSD(0.05) for soil depth: BD = 0.03; VMC = 2.3

treatment. Planting maize does not appear to be a good cultural practice for improving soil BD. But intercropping RRB or the local cultivar with maize at both 40,000 and 48,000 plants/ha has the capability of improving the BD by over 35%. Higher soil BD decreases soil permeability and water infiltration thus increasing runoff. According to Karuma *et al.* (2014), tillage practices under cropping systems do affect bulk density, porosity, or values. Soil bulk density decreased, and there was a perceptive increase in water infiltration rate in soil.

Volumetric moisture content (VMC)

The results showed considerable variation in volumetric moisture content (VMC) at different depths (0-10 and 10-20 cm). The VMC in the 0-10 cm depth was generally lower than those in the 10-20 cm depth. In general, intercropped plots had significantly ($p < 0.05$) higher VMC than the sole crops of maize and groundnut within the 10-20cm depths. This result is in agreement with the result reported by Ajayi (2015). The additional surface soil protection in maize groundnut intercrop enhanced soil and water conservation and with careful selection of intercrops, competition for water under intercropping may be reduced (Patil *et al*., 2015). The result further showed that when the BD was low the VMC went high and vice versa, which seems to buttress the fact that BD and VMC were inversely correlated (Bonarius, 1975). It was also evident that VMC among the intercropped treatments was higher than those of sole crops in the 10- 20 cm soil depth suggesting that groundnut in the intercropped treatments was capable of serving as live-mulch to protect the soil from direct sunlight, thereby limiting rapid loss of moisture from the soil. Furthermore, it was observed that maize absorbed moisture more than groundnut and in terms of the varieties of groundnut RRB appeared to have the capacity to absorb moisture more than the local. These observations correspond with those of Crookston and Kent (1976) that the amount and rate of water uptake depend on the ability of the roots to absorb water from the soil with which they are in contact, as well as the ability of the soil to supply and transmit water towards the roots at a rate sufficient to meet transpiration requirement for the plant. Intercropping RRB or the local cultivar with maize at both 40,000 and 48,000 plants/ha has the capability of improving the VMC of the soil by over 75%, which according to soil moisture classification by Fiedler and Reissig (1964) was very high.

Conclusion

The study highlights the intercropping as a beneficial soil conservation and management practice. The soil is characterized by a dominant textural class of sandy clay loam, strongly acid in reaction, low contents of organic carbon, available P and percentage base saturation as well as moderate contents of total nitrogen and effective cation exchange capacity. It should be noted that when the BD is low the VMC becomes high and vice versa due to the fact that BD and VMC are inversely related. Intercropping RRB or the Local cultivar and maize at 40, 000 or 48,000 plants/ha, the farmer has the capability of improving the BD of his soil by over 35% and VMC by over 75%. The results showed that soil bulk density, VMC of the soil were significantly affected by intercropping system and soil depth. The management strategies of the soils for crop production therefore include the following: despite the likely competition for water and plant nutrients in the intercropped system, soil moisture content and infiltration characteristics were better improved under intercropping than sole cropping.

AUTHORS` DECLARATION

We declare that this study is an original research by our research team and we agree to publish it in the journal.

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