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Efficacy study on the influence of Organic Manures and Tillage on Red Cowpea (*Vigna unguiculata* L.) performance in a Sahel Savannah region of Nigeria

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Abstract

The objectives of this work were to determine the effects of tillage depths, manure types, and the nature of their relationships with some performance indices and Grain Yield of red Cowpea (*Vigna unguiculata* L.). The experiment was laid out on a Split plot design; with Tillage depth (Zero, Shallow, and Deep Tillage) as main the plot, while Manure Type (No Manure, Cow Dung and Poultry Manure) was assigned to subplots. Upon analyses using R-Software, Plots treated with Poultry Manure showed the highest positive response compared to no manure and cow dung in terms of growth parameters, above ground biomass (523.3 Kgha^{-1}), and Grain Yield (696.0 Kgha^{-1}). Zero Tillage performed better than shallow and deep tillage. It was concluded that interaction between zero tillage and poultry manure proved the best to improve cowpea grain yield with value of (1063.8 Kgha^{-1}), above ground biomass (766.7 Kgha^{-1}), and can increase farmer's income and feed for their livestock. Pearson's Multiple Linear Correlation indicated high positive relationship between organic manure and all Cowpea parameters measured ($r \geq +0.65 \leq +0.92$). Tillage depth was found to significantly correlate with Pod length ($r = -0.36^*$) and Single Pod Weight ($r = -0.40^*$) at $P \leq 0.05$ in a negative passion.

Keywords: Correlation**,** Cowpea, Organic Manure, Tillage, Yield

Introduction

Vigna Unguiculata L. Walp, commonly known as Cowpea, Wake, or Beans in Nigeria, is a major leguminous crop of the Savanna regions of West Africa commonly found in either white or red coloration. The seeds and fodder as major sources of plant protein, vitamins, and energy for farmers and livestock due to its healthy nutritional status (Samndi et al., 2014). It is also a source of income to small and large-scale farmers. Cowpea fodder is usually stored for sale at the peak of the dry season, and has been reported to increase or stabilize farmers' annual income by about 25% in West Africa (Dugje et al., 2009). Young cowpea leaves and immature pods of cowpea are consumed as protein source. Cultivation of cowpea, if at all, require only a small amount of nitrogen at the initial stage of growth before the start of nodules formation, which is the onset of nitrogen fixation through which nitrogen availability is improved. Intercropping with cereal crops is also a practice by farmers as it inhabits microbes that actively participate in processes, extraction and supply of nitrogen to mixture and succeeding crops (such as millet and sorghum) when grown in rotation especially in areas where poor soil fertility is a problem (Aikins and Afuakwa, 2012). Cowpea yield of 1500 - 2000 Kgha^{-1} is attainable in the Savannah (Chude et al., 2012).

Cowpea can be grown under rainfall, irrigation or residual moisture conditions along river banks or flood plains and fadamas during the dry season. Its optimum temperature range is

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between 28^{0}C and 30°C (night and day) during the growing season. The crop performs well in agro-ecological zones where the rainfall range is between 500 and 1200 mmyr^{-1}. However, with the development of extra-early and early maturing cowpea varieties, the crop can thrive in the Sahel where the cumulative rainfall is less than 800 mmyr^{-1}. Some of these varieties are tolerant to drought and well adapted to sandy loams and poorly fertile soils. However, best cowpea yields are obtained in well-drained sandy loam to clay loam soils with pH between 6 and 7 (Dugje et al., 2009).

Land preparation, especially the disturbance of agriculturally important soil layers by Tillage was reported to be among management practices that affect soil properties and general crop performances (Adekiya et al., 2014; Shahzad et al., 2014; Aikins and Afuakwa, 2012; Adeyemo and Agele, 2010). Positive influences of Organic (OM) quantity and source on the performance and productivity of vegetables were evidently established by Usman (2015), cereals by Adeyemo and Agele (2010), tubers, and legumes by Tanimu and Lyocks (2013). The interaction effects of tillage and OM were also reported to be beneficial to crop production (Adekiya et al., 2014; Adeyemo and Agele, 2010). A study by Alhassan et al., (2018) recommended the combined use of conservational tillage and organic matter incorporation for uplifting soil productivity in Sudano-Sahelian Savannah region.

Sahel savannah is a biogeographic zone of transition in Africa between the Sahara to the north and Sudanian Savannah to the south. A belt of up to 1000 km (620 miles) wide that spans the 5400 km (3360 miles) from Atlantic ocean to Red Sea. In West Africa, the Sahel covers (from west to east); parts of northern Senegal, central Mali, northern Burkina Faso, the larger part of Niger Republic, the extreme northeastern part of Nigeria and central Tchad republic (Wikipedia, 2018).

In the Sahel Savannah with Average Farmers Yield (AFY) between 300 – 1000 Kgha^{-1} of Cowpea (Chude et al., 2012) however, farmers tend to be unmindful of the of positive or negative effects of tillage practices and manure uses despite its abundance, the interaction, and relationship of both practices with performance parameters and yield of legumes, and especially Cowpea, a major crop in the region. Therefore, an understanding of how tillage practices and OM application affect cowpea production in the Sahel Savannah will help farmers to make decision which will provide for more precise practices to improve cowpea production towards higher attainable yields. The objectives of this study were to evaluate the response of some cowpea performance indices and grain yield to tillage and organic manure additions. Also, it aimed to determine the effect of tillage and OM interaction on the parameters, as well as determining the linear correlation between tillage and OM with the cowpea performance indices and Grain yield in the Sahel Savannah.

Materials and Methods

Location

The research was carried out at Madamuwan Gabas located on latitude 12.012^{0}N and longitude 10.564^{0}E, in the Nigerian Sahel Savannah agro ecological zone. The Nigerian Sahel spans over a significant land area in northern Yobe, Borno and Adamawa states (Wikipedia, 2018). The soils of the study location are classified as Alfisols according to USDA system and predominantly Aeric Tropaqualfs characterized by deep and imperfect drainage, and derived from Alluvial weathered-Basement Complex parent materials of sedimentary origin (FDALR, 1990). The climate of Sahel was Aw (Koppen system) signifying Tropical wet and dry seasons (Dugje et al., 2009). The cumulative annual rainfall in the past three seasons in the study area ranged from 550mm – 750 mm as a unimodal occurrence between May and October, with an average annual temperature range of 27^{0}C – 41.6^{0}C across the study area from 2015 to date as in Table 1 (NASA, 2018).

Table 1. Average annual values of some climatic factors in the study area

	Average annual climatic factors			
Year	Max. Temp. (^{0}C)	Min. Temp (^{0}C)	Cum. Rainfall (mmyr^{-1})	Sol. Rad. (KJm^{-2}d^{-1})
2015	43	27	673	16.7
2016	41	26	550	18.1
2017	43	28	750	17.4

Max. = maximum. Min. = minimum. Cum. = cumulative. Sol. = Solar. Rad. = Radiation.

Experimental Design

The experiment was laid out based on split plot design consisting of plots measuring 6m^2 each with Tillage as main plots while OM as sub-plots, replicated three times. Treatments consisted of three three tillage levels: Zero Tillage (ZT) achieved through hand picking, Shallow (0-15cm) Tillage (ST) soil disturbance and Deep (0-30cm) Tillage through disturbing top-soil using calibrated diggers and three types of manures: No manure (No), Cow Dung (CD) and Poultry Manure (PM) applied at the rate of 5.0 tonnesha^{-1} 3 weeks before planting,

Interaction studies were based on the following: Zero Tillage x No Manure (Control – ZTNo), Zero Tillage x Cow Dung (ZTCD), Zero Tillage x Poultry Manure (ZTPM), Shallow Tillage x No Manure (STNo), Shallow Tillage x Cow Dung (STCD), Shallow Tillage x Poultry Manure (STPM), Deep Tillage x No Manure (DTNo), Deep Tillage x Cow Dung (DTCD) and Deep Tillage x Poultry Manure (DTPM).

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Sampling of soil and manures

Composite soil sample of the study location was collected using soil auger at 0-30cm depth prior to application of organic manures. Likewise, the manures used in the study were sampled at the application time.

Laboratory Analysis

Composite samples of the pre-planted Soil and Manures used in the experiment were prepared for physical and chemical properties analyses using standard laboratory samples preparation. Soil reaction (pH) and electrical conductivity (EC) were determined in 1:2.5 (Soil: Water) paste using glass electrode pH and EC meters respectively. Soil particle sizes were determined using the hydrometer method as described in Tanimu and Lyocks (2013). Bulk density (BD) was determined using core sampler (Aikins and Afuakwa, 2012). Organic carbon (OC) was determined using the Walkley-Black wet oxidation method (Walkley and Black, 1934). Total Nitrogen (N_T) was determined using the regular macro-kjeldhal distillation method as in Fedhasa and Tesfaya (2015). Available phosphorus (P) was determined using the method of Bray and Kurtz-Bray 1 extraction (Tanimu and Lyocks, 2013). Exchangeable Cations were extracted using 1M NH_4OAC. Calcium (Ca) and Magnesium (Mg) then read with Atomic Absorption Spectrophotometer (AAS), while Potassium (K) and Sodium (Na) were read using Flame Photometer (Ciesielski et al., 1997).

Agronomic Practices

Variety IT84E-108 was planted on flat land at the spacing of 45 x 45 cm as recommended by Chude et al., (2012). Plots were kept free of weeds to prevent competition with crop. Pod length (cm), Leaf area (cm^2), Plant Height (m), Single pod weight (g) were recorded at harvest while above ground biomass ($Kgha^{-1}$), and Grain yield ($Kgha^{-1}$) were weighed after harvest.

Statistical Analysis

Data collected were statistically analyzed using R software (3.4.3). Upon significant F-Test, Least Significant Difference (LSD) test was used for means separation (Amanullah et al., 2014). Pearson's multiple linear correlation analysis was performed using SPSS to determine the relationship between OM and Tillage, with cowpea performance parameters.

Result and Discussion

Physical and chemical properties of the experimental soil were shown in Table 2. The soil was found to be of Sandy Loam (SL) texture, the soil particle size distribution fall in the Sandy range classified by Hill Laboratories (2010). Sandy ranged soils indicate a high degree of weathering and clay eluviations from the surface layer (Nakao et al., 2009) it is difficult to detect such minor and progressive changes using conventional methods. We measured the amount of the frayed edge site (i.e. the weathering front of illitic minerals, with low OC content and probably nutrient loss through volatilization in the location as reported by Eghball and Power (1999). The findings on the experimental site soil conformed with those reported by Alhassan et al., (2018) on sahelian savannah soils of Bade, Nigeria.

Results in Table 3 showed that the Cow Dung used for the experiment had the least BD of 1.29 gcm^{-3} followed by the experimental PM with BD of 1.32gcm^{-3}. Both manures have lower densities than the soil (1.43gcm^{-3}). Organic carbon content and C: N ratio were higher in CD than PM. Bulk densities of the soil and experimental manures could be attributed to the OC contents of the three media analyzed, as seen in Tables 2 and 3. This attests to a report mentioned in Bouajila and Sanaa (2011) on improvement in BD as a result of high OC content.

A contrasting quality in Tables 2 and 3; is the highest N_T, P and K contents (fertility indices) found in PM as compared to CD and the Study Soil (SS). The soil of the site was very low in N_T, low in available P and high in exchangeable K. This implied that the SS may benefit from the N and P in the manures despite its low Effective Cation Exchange Capacity (ECEC) upon the summation of the basic cations in Table 2. The CD was lower than the soil in all basic cations while PM is higher than the soil in K but lower in all of Ca, Mg and Na contents.

Pod Length (cm)

Results presented in Table 4 indicated that OM had a significant effect on cowpea pod length. Mean pod length is higher in PM (18.2cm) than CD treated plots (16.5cm), while the least and significantly different pod length of 13.7cm was recorded in no manure plots. A study by Meena *et al.*, (2015) crop performance, energy relations and economics in greengram (Vigna radiata L. reported positive benefits of OM from crop residue on a leguminous crop. Tillage depth was also found to be significant. Although mean Pod length was statistically at par for all the depths, values obtained showed that the maximum (17.1cm) was recorded in ZT, while the minimum (14.7cm) was obtained with DT plots (Figure 1). In ST plot however, mean pod length was 16.5 cm. Tillage also established benefits to soil and Green gram (*Vigna radiata* L.) performance in the study of Meena et al., (2015).

Leaf Area (cm^2)

The results presented in Table 4 also showed that cowpea leaf area benefitted significantly from OM application. Mean leaf area values indicated that PM treated plot produced the maximum (138.5cm^2), CD treated plot was 86.8cm^2, and the control plot (No manure) had the minimum leaf area (70.2cm^2). Tillage has no significant effect on leaf area. The interaction of OM with Tillage was highly significant with highest leaf area (163.2cm^2) in ZTPM treated plots and least (54.9cm^2) in ZTNo treated plot as shown by Figure 2. The least performance of Non tilled plots attests to the report of Fuhrer and Chervet (2015).

Plant Height (m)

Statistical analysis of plant height in Table 4 showed the significance of OM application. Mean values of 0.54m and 0.65m that are statistically different for CD and PM were been observed over no manure plots with 0.43m as the mean height of the plants. This finding is at par with that of Idris et al., (2018) on cowpea in the Sahel Savannah of Niger with the addition of Phosphorus, and the study of Soretire and Olayinka (2013) for soya bean height in Abeokuta, Nigeria. Both Tillage type (Table 4) and the interaction between tillage and manure (Figure 3) were found to have no statistical significance on the plant height.

Single Pod Weight (g)

Mean values obtained for single pod weight in Table 4 indicated the significance of OM and that of Tillage for cowpea production in the Sahel savannah. The interaction of OM X Tillage was not significant from the analyzed data in the Table 4, but heavier pods were obtained upon OM interaction with the least soil disturbance (ZT) as seen in Figure 4. This could be attributed to the long term higher soil moisture retention with conservational (no tillage) reported in the study of Fuhrer and Chervet (2015).

Above Ground Biomass (Kgha^{-1})

Above Ground Biomass in CD plot (293.2 Kgha^{-1}) was not statistically different from the plot with no manure (233.0 Kgha^{-1}), while PM plot was statistically significant having a value of 523.3 Kgha^{-1}. ZT (400 Kgha^{-1}), ST (316.6 Kgha^{-1}) and DT (333.3 Kgha^{-1}) were all statistically insignificant in terms of biomass. Tillage X OM was highly significant as depicted by Figure 5. (Idriss et al., 2018) reported a significant increase in cowpea performance in both Niger and Burkina Faso due to OM. Mando and Vanlauwe (2005) also reported a significant long term interaction between tillage and manure on general crop performance and soil properties improvement in the dry Sahelian regions of West Africa.

Grain Yield (Kgha^{-1})

Results in Table 4 also showed that Grain Yield in CD-treated plots (394.7 Kgha^{-1}) was not statistically different from the plot with no manure (216.3 Kgha^{-1}), while yield of (696.0 Kgha^{-1}) from PM treated plots was statistically significant. Findings reported by Olatunji et al., (2012) were at par with this study on PM application. The ZT (503.6 Kgha^{-1}), ST (338.8 Kgha^{-1}) and DT (464.3 Kgha^{-1}) were all statistically insignificant. This conforms with the findings of a number of studies (Idriss et al., 2018; Mando & Vanlauwe, 2005; Meena et al., 2015). The interaction was significant in such a way that the grain yield produced is higher at PM plots in a succession of ZT, ST then DT plots from Figure 6. The yield obtained in ZTPM plot (1063.8 Kgha^{-1}) surpassed the AFY of between 300-1000 Kgha^{-1} highlighted in Chude et al., (2012).

Linear relationships

Correlation analysis between treatments and performance parameters showed that OM had a positive and highly significant correlation with all the cowpea performance parameters and grain yield (Table 5) in the order Plant Height (r = 0.92), Leaf Area (r = 0.86), Single Pod Weight (r = 0.76), Biomass (r = 0.72), Pod Length (r = 0.67) and Grain Yield (r = 0.65). Fertility indices in the OM treated soils are therefore important in such a way that PM gave the highest NPK content which produced the highest results in all the parameters when compared to CD and no manure accordingly.

Tillage, on the other hand, was found to have a negative correlation with the Cowpea performance parameters. Statistically insignificant correlation was observed with Biomass (r = -0.18), Leaf Area (r = -0.09), Grain Yield (r = -0.05) and Plant Height (r = -0.01) as in Table 3, and significant negative relationship was seen with both Single Pod Weight (r = -0.40) and Pod Length (r = -0.36) on Table 5.

Figure 1. Response of cowpea pod length to tillage and OM

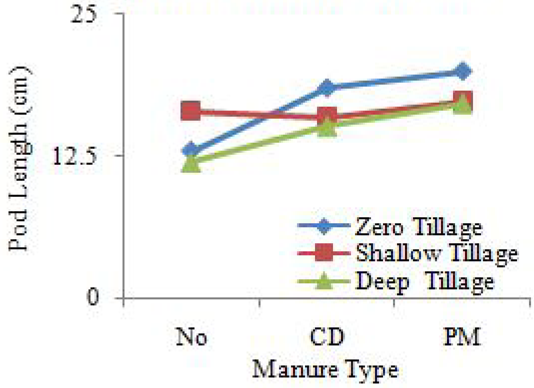


Figure 2. Response of cowpea Leaf Area to t'llage and OM

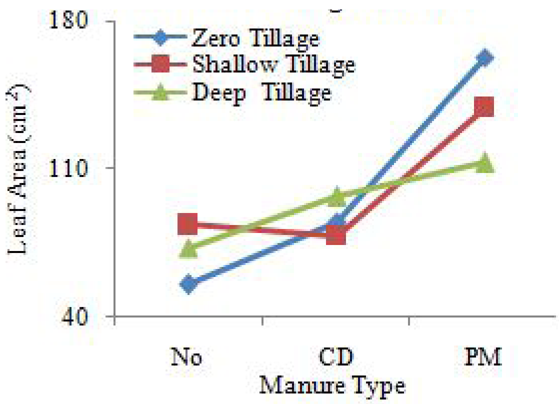


Figure 3. Response of cowpea plant height to tilage and OM

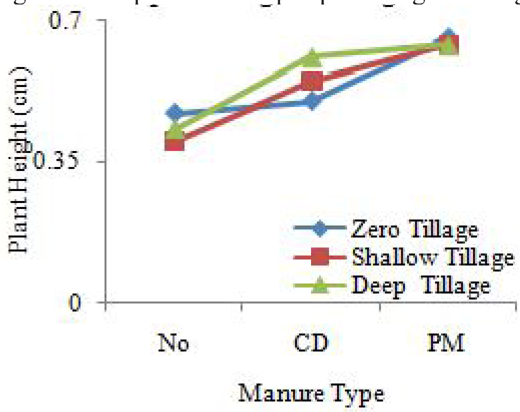


Figure 4. Response of cowpea single pod weight to tillage and OM

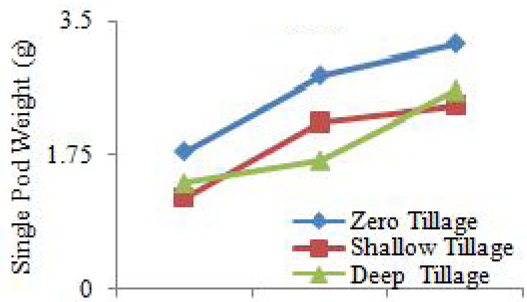


Figure 5. Response of cowpea above ground biomass to tillage and OM

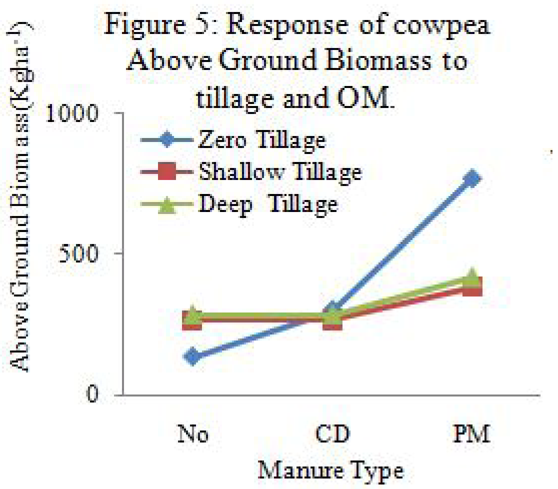
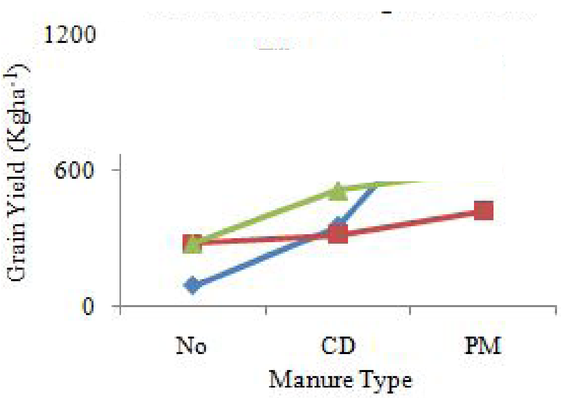


Figure 6.Response of cowpea grain yield to tillage and OM



Conclusion

In conclusion, Interaction between Zero Tillage (ZT) and Poultry Manure (PM) proved to be the best combination to improve cowpea Grain Yield (Kgha^{-1}) and above ground biomass (Kgha^{-1}) in the Sahel Savannah. Manure was found to show high correlation with all the growth parameters and grain yield of cowpea. Tillage depth was also found to significantly correlate negatively with Pod length ($r = -0.36^*$) and Single Pod Weight ($r = -0.40^*$) at $P \geq 0.05$.

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Table 2. Physical and Chemical Properties of the Experimental Site

Analyzed Properties														
Medium	Physical Properties							Chemical Properties						
Texture	Sand	Silt	Clay	BD	OC	EC	pH	N_T	P	K	Ca	Mg	Na	
SS	SL	72	17	11	1.43	1.38	0.88	6.75	0.13	0.36	1.82	4.61	15.4	1.38

SS = Study Soil. Sand, Silt, Clay, OC, and N_T are all in percentages (%). BD is in gcm^{-3}. EC is in dScm^{-1}. P, K, Ca, Mg and Na are in cmol (+) kg^{-1}. N_T = total Nitrogen.

Table 3. Analyzed Properties of the Manures used in the study

Manure	Analyzed Properties									
	BD	OC	EC	pH	N_T	P	K	Ca	Mg	Na
CD	1.29	15.1	Nd	6.70	0.36	0.83	1.31	2.41	0.86	0.98
PM	1.32	12.6	Nd	6.51	0.60	1.30	2.40	3.21	2.00	0.90

CD = Cow Dungs. PM = Poultry Manure. Sand, Silt, Clay, OC, and N_T are all in percentages (%). BD is in gcm^{-3}. EC is in dScm^{-1}. P, K, Ca, Mg and Na are in cmol (+) kg^{-1}. Nd = Not determined. N_T = total Nitrogen.

Table 4. Performance Parameters and Grain Yield of Cowpea as affected by OM and Tillage Methods

Treatments	Pod Length (cm)	Leaf Area (cm^2)	Plant Height (m)	Single Pod Weight (g)	Above Ground Biomass (kgha^{-1})	Grain Yield (Kgha^{-1})
OM (5.0 tonha^{-1})						
Zero	13.7^b	70.2^b	0.43^c	1.4^c	233.0^b	216.3^b
Cow dung	16.5^a	86.8^b	0.54^b	2.2^b	293.2^b	394.7^b
Poultry manure	18.2^a	138.5^a	0.65^a	2.7^a	523.3^a	696.0^a
LSD (0.05)	2.0	17.1	0.04	0.5	115.0	232.2
Tillage						
Zero	17.1^a	101^{ns}	0.54^{ns}	2.6^a	400.0^{ns}	503.6^{ns}
Shallow	16.5^a	100^{ns}	0.53^{ns}	1.9^b	316.6^{ns}	338.8^{ns}
Deep	14.7^a	94^{ns}	0.54^{ns}	1.9^b	333.3^{ns}	464.3^{ns}
LSD (0.05)	2.5	-	-	0.7	-	-
Interaction						
OM X Tillage	Ns	**	Ns	Ns	**	*

Means in the same category followed by different letters are significantly different at P ≤0.05 levels. Ns = non-significant, * significant at 0.05 probability level, ** significant at 0.01 probability level (highly significant).

Table 5. Linear Correlation between OM, Tillage and Cowpea Performance Parameters

Parameters	Organic Manure	Tillage
Grain Yield	0.65**	-0.05
Above Ground Biomass	0.72**	-0.18
Single Pod Weight	0.76**	-0.40*
Plant Height	0.92**	-0.01
Leaf Area	0.86**	-0.09
Pod Length	0.67**	-0.36*

*Correlation is significant at the 0.05 probability level.
** Correlation is significant at the 0.01 probability level (highly significant).

Appendix 1. Effects of OM and Tillage on Cowpea Performance indices as affected by OM and Tillage obtained at Harvest

Treatments	Pod Length (cm)	Leaf Area (cm^2)	Plant Height (m)	Single Pod Weight (g)	Above Ground Biomass ($Kgha^{-1}$)	Grain Yield ($Kgha^{-1}$)
Control	12.9	54.9	0.47	1.8	133.3	92.6
ZTCD	18.5	85.2	0.50	2.8	300.0	354.9
ZTPM	20.0	163.2	0.66	3.2	766.7	1063.8
STNo	16.4	83.4	0.40	1.2	266.7	277.5
STCD	15.9	78.5	0.55	2.2	266.7	317.2
STPM	17.3	139.3	0.64	2.4	383.3	421.7
DTNo	12.0	72.4	0.43	1.4	283.3	278.8
DTCD	15.1	96.7	0.61	1.7	283.3	511.8
DTPM	17.1	113.0	0.61	2.6	416.7	602.3

Control = Zero Tillage x No Manure, ZTCD = Zero Tillage x Cow Dung, ZTPM = Zero Tillage x Poultry Manure, STNo = Shallow Tillage x No Manure, STCD = Shallow Tillage x Cow Dung, STPM = Shallow Tillage x Poultry Manure, DTNo = Deep Tillage x No Manure, DTCD = Deep Tillage x Cow Dung and DTPM = Deep Tillage x Poultry Manure.

Appendix 2. Linear Correlation Matrix between OM, Tillage and measured Cowpea Performance Parameters

Parameters	OM	Tillage	Grain Yield	Above Ground Bio-mass	Single Pod Weight	Plant Height	Leaf Area	Pod Length
OM	1							
Tillage	-	1						
GY	0.65**	-0.05	1					
AGB	0.72**	-0.18	0.84**	1				
SPW	0.76**	-0.40*	0.59**	0.64**	1			
PH	0.92**	-0.01	0.59**	0.67**	0.71**	1		
LA	0.86**	-0.09	0.77**	0.90**	0.59**	0.78**	1	
PL	0.67**	-0.36*	0.54**	0.66**	0.64**	0.55**	0.67**	1

*Correlation is significant at the 0.05 probability level.
** Correlation is significant at the 0.01 probability level (highly significant).
GY = Grain Yield, AGB = Above Ground Biomass, SPW = Single Pod Weight, PH = Pant Height, LA = Leaf Area, and PL = Pod Length.