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Effects of Biochar and Animal Manure on Soil Properties, Nutrient Uptake and Yield Performances of Groundnut (Arachis Hypogeal) in a Tropical Environment

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Abstract: High cost of inorganic fertilizers and poor soil fertility levels are major constraints to food production in Nigeria. Utilization of organic amendments that are environmentally friendly sustainable is a panacea to improving crop yield. This work was carried out in 2018 and 2019 to evaluate the effects of applying sawdust biochar and pig manure on soil physicochemical properties, nitrogen, phosphorus and potassium uptakes and growth attributes of groundnut. Five treatments were evaluated namely: control plot without amendment (T1), 5 tha^{-1} biochar (T2), 5 tha^{-1} pig manure (T3), 5 tha^{-1} biochar + 10 tha^{-1} pig manure (T4) and 10 tha^{-1} biochar +5 tha^{-1} pig manure (T5). The treatments were laid out in a randomized complete block design and replicated five times. Pre-planting and post-planting soil analysis and nutrient uptakes of N, P and K were analyzed. Growth and yield parameters of groundnut were measured. Data were analysed using analysis of variance (ANOVA) and significant means among treatments were separated using Least Significant Difference at 5% probability level. Results showed that plots amended with 5 tha^{-1} biochar + 10 tha^{-1} pig manure increased soil pH by 20.5%, organic matter by 62.1% and total nitrogen by 80.9%. The same rate increased available phosphorus by 49.8% and base saturation by 41.7%. There were 81%, 72% and 62% increase in N, P and K uptakes with application of 5 tha^{-1} biochar + 10 tha^{-1} pig manure when compared to control plot. The highest shoot dry matter (9.05 $kgha^{-1}$), number of groundnut pods (204) and weight of pods (1.15 $kgha^{-1}$) were obtained on plots amended with 5 tha^{-1} biochar + 10 tha^{-1} pig manure. The study showed that amending low fertile soil with biochar in conjunction with pig manure improved the quality, nutrient availability and yield of groundnut and these improvements manifested more when 5tha^{-1} biochar + 10 tha^{-1} pig manure is applied.

Keywords: biochar, eroded soil, nutrient absorption, pig manure, soil fertility, soil quality

Introduction

Among the major factors affecting agricultural production in Nigeria is the problem of soil fertility which is caused by excessive precipitation, leaching of cations, land degradation and runoff. There has been an increase in farm inputs without corresponding increase in the yield among subsistent farmers. In other to solve these problems, pyrolyzing organic waste such as leaves, wood shavings, kitchen wastes etc into biochar for soil amendment has been advocated. Many researchers have stated that biochar is an effective material that reduces the concentration of CO_2 (Meiirkhanuly et al., 2020; Sohi et al., 2010; Lehmann, et al., 2002) and increase the carbon concentration in soils (Thomas et al., 2018; Mensah and Frimpong, 2018).

Biochar is made by heating organic materials under little or no oxygen (Onwudike et al., 2015; Lehmann, 2007) thereby increasing soil quality fixing atmospheric carbon dioxide in the soil (Lehmann, 2007). Soil amended with biochar has been reported to have high fertility status when compared to the soils without biochar (Meiirkhanuly et al., 2020; Yanai et al., 2007). Major et al., (2010) and Chan et al., (2007) have shown that amending soils with biochar increases soil exchangeable bases and reduces soil acidity while Van-Zwieten et al.(2010) reported an increase in soil organic carbon and available phosphorus in soils amended with biochar. Major et al. (2010) have reported that the uptake of soil nutrients by plants was increased in soils with biochar which increases the availability of calcium and magnesium. Biochar improves the ability of soils to hold plant available water and nutrient and also reduces leaching of agricultural chemicals and soil nutrient (Laird et al., 2010) and increase base saturation of the soil. It is a low density material that reduces the bulk density of the soil (Laird et al., 2010) and hence increases water infiltration, root penetration and soil aeration as well as increases soil aggregate stability (Glaser et al., 2002).

Despite these numerous advantages of biochar as soil amendment, most farmers especially those in rural areas where 80% of the groundnuts are produced are not aware of its usefulness as soil amendment and as substitute to chemical fertilizers that are now scarce and unaffordable. There is paucity of information on the effects of biochars and pig manure on groundnut production and uptakes of macronutrients in south-eastern Nigeria. This study aimed at evaluating the effects of biochar and pig manure on soil properties, nutrient uptakes and yield of groundnut in Owerri, Imo State Nigeria.

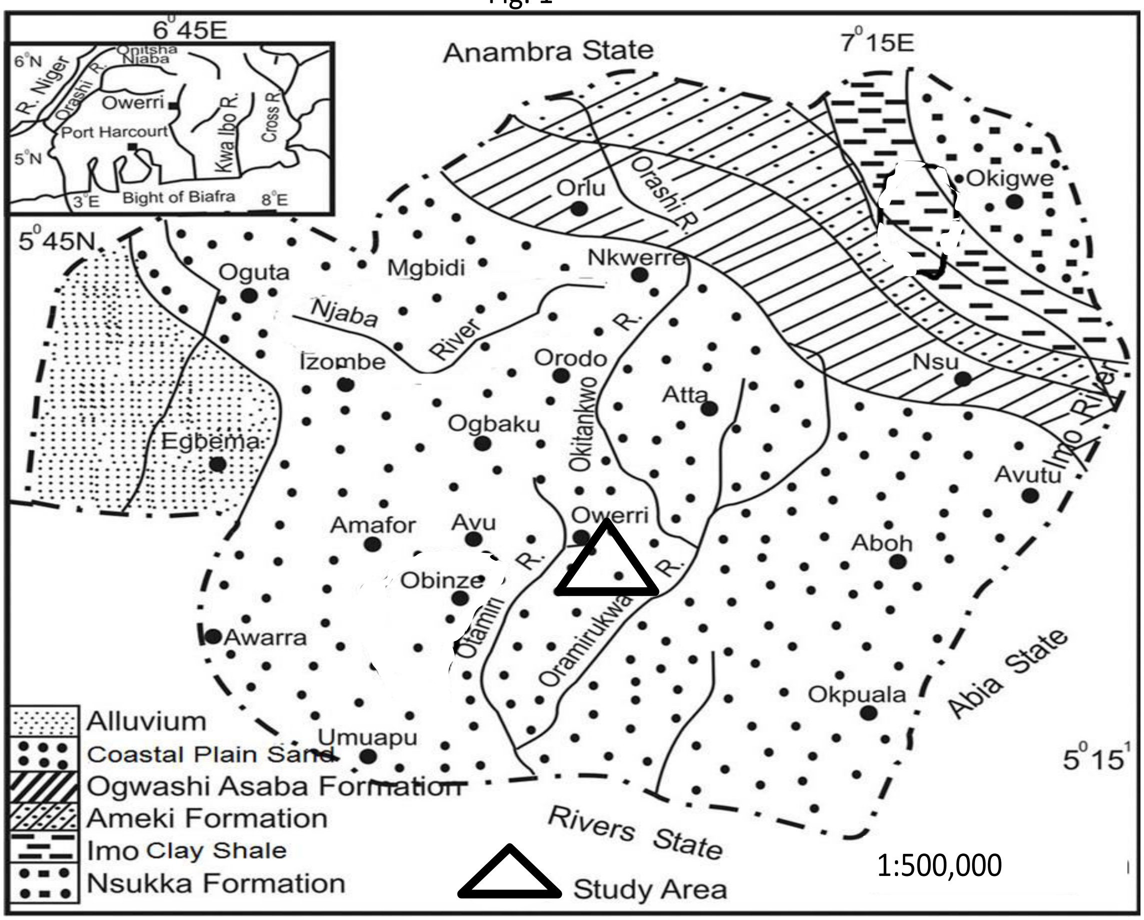
Materials and Methods

Study area

The study was carried out at the Teaching and Research Farm in Federal University of Technology Owerri, Imo State, South-eastern Nigeria during 2018 and 2019 planting seasons. The area lies between latitude $5^{o}17^{1}$N and $5^{o}38^{1}$N and longitude

7°11¹E and 7°45¹E. Annual average rainfall of the area ranged from 1950 —2250 mm with annual mean temperature of 27ºC and 79% annual average relative humidity. Soils in this area have been classified as typic haplusault with coastal plain sand as major parent material (Figure 1). Over 60% of people living in the area are subsistent farmers. Crops mainly grown in the area are maize (Zea mays), cassava (Manihot esculanta), yam (Dioscora specie), groundnut (Arachis hypogeae), vegetables and plantation crops and farmers improve the fertility status of the soil by application of both organic and inorganic fertilizers.

Fig. 1



Geological Map of Imo State showing the Study Area.

materials

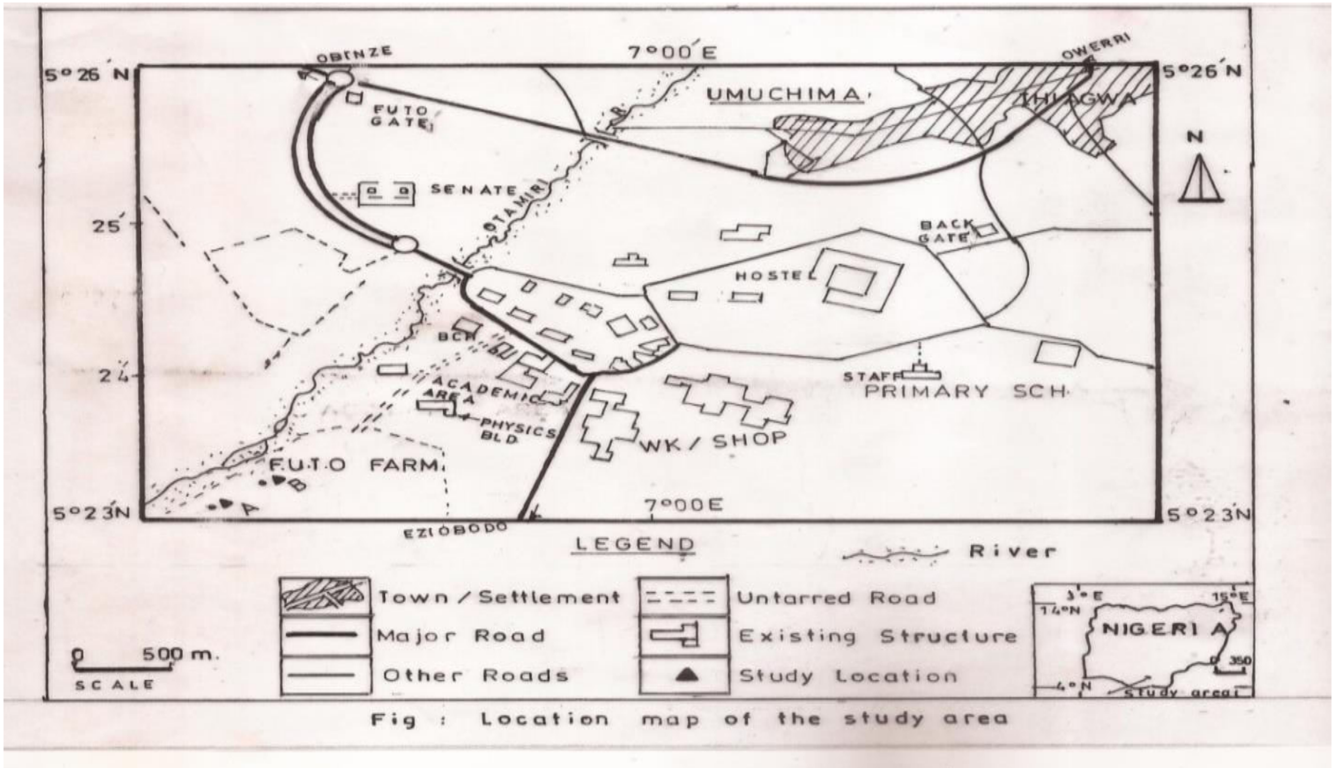


Fig. 2: Location map of the study locations in Federal University of Technology Owerri (Source: Onwudike et al., 2016)

Field preparation, experimental design and treatments

The experiment was a Randomized Complete Block Design (RCBD) with five treatments which were replicated five times. The experimental plot measured $4m^2$ with 1m spacing between plots and blocks. The experiment was carried out in 2018 and repeated in 2019 at different location within the university farm. Treatments used in the study were: T_1= Control plot, T_2 = 5 tha^{-1} biochar, T_3 = 5 tha^{-1} pig manure, T_4 = 5 tha^{-1} biochar + 10 tha^{-1} pig manure, T_5 = 10 tha^{-1} biochar + 5 tha^{-1} of pig manure.

Description of Materials Used

Pig manure was obtained from the piggery farm at the Teaching and Research Farm of Federal University of Technology Owerri while the biochar was obtained by the pyrolysis of sawdust (Figs.3 and 4) which was obtained from Naze Timber Market, Owerri. The sawdust was pyrolyzed under no oxygen in a local drum under controlled environment.

Fig. 3: sawdust biochar

Fig. 4: sawdust before pyrolysis

Treatment application

Treatments were applied by measuring the quantities of treatments allocated for each treatment plot using a weighing balance. The treatments were allowed to incubate for 4 days after application before the test crop was planted.

Planting of test crops

Groundnut (Arachis hypogeal) was used as test crop. Two groundnut seeds were planted at a planting distance of 50 x 50 cm and depth of 3 cm on 4m^2 beds. A week after planting, the seeds were thinned to one seedling per stand giving a plant population of 40, 000 per hectare. The planting procedures were repeated in both years.

Sample collection

Pre-planting and post-planting soil analysis was carried out to determine soil physiochemical properties before and after planting. For pre-planting soil analysis, twenty soil sampling points were collected and bulked together and a composite soil sample was collected for laboratory analysis. Core samples were collected by using a cylindrical metal core of 5.0 cm internal diameter and 5.0 cm height. For post planting analysis, three random composite samples were collected with soil auger from the treatment plots to determine the effect of treatments on soils physicochemical properties.

Laboratory analysis

Particle Size Distribution was determined using hydrometric method. The bulk density was determined by using core sampling methods as described by Grossman and Reinsch (2002) as

$$BD = \frac{MS}{Vt(gcm3)} \text{..................................eqn1}$$

Where Ms =Mass of oven dry soil , Vt =Total soil volume (cm^3)

The total porosity was calculated from the values gotten from the bulk density as

$$\text{Porosity (\%)} = 1 - \frac{BD}{\rho d} \times 100 \text{ .... eqn 2}$$

Where ρd = Particle density, BD = Bulk Density

Soil moisture content was determined using gravimetric method and calculated as shown below.

$$\text{Moisture Content (Water Content \%)} = \frac{(W2-W3)}{(W3-W1)} \times \frac{100}{1} \text{....................eqn 3}$$

Where W_1 = Weight of can, W_2 = Weight of can + wet soil, W_3 = Weight of can + dry soil

Total nitrogen was determined in the laboratory using micro/macham distillation method according to Bremner and Yeomans (1988). Soil pH was determined using glass electrode pH mater according to Hendershot et al. (1993) while soil organic carbon (C) was determined using IN KCl extraction method (Mclean, 1982). Available phosphorus was extracted using Bray II solution method according to Olsen and Somers (1982). Exchangeable potassium and sodium was determined using a flame photometer, while exchangeable calcium and magnesium was determined by EDTA titration method. Effective cation exchange capacity was calculated by the summation of exchangeable bases (Ca, Mg, K and Na) and exchangeable acidity. Percentage base saturation (BS) was obtained by dividing the total exchangeable bases (Ca, Mg, K and Na) by the effective cation exchange capacity. Elemental ratios (C/N, Ca/Mg, and K/ Mg) were obtained by calculation.

Nutrient uptake determination

Two groundnut plants were selected from each experimental plot and air dried at room temperature. Willey hammer was used to grind the sample. The samples were sieved and digested with hydrochloric-nitric- pechloric acid (TEL and Hagarty, 1984). The N, P and K contents in the samples were determined using the procedures used in soil analysis.

Measurement of growth and yield parameters of test crop

Plant height was measured at 2 weeks interval three weeks after planting. Three plants were tagged in each plot and the heights were measured from soil surface to the highest level of leave. Number of branches and number of leaves were counted from the tagged plants at 2 weeks interval. Shoot dry matter was determined by drying the sample of the tagged plants in a dehydrator to a constant weight and the shoot dry matter was calculated by dividing the dried weight with the wet weight. Weight of cobs was measured using weighing balance while number of cobs per tagged plants was counted manually. The average values of the tagged plants were recorded represent each treatment plot.

Statistical analysis

Data collected from soil analysis and growth parameters of groundnut in 2018 and 2019 were matched together and mean values were subjected to analysis of variance and significant means was separated at 5% probability level using Least Significant Difference (LSD).

Results and Discussions

Pre-planting soil physicochemical properties

Properties of soils used in the study are presented in Table 1. Sand fraction dominated the soil fraction. The high sand percentage may be responsible for poor fertility level since high sand fraction favours leaching of plant nutrients. The soil is strongly acidic. Soil organic matter and available phosphorus were low. Exchangeable bases were low according to FAO (2006) fertility rating. The nutrient status of the soil was low and therefore requires an external input for optimum crop yield.

Nutrient composition of biochar and pig manure used in the study

The pH of sawdust biochar was alkaline and higher than that of pig manure which will serve as lime to reduce the acidity of the soil. Organic carbon in biochar was high and above the value in pig manure. However, pig manure contains higher nitrogen and available phosphorus. Biochar has higher C/N than poultry manure indicating lower rate of mineralization process in biochar. Therefore combining two sources of plant nutrients with different rates of mineralization is expected to improve nutrient retention in soils for better crop yield.

Table 1: Pre-planting soil physicochemical properties in 2018 and 2019 study

Soil properties	2018	2019
Sand (gkg^{-1})	735.1	742.3
Silt (gkg^{-1})	112.1	118.6
Clay (gkg^{-1})	152.8	139.1
Textural class	loamy sand	loamy sand
Bulk density (gcm^{-3})	1.11	1.19
Total porosity (%)	58.11	55.1
Moisture content ($gk^{-1}g$)	140.1	152.7
pH(H_2O)	5.02	5.27

Organic matter (gkg^{-1})	5.61	5.82
Total nitrogen (gkg^{-1})	0.10	0.18
Available phosphorus ($mgkg^{-1}$)	6.53	6.11
Exchangeable Ca^{++}) ($cmolkg^{-1}$)	1.39	1.26
Exchangeable Mg^{++}) ($cmolkg^{-1}$)	0.42	0.28
Exchangeable k^{+} ($cmolkg^{-1}$)	0.29	0.16
Exchangeable Na^{+}) ($cmolkg^{-1}$)	0.02	0.06
TEA ($cmolkg^{-1}$)	2.41	2.17
TEB ($cmolkg^{-1}$)	2.12	2.67
ECEC($cmolkg^{-1}$)	4.53	4.84
BS (%)	46.8	55.2

Table 2: Nutrient composition of biochar and pig manure used in the study

Nutrient element	Biochar		Pig manure	
	2018	**2019**	**2018**	**2019**
pH (H_2O)	10.83	10.15	8.32	8.63
Organic carbon (gkg^{-1})	14.20	13.42	10.32	9.47
Nitrogen (gkg^{-1})	0.52	0.67	0.95	0.84
Phosphorus ($mgkg^{-1}$)	1.62	1.72	1.93	1.69
Potassium (%)	5.92	6.11	4.53	3.64
C/N ratio	17.32	20.02	10.86	11.27

Effects of the amendments on soil physical properties

Table 3 showed the effects of sawdust biochar and pig manure on soil physical properties. Application of biochar or pig manure did not significantly ($p = 0.05$) change the texture of the soil. Onwudike et al. (2016) have stated that application of organic manure at short term period did not change the texture of the soil because soil texture is an inherent characteristic of soil and can only be altered by some soil forming factors such parent material, topography and land use system, biological activities and time. However, the amendments significantly improved soil bulk density, total porosity and moisture content when compared to control. Application of 10t/ha biochar+5t/ha pig manure reduced bulk density by 21% and increased total porosity and moisture content by 16% and 42.8% respectively when compared to control. The next treatment following this was plots amended with 5t/ha biochar+10t/ha pig manure. Applying biochar in conjunction with pig manure showed better performance than their sole application. Increase in soil total porosity, moisture content and reduction in soil bulk density of the soil on amended plots could be attributed to high organic matter content in the pig manure and biochar. Previous works have shown that application of organic manure helps to conserve soil moisture and improve soil total porosity and bulk density for root developments and elongation (Onwudike, et al., 2016). Increase in the moisture content of soil with biochar and pig manure application could be due to that fact that biochar is highly porous and depending on the geometry and size of the particles, it may enhance the volume of soil inter-pores (Xiao et al., 2016; Bass et al., 2016; Abel et al., 2013) thereby increasing gravimetric moisture content.

Table 3: Effect of biochar and pig manure on soil physical properties

Treatment	Sand gkg^{-1}	Silt gkg^{-1}	Clay gkg^{-1}	TC	BD gcm^{-3}	TP %	MC gkg^{-1}
T1	780.50	117.25	102.25	Loamy sand	1.13	55.35	149.73
T2	752.50	98.50	149.00	Loamy sand	1.03	61.04	190.33
T3	742.25	104.50	153.25	Loamy sand	1.02	61.10	179.50
T4	747.25	105.00	147.75	Loamy sand	0.98	63.02	257.13
T5	755.50	102.00	142.50	Loamy sand	0.90	66.04	262.10
F-LSD$_{(0.05)}$	Ns	Ns	Ns		0.07	3.83	22.25

Values are means of 2018 and 2019 data, ns = not significant, TC = textural class, BD = bulk density, TP = total porosity, MC = moisture content, T1= control, T2 = 5 t/ha biochar, T3 = 5t/ha pig manure, T4 = 5t/ha biochar+10t/ha pig manure, T5 = 10t/ha biochar + 5t/ha pig manure

Effects of amendments on soil chemical properties

Table 4 showed the effects of sawdust biochar and pig manure on soil chemical properties. The amendments significantly increased soil pH, organic matter, total nitrogen and available phosphorus when compared to control. Plots amended with $5tha^{-1}$ biochar + 10 tha^{-1} pig manure was able to increase soil pH by 21%, organic matter by 62%, total nitrogen by 80.8% and available P by 49.8% when compared to control. Exchangeable bases (Ca, Mg and K) were significantly increased with the amendments except in exchangeable that showed no significant effect. Application of $5tha^{-1}$ biochar+$10tha^{-1}$ pig manure significantly increased exchangeable Ca and K by 48% and 22% respectively while there was 76% increase in exchangeable Mg with application of 10t/ha biochar+5t/ha pig manure. Similarly, application of 5t/ha biochar+10t/ha pig manure increased total exchangeable bases, ECEC, and base saturation by 53%, 18% and 42% respectively. There was 62% decrease in total exchangeable acidity on plots amended with 5t/ha biochar+10t/ha pig manure.

Effects of biochar and pig manure on C/N ratio and K/Mg ratio are presented in Figures 5 and 6 respectively. There was significant reduction in the C/N in the amended plots when compared to control. Plots amended with 5tha^{-1} biochar+10tha^{-1} pig manure recorded the lowest C/N ratio (32.2). Control plots recorded the highest Ca/Mg ratio (4.27) and K/Mg ratio (0.83) when compared to amended plots.

Higher soil pH on plots treated with biochar and pig manure could be attributed to the alkaline property of the amendments (Table 2). It has been shown that during mineralization of organic compounds, basic cations and organic anions are produce which neutralizes the hydrogen ion thereby increasing the pH (Busari et al., 2008). Also, biochar and animal manures contain bicarbonates and calcium carbonate that help to increase the pH of the soil (Whalen et al., 2000). The observation agreed with Raboin, et al. (2016) who stated that biochars are highly alkaline and can increase soil pH by a liming effect driven mainly by the formation of carbonates. Diri et al. (2024) recorded an increase in soil pH with application of organic amendment and attributed the reason to the strong bonds that chelate with hydrogen and aluminium ions thereby reducing the solubility of acid forming cations. Over 60% increase in organic matter resulting from application of these amendments is in line with Whalen et al., (2000) who reported an increase in organic matter content of the soil. Increase in soil pH on amended soils could contribute to the increase in soil organic matter (Jeffery et al., 2011; Barrow, 2012).

High N in the amended soil could be attributed to the ability of biochar in the stimulation of N fixation (Thomas et al., 2018). Therefore, application of biochar on legume crop such as groundnut is expected to increase soil N- bacteria in the root nodules which help in N fixation. In general, biochar is not a direct source of available N and can reduce the availability of nitrate and ammonium (Gao et al., 2019), however, Mensah et al., (2019) and Agegnehu et al., (2016) have shown that biochar improves total N status in several previous tropical studies if applied in conjunction with high N source. High phosphorus level on amended soils could be attributed to the phosphorus contents in biochar and pig manure. This result is in line with Hong and Lu (2018), and Ch'ng et al. (2017) who reported an increase in soil P with biochar applications in tropical soils.

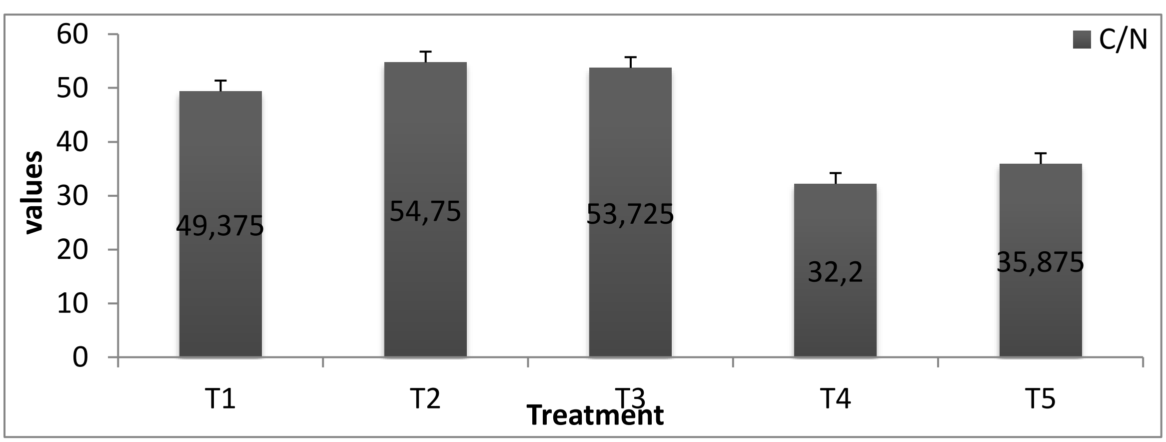
Biochar contains high potassium and this can increase soil K availability by providing K-containing salts such as $KHCO_3$ (Ch'ng et al. 2017). Many tropical field experiment in agricultural systems have reported an increase in soil K with biochar application (Alling et al., 2014; Bass et al., 2016, Lehmann and Joseph, 2009) although, this could be influenced by several soil properties such as clay mineralogy (Yao et al., 2011) and native K- supplying capacity (Li et al., 2009). Organic matter serves as reservoir for basic cations and therefore high organic matter in pig manure could be responsible for significant increase in exchangeable

Treatment	pH(H_2O)	OM	TN	AP	Ca	Mg	K	Na	TEB	TEA	ECEC	BS
		gkg^{-1}	gkg^{-1}	$Mgkg^{-1}$	←		$Cmolkg^{-1}$				→	%
T1	5.03	9.75	0.09	6.22	1.36	0.35	0.28	0.03	2.01	2.43	4.44	45.78
T2	5.20	19.71	0.22	8.75	1.88	1.28	0.34	0.04	3.54	1.79	5.32	66.28
T3	5.66	23.76	0.26	9.62	1.63	1.36	0.28	0.05	3.38	1.27	4.64	72.73
T4	6.33	25.72	0.47	12.40	2.50	1.36	0.38	0.05	4.29	1.18	5.47	78.48
T5	5.88	25.70	0.42	11.86	2.30	1.47	0.36	0.03	4.16	1.22	5.38	77.28
F-LSD(0.05)	0.45	**2.07**	**0.03**	**0.98**	**0.39**	**0.11**	**0.10**	**ns**	**0.39**	**0.18**	**0.47**	**2.90**

bases in amended plots. Brady and Weil (2005) reported that applying organic amendments on low fertile soil will enhance soil nutrient reserves, promote nutrient availability and foster fertility development with resultant increase in crop yield. Amended plots recorded lower C/N ratio indicating an increase in the mineralization of organic materials. Research has shown that high C to N ratio in soil could lead to nitrogen immobilization and therefore, lower values of C to N ratio in plots amended with combination of biochar and pig manure could be responsible for high total nitrogen in these plots (Kuzyakov et al., 2009).

Table 4: Effect of biochar and pig manure on soil chemical properties

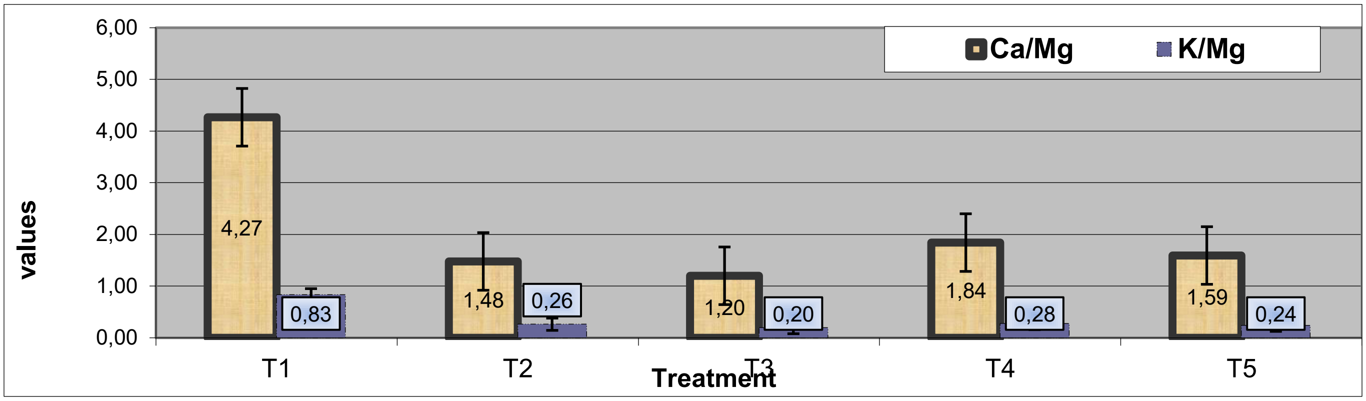
Values are means of 2018 and 2019 data, ns = not significant at 0.05 probability level, OC = organic carbon, OM = organic matter, TN = total nitrogen, AP = available phosphorus, TEB = total exchangeable bases, TEA = total exchangeable acidity, ECEC = effective cation exchange capacity, BS = base saturation, T1= control, T2 = 5 t/ha biochar, T3 = 5t/ha pig manure, T4 = 5t/ha biochar+10t/ha pig manure, T5 = 10t/ha biochar + 5t/ha pig manure.



Values are means of 2018 and 2019 data

T1= control, T2 = 5 tha^{-1} biochar, T3 = 5tha^{-1} pig manure, T4 = 5tha^{-1} biochar+10tha^{-1} pig manure, T5 = 10tha^{-1} biochar + 5tha^{-1} pig manure

Fig. 5: Carbon to Nitrogen ratio as influenced by biochar and pig manure



The amendments significantly increased the N, P and K uptakes when compared to control. Application of 10tha^{-1} biochar + 5tha^{-1} pig manure increased N uptake by 81%, P uptake by 72% and K uptake by 62% when compared to control. This was followed by application of 5tha^{-1} biochar + 10tha^{-1} pig manure. Application of biochar and pig manure increased soil organic matter, soil pH and exchangeable bases as well lowering the C/N ratio of the soil. These attributed contributed to the increase in the N, P and K uptakes in the amended plots. Organic, organomineral and NPK fertilizers applied at all levels were found to increase the yield of maize compared with control. This agrees with the work of Olaniyi and Akanbi, (2007) who found that OG and OMF increased the yield of fluted pumpkin (Telfaira occidentalis)

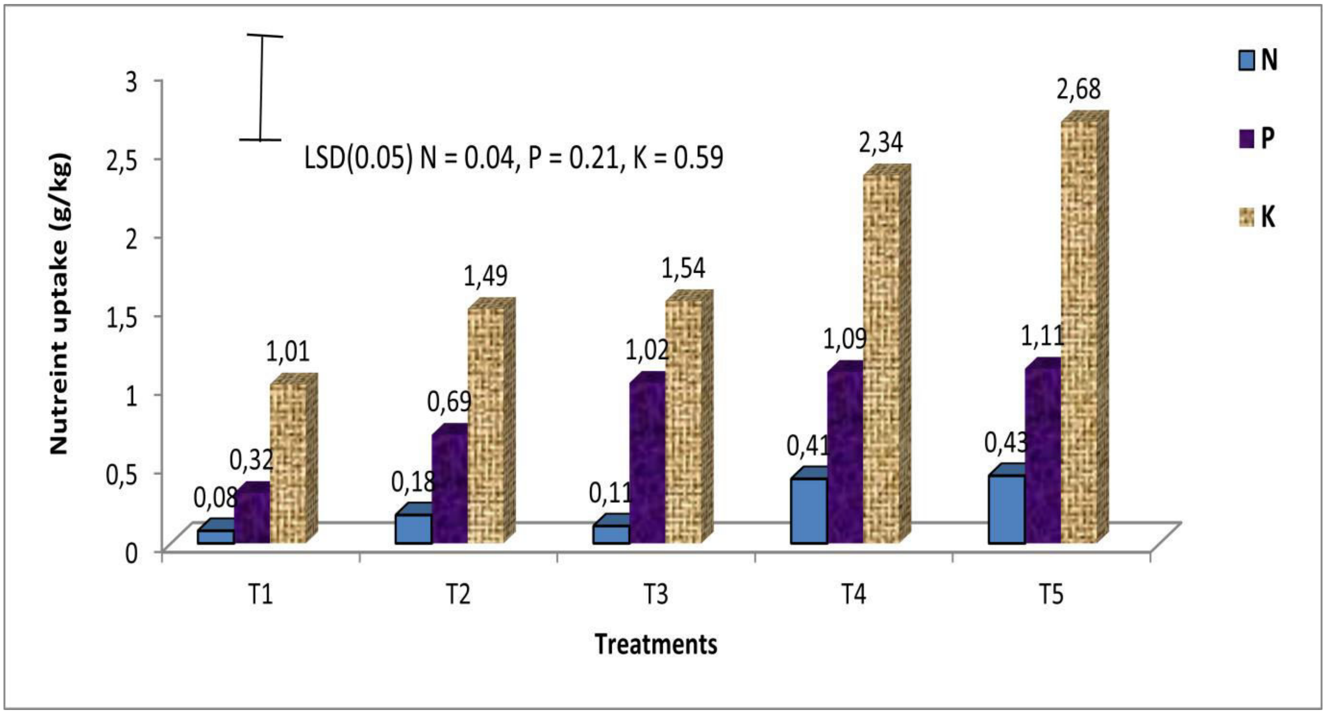
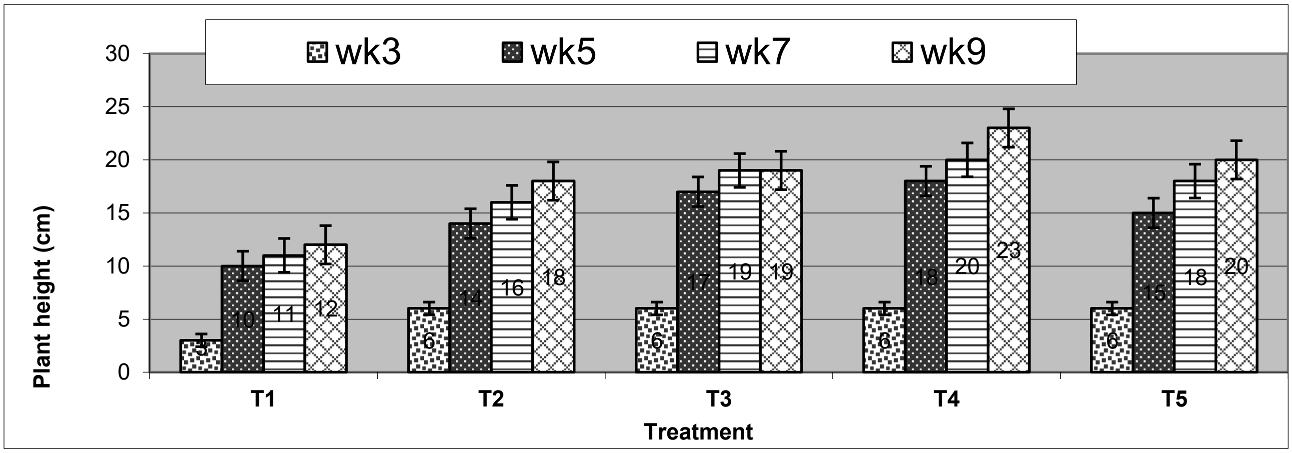
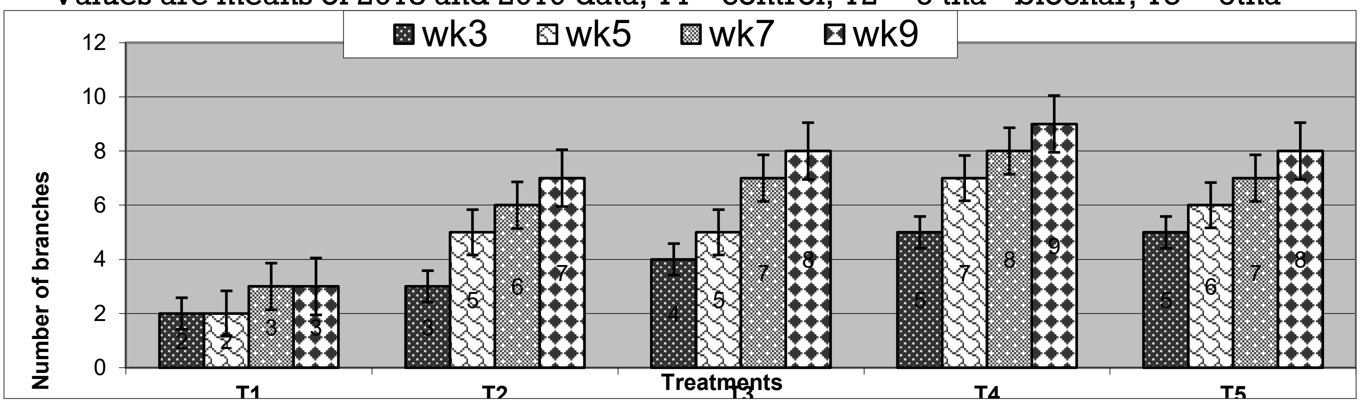


Figure 7. Effect of amendments on growth parameters of groundnut

Effects amendments on groundnut height are shown in Figure 8. The amendments significantly increased the height from 5th weeks after planting. Plots amended with 5tha^{-1} biochar+10tha^{-1} pig manure recorded the highest plant height of 23 cm. This was followed by 10t/ha biochar + 5tha^{-1} pig manure which recorded 20cm plant height. Similarly, the same observation was made on number of branches (Figure 9) and number of leaves (Figure 10). Plots treated with 5tha^{-1} biochar+10tha^{-1} pig recorded the highest number of groundnut branches (9) and highest number of leaves (33). The sequence of performance for both number of branches and number of leaves was T4 >T5 >T3> T2>T1. Combination of biochar and pig manure produced higher height, number of leaves and branches than biochar alone. This observation is in line with Gathorne-Hardy et al. (2009) that recorded higher growth and yield of crop on soil amended with biochar and N- fertilizer than on soil amended with only –fertilizer or biochar and attributed the reason to high affinity characteristics of biochar for water and nutrients which reduces nutrient losses through leaching. This result also agreed with Sujathan et al, (2008), Jayaprakash et al (2003) and Freitas and Stamford (2002) that recorded significant increase in the height of maize with application of organic amendments. Significant increase in the number of leaves and number of branches with application of biochar and pig manure could be attributed to high macronutrients contained in these materials which help in cell division and elongation (Sujathan et al., 2008).

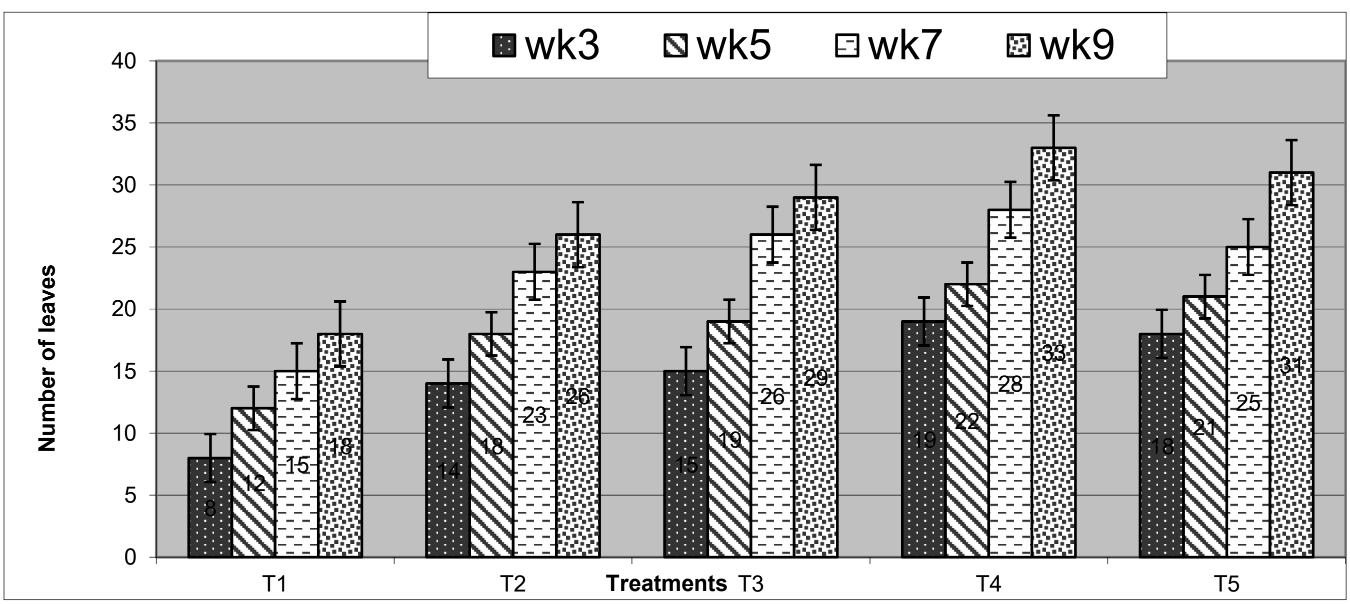


Values are means of 2018 and 2019 data, T1= control, T2 = 5 tha^{-1} biochar, T3 = 5tha^{-1}



pig manure

Fig. 9: Effects of biochar and pig manure on number of branches of groundnut

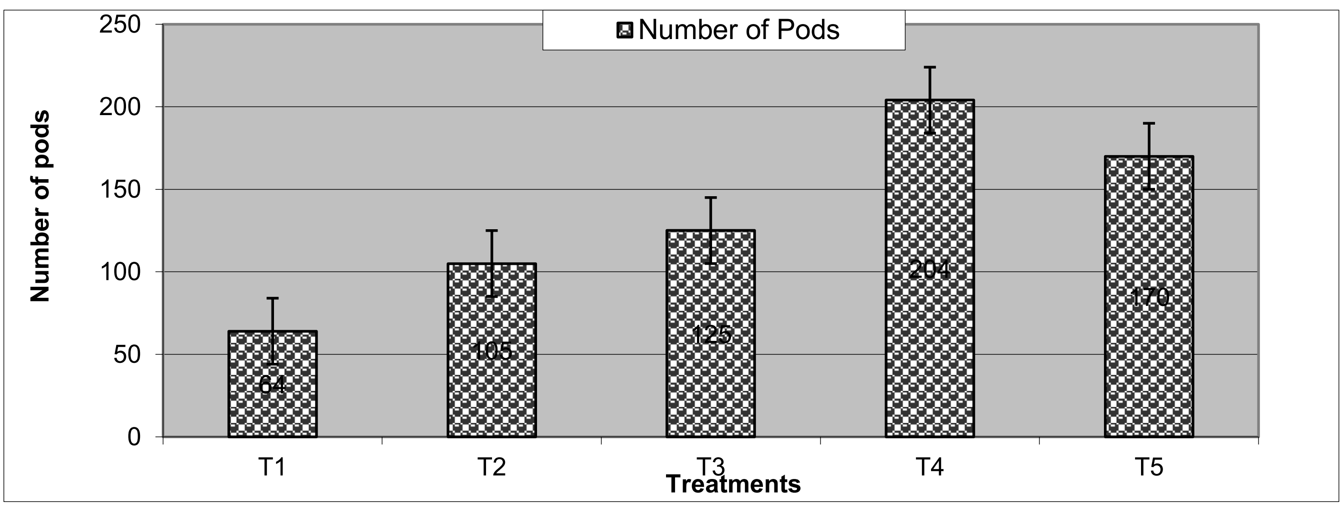


pig manure

Fig. 10: Effects of amendments on number of leaves of groundnut plant

Effect of amendments on yield of groundnut

Effects of amendments on number of pods, shoot dry matter and weight of pods of groundnuts are presented in Figures 11, 12 and 13 respectively. The amendments significantly increased the number of pods, shoot dry matter and weight of pods of groundnut when compared to control. Plots amended with 5t/ha biochar+10tha^{-1} pig manure recorded the highest number of pods (202), highest shoot dry matter (9.06kgha^{-1}) and highest weight of pods (1.15kgha^{-1}) when compared to other treatments. In all these yield parameters, the sequence of performance was T4>T5>T3>T2>T1. Increase in the shoot dry matter with the amendments could be attributed to the nutrient contents in biochar and pig manure. Reduction in soil bulk density, increase in the porosity and gravimetric moisture content of soil, increase in soil ph, organic matter and exchangeable bases as well as reduction in the C.N ratio of soils amended with sawdust biochar and pig manure contributed to higher pods, shoot dry matter and weight of cobs than control plot. Ojeniyi et al. (2010) recorded significant increase in shoot dry matter with application of organic amendment.



Values are means of 2018 and 2019 data, T1= control, T2 = 5 tha^{-1} biochar, T3 = 5tha^{-1} pig manure, T4 = 5tha^{-1} biochar+10tha^{-1} pig manure, T5 = 10tha^{-1} biochar + 5tha^{-1} pig manure

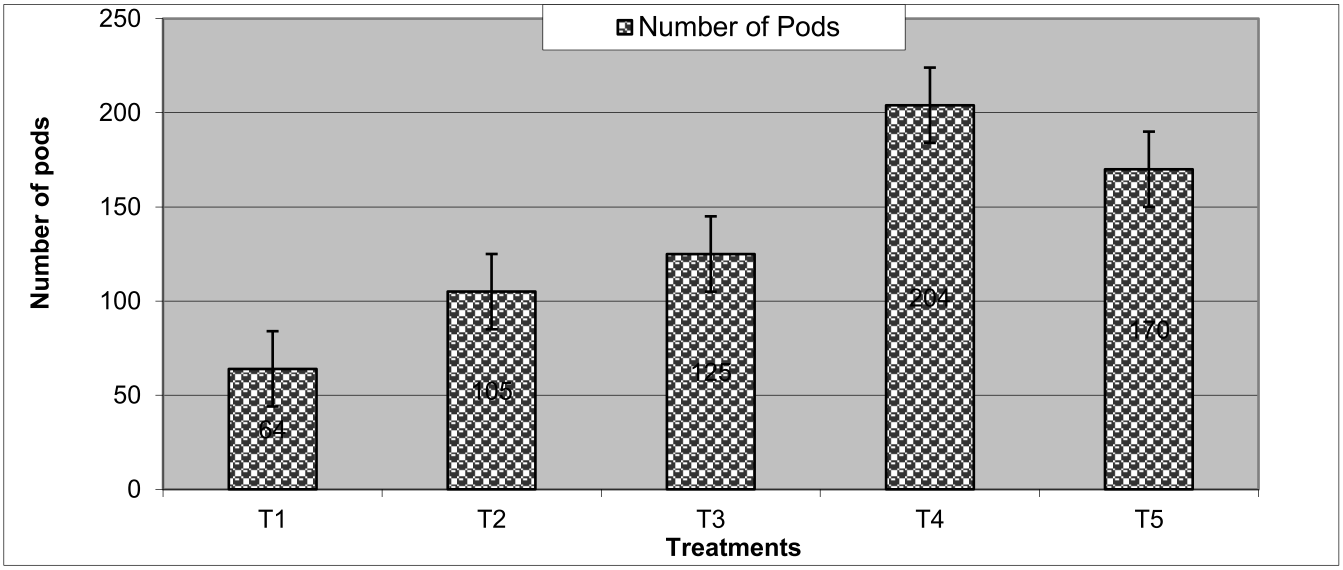
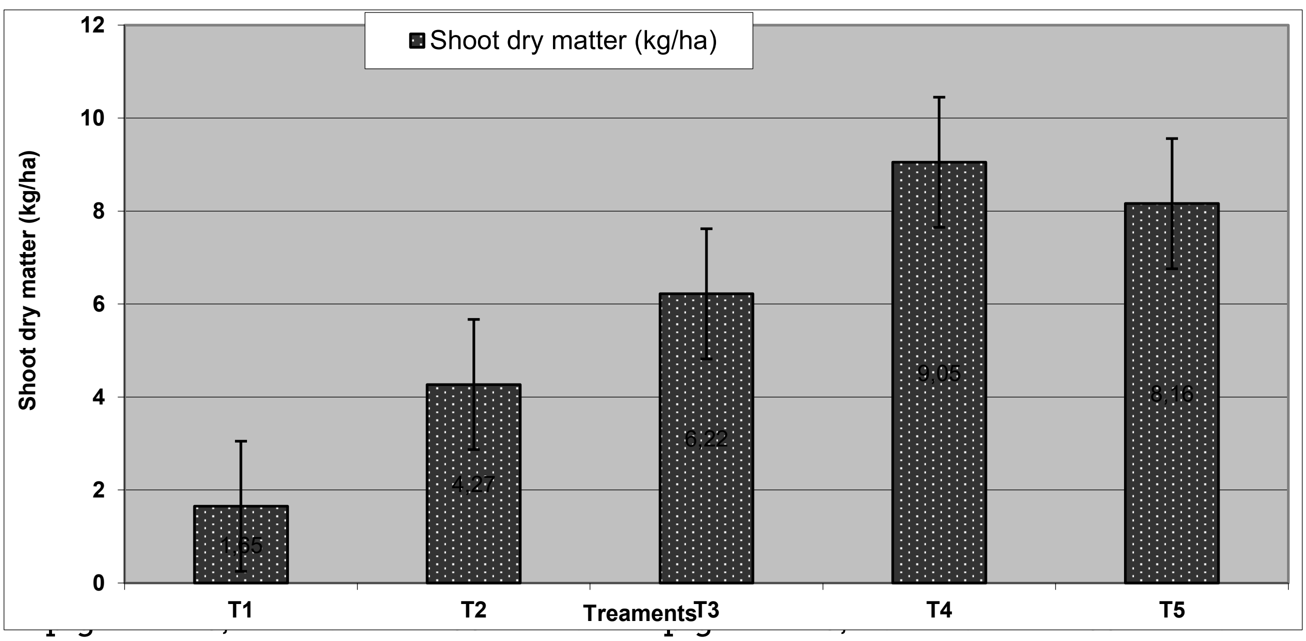
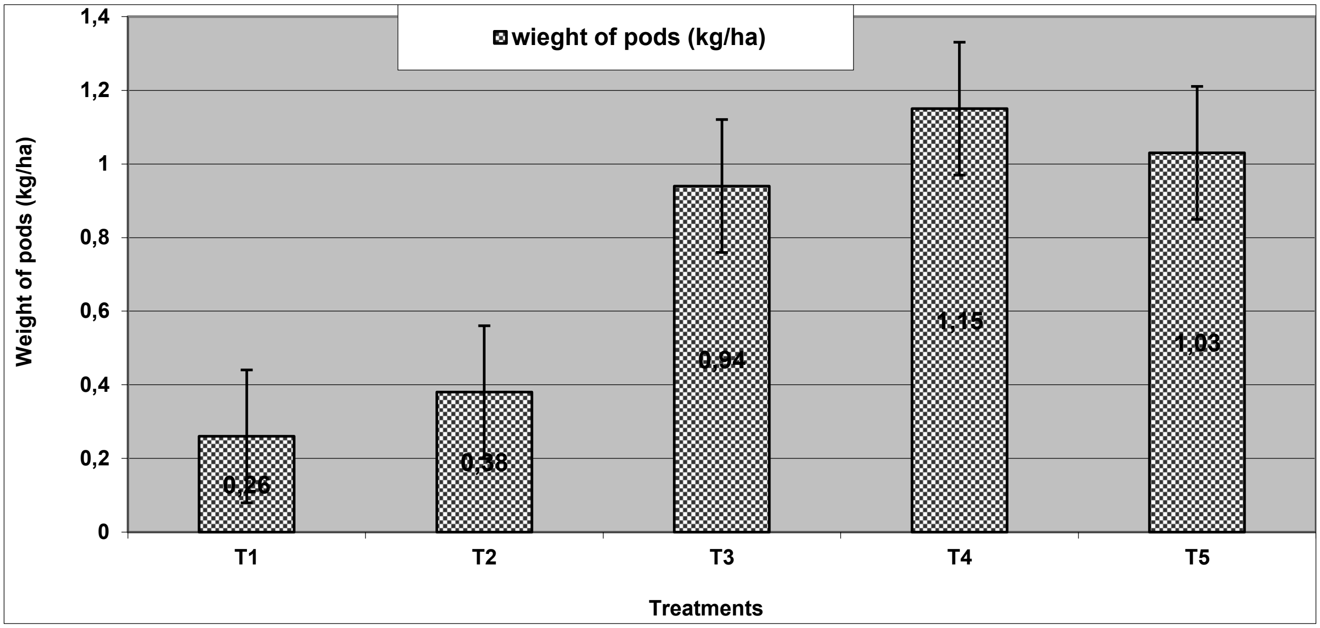


Fig. 11: Effects of biochar and pig manure on number of pods of groundnut plant



pig manure

Fig. 12: Effects of biochar and pig manure on shoot dry matter of groundnut plant



Values are means of 2018 and 2019 data, T1= control, T2 = 5 tha^{-1} biochar, T3 = 5tha^{-1} pig manure, T4 = 5tha^{-1} biochar+10tha^{-1} pig manure, T5 = 10tha^{-1} biochar + 5tha^{-1} pig manure

Fig. 13: Effects of biochar and pig manure on weight of pods of groundnut plant

Conclusion

Application of sawdust biochar in conjunction with pig manure significantly improved soil physicochemical properties, nutrient uptakes of N,P and K and yields of groundnut planted on a loamy sady soil in a tropical environment. Among the treatments evaluated, soils amending soil with 5tha^{-1} biochar+10tha^{-1} pig manure increased soil pH by 20.5% and organic matter by 62.1%. The nitrogen content of the soils which were low before the study were raised by 80.9% and total exchangeable bases were increased by 53.1%. Nitrogen, phosphorus and potassium uptakes were increase with application of both biochar and pig manure and this reflected on the growth and yield of the crop when compared with the control. Therefore applying 5tha^{-1} biochar+10tha^{-1} pig manure on a loamy sandy soil is recommended to improve soil nutrient levels and the yield of groundnut. There is need to confirm the results of this work in other agro-ecological zones and different soil types.

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