Growth and yield of bambara groundnut (*Vigna subterranea L.* Verdc) as influenced by tillage and phosphorus application.

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Citation
Eifediyi, E. K., Ahamefule, H. E., Izuogu, B. N., Ogedegbe, F. O., & Remison, S. U. (2020). Growth and yield of bambara groundnut (*Vigna subterranea L.* Verdc) as influenced by tillage and phosphorus application. *Rastenievadni nauki, 57*(3), 59-70

Abstract
Bambara groundnut (*Vigna subterranea* L. Verdc.) is an indigenous leguminous crop grown in the savannah zones of Nigeria by peasant farmers who rely on low inputs for its growth and yield improvement. But the yield of the crop has remained very low due primarily to the use of unimproved cultivars, poor cultural practices and poor moisture conservation practices. A field experiment was conducted at the Teaching and Research Farm, University of Ilorin, Ilorin Nigeria during the 2017 and 2018 cropping seasons to investigate the effects of tillage methods and phosphorus application on the growth and yield of the crop. The experiment was laid out as a split plot arrangement which comprised of three tillage methods (zero, conventional and traditional); as the main plots and five rates of phosphorus application (0, 20, 40, 60 and 80 kg ha^{-1}) as the subplots. The treatments were fitted into a randomized complete block design replicated three times. The result of the study showed that the bulk density and total porosity of tillage plots were significantly different ($p< 0.05$) at all sampling periods. The result of the study further revealed that using the zero tillage gave the highest physiological growth and yield attributes in both years. The total dry matter increased up to the highest level of P applied (80 $kgha^{-1}$) but seed weight was highest at 40 kg^{-1} P. The increase in seed weight at 40 kg^{-1} P in 2017 was 41.3% greater than control. In 2018, the increase in seed weight was at 40 kg^{-1} P with 35% greater than control. The proximate analyses of the seeds showed that the fat, ash, fibre, carbohydrate and protein contents had similar values which were not significantly affected by the treatments imposed. This therefore suggests that the nutrient composition is a function of genetic composition. The study further showed the presence of essential nutrients in adequate amount and proportion in the seeds and re-affirms its use as a complete food for people living in the rural areas in Nigeria who cannot afford fish, meat or other dietary supplements.

Keywords: Bambara groundnut; phosphorus; tillage; growth; yield

INTRODUCTION

The soils of the southern Guinea savannah zone of Nigeria are low in organic matter content, prone to soil erosion due to sparse vegetation and are also noted for rearing of farm animals because of the abundance of grasses which promotes the extensive grazing of animals. In some cases, the areas are overgrazed which often results in soil compaction and this promotes erosion (Aina, 1979). Although, the soils are low in clay content, crusting and caking during the dry season is a common feature. Farmers in the zone therefore exert a lot of energy in land preparation using traditional hoes to pulverize their soil for the cultivation of bambara groundnut and this often increases the cost of production. In addition, the drudgery which is associated with the use of hoes for tillage has made the cultivation of the crop unattractive to peasant farmers. However, the rich farmers in the zone who can afford the cost of land preparation using conventional tillage equipment are not interested in the cultivation of bambara groundnut due to low yield. But the crop is a staple food in this area.

Conventional tillage is the use of motorized implements in land preparation; while the traditional tillage is the use of crude implements such as hoes, diggers and other tools in land preparation while the zero tillage is the sowing of seeds with minimum disturbance to the soil which is a soil conversation approach in tillage. Although, cultural practice such as tillage will ensure better root penetration, weed and erosion control infiltration and water conservation which will prevent losses from runoff and evaporation to a minimum. But reduced tillage results in increased organic matter and more water-stable aggregates near the soil surface over time, along with higher bulk densities compared to conventional tillage (Kladivko et al., 1986). Similarly, Hernanz et al. (2002) and Heard et al. (1988) reported that zero tillage had higher bulk densities compared to conventional tillage. Laddha & Totawat (1997) reported that conventional tillage reduces soil bulk density. Holloway and Dexter (1991) also reported that conventional tillage improved water storage in the soil, enhanced root growth and increased crop production (Ghosh et al., 2006) over a short period of time. However, Mosaddeghi et al. (2009) reported that soil conditions under a no-tillage conservation system were better than those under conventional system in arid and semi-arid environments. Zero tillage has thus become increasingly popular, due in part to rising cost of fuel, time, labour and has also been shown to reduce erosion and runoff (Lal et al., 2007).

Bambara groundnut (*Vigna subterreanea* L. Verdc) is a member of the family, Fabaceae and the third most important leguminous crop south of the Sahara after cowpea (*Vigna unguiculata)* and groundnut *(Arachis hypogaea)* (Doku, 1995). Bambara groundnut has its fruits (pods) formed underground like groundnut and the soil is sometimes pulverized to facilitate the penetration of pegs which carry pods into the soil that develops into seeds underground. Oseghale et al. (1991) reported the use of traditional tillage methods for the improvement of growth and yield components of bambara groundnut. Howell et al. (1987) attributed higher pod yield of groundnuts to pulverized soils following conventional tillage whereas Colvin (1987) reported the use of minimum tillage for maximum yield in groundnuts.

The soils of the study site is deficient in phosphorus which can be attributed to the reduction in fallow periods (1 – 4 years) due to increase in population, infrastructural development and the burning of crop residues after harvesting, which further aggravates the greenhouse gases in the atmosphere. Bambara groundnut is cultivated in the region without the use of external inputs and this often results in low yield. However, it is a complete food because of high nutritional value (Linnemann & Azam – Ali, 1993), hence can be used for feeding malnourished children and adults displaced by Boko - Haram insurgency living in displacement camps in the region. Moreover, the crop can be used to mitigate food security issues in the region because of its tolerance to drought and improvement of soil fertility by better enhancement of nitrogen fixation compared to other legumes (Karunaratne, 2009). However, it requires external phosphorus application in poor soils for maximum yield. Schulze et al. (2006) reported the role of phosphorus in promoting root development, enhancement of root nodulation and increased yield in legumes. Yakubu et al. (2010) reported increase in the yield of legumes following phosphorus application. Weber (1996) reported the application of 30 kgha^{-1} of phosphorus for optimal growth and nitrogen fixation in legumes in the southern Guinea savannah zone of Nigeria whereas Balarabe et al. (1998) reported the application of 20 – 40 kgha^{-1} of phosphorus for yield improvement in bambara groundnut in the savannah zone of Nigeria. Sessay et al. (2004) reported that improved agronomic practices can be used by farmers to increase growth and yield of crops. Such practices could include tillage and phosphorus fertilizer application as this will improve crop growth and yield potentials due to moisture conservation, improved aeration for roots of crops, increased weed control and better nutrient utilization. Phosphorus application will increase nitrogen fixation and hence soil fertility. The main objective of this study was to assess the effects of tillage and phosphorus rates on the growth and yield of bambara groundnut (V*igna subterranea (*L.) Verdc) in the southern Guinea savannah zone of Nigeria. The specific objectives were to;

(i) determine the physical and chemical properties of the soil before and after the experiment;

(ii) assess the effect of tillage practices and phosphorus application on bulk density and total porosity of the soil;

(iii) evaluate the effect of tillage practices and phosphorus application on number of leaves and leaf area index of bambara groundnut; and

(iv) determine the effect of tillage and phosphorus application on the proximate analyses of bambara groundnut seed.

MATERIALS AND METHODS

Description of the Experimental Site

The experiment was conducted at the Teaching and Research Farm of the University of Ilorin, Ilorin - Nigeria (latitude 8^0 49^1 and longitude 4^0 58^1 East and 307 m above sea level) during the 2017 and 2018 cropping seasons in a southern Guinea savannah zone of Nigeria. The climate of the area is tropical humid with an average rainfall of 1186 mm. The rainfall pattern is intermittent rather than consistent with a mean annual temperature of 29ºC while the average annual relative humidity is about 85%. The soils of the study site are well drained, shallow to deep and the soil order is Alfisols with a textural class of sandy loams belonging to the Tanke series (Ogunwale *et al*., 2002). The soil pH of the area is slightly acidic; clay contents are low with low moisture holding capacity with little structural development. The soils are prone to erosion due to low vegetation cover and the soil depth sometimes shallow due to underlying layers of metamorphic rocks (Jimoh, 2011), which are often, exposed as outcrops in some locations. The features of the farming system of the area are; small scale subsistence farming which rely on low levels of inputs. The study site was under a 2 - year fallow period after maize and cassava cultivation The common crops cultivated range from cereals such as maize (*Zea mays*), rice (*Oryza sativa)* and Guinea corn (*Sorghum bicolor)*; legumes such as cowpea (*Vigna unguiculata*) and soyabean (*Glycine max*); roots and tubers such as cassava (*Manihot esculenta*), yam (*Dioscorea* spp.) and sweet potato (*Ipomea batatas*); leafy and fruit vegetables include amaranths (*Amaranthus* spp.), celosia (*Celosia argentea*), fluted pumpkin (*Telfaria occidentalis*) and okra (*Abelmoschus esculentus*). Cultivation of these crops is mainly during the rainy season, with little cultivation of these crops during the dry season in areas close to streams and rivers. The land is continually cultivated with short period of fallow; and livestock (cattle, sheep and goats) are extensively grazed and this often leads to soil degradation.

Land Preparation and Sowing

In the conventional tillage (7.6 - 15cm), land preparation was done by deep ploughing and harrowing using a tractor mounted disc plough and harrow; while the traditional tillage (0 – 7.5 cm) was done by the use of traditional West Indian hoes whereas in the zero tillage plots; herbicide (glyphosate [N-(phoshonomethyl) glycine]) at the rate of 1.0 kg/ha was applied to control the weeds. Bambara groundnut ((cv. local cream)) seeds were bought in a local market (Ipata market) in Ilorin. Two seeds were sown on the 23rd July 2017 and repeated on the 22^{nd} July 2018 at a spacing of 30 x 30 cm and later thinned to one seedling per stand, three weeks after sowing (WAS).

Experimental Design

The experiment was laid out in a split plot arrangement fitted into a randomized complete block design (RCBD). The main plots was tillage [zero tillage, conventional tillage (7.6 - 15 cm) and traditional tillage (0 -7.5 cm)] while the subplots were the P fertilizer rates (single super phosphate) at (0, 20, 40, 60 and 80 $kgha^{-1}$) which were replicated three times. The plot size was 4 x 4 m with a 1 metre alleyway between plots and 5 metres between the main plots.

Soil Analysis: Twenty soil samples were collected using a soil auger and the grid method, bulked and a composite sample was taken (0-30 cm depth) before sowing and at harvest, individual plots were analyzed for physical and chemical properties. Soil pH was measured (soil: water ratio, 1:2) using a glass electrode; total N content was determined by macro-Kjeldahl method (Bremner, 1965); available phosphorus was determined following Bray No 1 (1N NH4F + 0.5N) extractant by vanadomolybdophosphoric acid method (Kuo, 1996), organic carbon was determined by using the modified Walkley-Black method (Nelson and

Sommers, 1996) and extraction of exchangeable bases was done by using IN ammonium acetate, exchangeable K and Na were determined by using flame photometry while calcium and magnesium were analyzed by atomic absorption spectrophotometry.

The bulk density and total porosity were assessed at 5, 7 and 9 weeks after sowing. Bulk density was calculated based on the work of Cresswell and Hamilton (2002) = soil weight (g)/Dry Soil volume (cm^3), while the total porosity was determined by using the formula; 1 - bulk density / particle density x 100 where particle density was assumed to be 2.65g/cm^3 (Cresswell and Hamilton, 2002).

Data Collection

Data were collected on morphological growth parameters (leaf area index, number of leaves) dry matter component (total dry matter per plant) and yield components (yield per net plot and yield per hectare). Data on leaf area estimation were based on a non-destructive leaf area assessment by measuring the width of the middle leaflet and length based on the procedure of Molosiwa (2012) which is leaf area = 0.74 x 3 x number of leaves x (leaflet Length x Width x π/4) while the leaf area index = leaf area of the plant/ground surface area. The number of leaves was assessed by visual count of the leaves on the five - tagged plants in the middle rows of each plot at 5, 7 and 9 weeks after sowing while the total dry matter accumulation was done by the use of destructive sampling of five plants from the border rows at the end of the cropping seasons. The samples were later oven dried at 60^oC until a constant weight was attained. The seed weight per net plot was assessed by taking the weight of the seeds of the five tagged plants after drying and shelling using a sensitive balance (S. Mettler model). The seeds of the five - tagged plants (net plot) were weighed and extrapolated to get the yield per hectare ($kgha^{-1}$).

Proximate Analyses of the seeds

Crude protein, ash, fibre, moisture, carbohydrate and fat contents were determined by standard methods (AOAC, 2000).

Data analysis

Data collected were subjected to analysis of variance using the Genstat statistical software 17th edition. Means that were significantly different were separated using the Duncan Multiple Range Test (DMRT) at 5% level of probability.

RESULTS

The soil physical and chemical properties are summarized in Table 1. The soil texture is sandy loam and the pH ranges between 6.10 – 6.50 and the exchangeable complex is dominated by Al^{++} ions as shown by the high exchangeable acidity. The soil is low in all plant nutrients evaluated before cropping in 2017; but there was an increase in the nutrient composition at the end of the cropping in 2017.

The soil physical and chemical properties after cropping in 2018 are presented in Table 2. The data on soil pH indicated that irrespective of the tillage method used, the soil was slightly acidic and no significant difference was observed between the treatments. However, using the phosphorus at different rates produced soils which were slightly acidic and the 40 kg ha^{-1} treated plots produced a pH (6.49) which was significantly higher than others. The data on the organic carbon indicated that the zero tillage plot produced the highest values (1.88) (moderate) which was significantly ($p<0.05$) higher than other tillage methods. The P at the rate of 60 kg ha^{-1} produced the highest organic carbon but no significant difference was observed between the treatments. The data on the nitrogen content showed that irrespective of the tillage method used, the zero tillage

Table 1. Physical and chemical properties of the soil before and after cropping in 2017.

Soil Properties	2017a	2017b
pH (H_2O)	6.45	6.10
Organic C (%)	0.42	0.84
Organic matter content %	0.73	1.50
N (g/kg)	0.73	1.45
Ca (Cmol/kg)	0.02	0.08
Mg (Cmol/kg)	1.60	2.80
Na (Cmol/kg)	0.49	0.76
Exchangeable acid	0.15	0.24
K (Cmol/kg)	2.2	3.47
P (mg/kg)	2.20	2.19

2017a - Before cropping, 2017b end of cropping produced significantly higher (0.43%) soil nitrogen than other tillage methods. The use of phosphorus at different rates showed that the 40 $kgha^{-1}$ produced the higher nitrogen content (0.39%) than other rates but no significant difference was observed. The data on P, K, Mg and Ca showed that the zero tillage produced the highest values which was significantly different ($p<0.05$) from the other treatments. The use of P rates on P, K, Mg, and Ca produced values which were significantly ($p <0.05$) different from each other. However, there were no significant tillage and P rates on sodium. There was no significant interaction between tillage and phosphorus rates.

The results on the effects of tillage methods and phosphorus rates on the bulk density in 2017 and 2018 at 5, 7 and 9 weeks after sowing are presented

Table 2. Physical and chemical properties of soil after the experiment in 2018

Treatments Tillage methods	pH in H_2O	OC %	OM %	N %	P $mgkg^{-1}$	K cmol/kg	Ca cmol/kg	Mg cmol/kg	Na cmol/kg
Zero	6.47	1.88a	3.25a	0.43a	6.96a	0.52a	3.37a	5.08a	0.44
Conventional	6.46	1.06b	1.70b	0.33b	6.80b	0.51b	3.28b	4.39b	0.44
Traditional	6.46	0.86c	1.46c	0.32c	6.68c	0.49c	3.26c	4.32c	0.44
DMRT (0.05)	Ns	*	*	*	*	*	*	*	Ns
P (kg/ha)	6.45c	1.19	2.05	0.35	6.80e	0.50c	3.24e	4.28e	0.43
20	6.46b	1.31	2.18	0.35	6.81d	0.50c	3.28d	4.59d	0.43
40	6.49a	1.28	2.25	0.39	6.84c	0.50c	3.29c	4.64c	0.44
60	6.46b	1.34	2.05	0.35	6.88b	0.52a	3.33b	4.72b	0.44
80	6.45c	1.22	2.12	0.35	6.90a	0.51b	3.39a	4.74a	0.46
DMRT(0.05)	*	Ns	Ns	ns	*	*	*	*	Ns
Interaction	ns	Ns	Ns	ns	Ns	ns	ns	Ns	Ns

Values with the same letter in the same column are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT)

Table 3. Effects of tillage and phosphorus application on the bulk density (g/cm^3) of the soil in 2017 and 2018

Treatments	Soil Bulk Density (WAS) 2017			2018		
Tillage	5	7	9	5	7	9
Zero	1.61a	1.66a	1.73a	1.42c	1.39c	1.38c
Conventional	1.41c	1.34c	1.39c	1.44b	1.42b	1.46b
Traditional	1.47b	1.45b	1.43b	1.66a	1.66c	1.71a
DMRT $_{(0.05)}$	*	*	*	*	*	*
P rates 0	1.49	1.51	1.52	1.52	1.51	1.53
20	1.48	1.50	1.52	1.51	1.50	1.52
40	1.49	1.48	1.52	1.51	1.49	1.52
60	1.50	1.47	1.52	1.51	1.48	1.51
80	1.50	1.46	1.51	1.48	1.49	1.50
P DMRT $_{(0.05)}$	Ns	Ns	Ns	ns	Ns	ns
Interaction	Ns	Ns	Ns	ns	Ns	ns

Values with the same letter in the same column are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT)

in Table 3. The zero tillage had the highest range of bulk density (1.61 – 1.73g/cm^3) while the conventional tillage had the lowest range of bulk density (1.34 – 1.42g/cm^3) at the various sampling periods of 5, 7 and 9 weeks after sowing in the two years of study which was significantly ($p<0.05$) different from the other tillage methods. Whereas in the phosphorus treated plots, the highest bulk density (1.53g/cm^3) was observed at 9 WAS in 2018 and the lowest bulk density (1.47g/cm^3) was recorded at 7 WAS in 2017. The application of phosphorus at different rates had no significant effect on the bulk density at the various sampling periods in the two years of study. The absence of significant interaction might be attributed to the treatments responding differently at the various sampling periods in the two years of study.

The results on the effects of tillage and phosphorus application on the total porosity of bambara groundnut in 2017 and 2018 cropping seasons is presented in Table 4.The maximum total porosity of (48.99%) was attained by using the conventional tillage at 7 WAS in 2017, while the lowest porosity (34.39%) was recorded at 9 WAS by using the zero tillage in 2018. The analysis showed a significant difference ($p<0.05$) at the various sampling periods in the two years of study. The highest total porosity (48.08%) was attained at 9 WAS in 2018 when different rates of phosphorus were applied while the minimum total porosity (39.13%) was observed at 5 WAS in 2017. The analysis revealed that no significant differences were observed by using the different phosphorus rates in the two years of study. No significant interaction was also observed in the two years of study.

The result on the number of leaves of bambara groundnut at 5, 7 and 9 weeks after sowing are presented in Table 5. The result of number of leaves showed that the conventional tillage produced the least number of leaves (27.68) and highest number of leaves (36.66) at 5 and 9 WAS in 2017 respectively. The analysis revealed that no significant ($p<0.05$) differences were observed in the two years of study except at 9 WAS in 2017. The effect of phosphorus on the number of leaves in the two years of study were significant ($p<0.05$) at the three sampling periods of 5, 7 and 9 WAS. The highest number of leaves (40.84) was attained at 9 WAS in 2017 when phosphorus was applied at 60kgha^{-1} while the least number of leaves (21.05) was observed at 5 WAS in the same year. The interaction between the tillage methods and phosphorus rates was significant ($P<0.05$) only at 9 WAS in 2017.

The results on the leaf area index (LAI) of bambara groundnut in 2017 and 2018 are presented in Table 6. The highest peak of leaf area index (5.26)

Table 4. Effects of tillage and phosphorus application on the total porosity (%) of the soil in 2017 and 2018 cropping seasons

Treatments	2017			2018		
Tillage methods	5	7	9	5	7	9
Zero	39.25c	37.24c	34.39c	46.61a	47.75a	48.00a
Conventional	46.99a	48.99a	47.55a	45.21b	46.28b	44.74b
Traditional	44.62b	45.23b	46.01b	36.68c	37.14c	35.26c
DMRT $_{(0.05)}$	*	*	*	*	*	*
P rates 0	39.23	42.90	42.79	42.36	42.96	48.08
20	39.33	43.40	42.54	42.63	43.35	42.32
40	39.10	43.93	42.60	42.90	43.81	42.70
60	39.13	44.01	42.56	42.94	44.17	42.97
80	39.46	44.87	42.76	43.17	44.31	43.26
P DMRT $_{(0.05)}$	Ns	ns	Ns	ns	Ns	ns
Interaction	Ns	ns	Ns	ns	Ns	ns

Values with the same letter in the same column are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT)

using 80kgha^{-1} was reached at 9 WAS in 2018 while the maximum LAI (5.12) using the same rate of P kgha^{-1} was attained in 2017. The analyses showed no significant differences except at 5 weeks after sowing in the two years of study. However, using phosphorus at different rates had significant effects ($p<0.05$) on the LAI at the three sampling periods in the two years of study. The highest peak (5.26)

Table 5. Effects of tillage and phosphorus application on the number of leaves of bambara groundnut at in 2017 and 2018

Treatments Tillage methods	Weeks after sowing (WAS) Number of Leaves 2017			2018		
	5	7	9	5	7	9
Zero	27.68	36.10	36.66a	23.94	33.30	34.64
Conventional	31.96	35.51	36.06b	22.42	32.57	34.04
Traditional	31.81	35.46	35.65c	23.18	32.39	33.49
DMRT $_{(0.05)}$	Ns	Ns	*	ns	ns	ns
P rates 0	21.09d	26.15e	27.12e	21.48e	24.92e	26.09e
20	27.78c	31.57	32.08d	22.46d	29.60d	30.71d
40	35.75b	38.56c	38.98c	23.34c	34.62c	35.65c
60	37.68a	40.55b	40.84b	23.91b	35.86b	37.41b
80	37.97a	41.61a	41.68a	24.70a	38.92a	40.42a
P DMRT $_{(0.05)}$	*	*	*	*	*	*
Interaction	Ns	ns	*	ns	ns	ns

Values with the same letter in the same column are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT)

Table 6. Effects of tillage and phosphorus application on the leaf area index of bambara groundnut at 5, 7 and 9 weeks after sowing in 2017 and 2018.

Treatments Tillage methods	Weeks after sowing (WAS) Leaf Area Index 2017			2018		
	5	7	9	5	7	9
Zero	0.24c	2.89	4.75	0.35	2.94	4.81
Conventional	0.35a	3.06	4.76	0.38	3.02	4.86
Traditional	0.31b	3.33	4.84	0.36	2.98	4.81
DMRT $_{(0.05)}$	*	ns	Ns	*	Ns	Ns
P rates 0	0.22e	2.30d	4.21c	0.24e	2.12e	4.27e
20	0.27d	2.84c	4.59b	0.30d	2.58d	4.53d
40	0.31c	3.00c	4.96ab	0.37c	2.87c	4.95c
60	0.35a	3.31b	5.03a	0.44b	3.24b	5.11b
80	0.33b	4.01a	5.12a	0.47a	4.08a	5.26a
P DMRT $_{(0.05)}$	*	*	*	*	*	*
Interaction	*	ns	Ns	Ns	ns	ns

Values with the same letter in the same column are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT)

was attained at 9 weeks after sowing in 2018 while the lowest LAI (0.22) was attained at 5 weeks after sowing in 2015. The interaction between tillage methods and phosphorus rates were significant ($P<0.05$) at 5 WAS in 2017 only.

The total dry matter accumulation as influenced by tillage methods and phosphorus rates in 2017 and 2018 is shown in Table 7. The data on the total dry matter accumulation of (10.15g) was at a maximum in the two years of study when the zero tillage method was used in 2017, while the least total dry matter (6.21g) was observed in the traditional tillage method in 2017. The statistical analysis showed significant ($p<0.05$) differences between the treatments in the two years of study. The use of phosphorus at different rates produced the high-

Table 7. Effects of tillage practices and phosphorus application on the total dry matter and yield components of bambara groundnut in 2017 and 2018.

Treatments	2017	2018	2017	2018	2017	2018
Tillage methods	Total dry matter wt.(g)	Total dry matter	Seed Wt./plot (g)	Seed Wt./plot (g)	Seed wt./ha (kg)	Seed wt./ha (kg)
Zero	10.17a	9.35a	136.80a	112.01a	3040a	2488.9a
Conventional	7.75b	8.73b	131.81b	103.59b	2929b	2301.7b
Traditional	6.21c	6.56c	112.82c	102.17b	2505c	2270.3c
DMRT $_{(0.05)}$	*	*	*	*	*	*
P rates 0	5.63e	4.57e	87.29c	78.63e	1939d	1747.20e
20	6.58d	5.72^{d}	146.42a	118.65b	3253a	2636.4b
40	8.35c	8.28c	148.68a	148.68a	3304a	2711.10a
60	10.70b	10.36b	140.47b	107.57c	3131b	2390.2c
80	12.28a	12.12a	112.86	102.76d	2508c	2283.2d
P DMRT $_{(0.05)}$	*	*	*	*	*	*
Interaction	*	*	*	*	*	*

Values with the same letter in the same column are not significantly different at P = 0.05 using Duncan's Multiple Range Test (DMRT)

Table 8. Proximate analyses of seeds

Treatments / Tillage methods	Moisture content (%)	Dry matter (%)	Crude fat (%)	Total ash (%)	Crude protein (%)	Crude fibre (%)	Total carbohydrate (%)
Zero	8.81	91.75	5.41	3.09	23.98	2.99	56.25
Conventional	8.87	91.97	5.41	3.08	24.01	2.89	56.26
Traditional	8.87	91.83	5.42	3.08	24.00	2.88	56.20
DMRT$_{(0.05)}$	Ns	ns	Ns	Ns	ns	ns	Ns
P rates 0	8.88	91.26	5.40	3.06	23.99	2.89	56.05
20	8.84	91.68	5.41	3.04	23.99	2.88	56.22
40	8.85	92.11	5.41	3.10	24.01	2.89	56.27
60	8.85	92.02	5.41	3.11	24.00	2.90	56.32
80	8.86	92.29	5.42	3.12	23.99	2.90	56.31
DMRT$_{(0.05)}$	Ns	ns	Ns	Ns	ns	Ns	Ns
Interaction	Ns	ns	Ns	Ns	ns	Ns	Ns

est dry matter (12.28g) in 2017, while the control produced the least total dry matter (4.57g) in 2018. The statistical analysis showed that significant differences ($p<0.05$) between the treatment means was observed. In addition, there was significant interaction ($p<0.05$) between tillage and phosphorus application only in 2017.

The seed weight per plot in 2017 and 2018 is presented in Table 7. The data indicated that the highest seed weight (136.80g) was produced by the zero tillage in 2015 and the lowest seed weight (102.17g) was produced by the shallow tillage. The analysis showed significant ($p<0.05$) differences at the two years of study. The use of phosphorus also showed that the highest seed weight per plot (146.42 g) was produced at the 40kg ha^{-1} in 2015, while the lowest seed weight per plot (78.63g) was produced in the control in 2016. The analysis indicated significant ($P<0.05$) differences was observed between the different tillage practices and the control. Moreover, there was significant interaction ($p<0.05$) between the tillage methods and the phosphorus rates in the two years of study.

The data on the seed weight per hectare in 2017 and 2018 is presented in Table 7. The data indicated that the use of zero tillage produced the highest seed weight per hectare (3,040 kg) and the shallow tillage produced the lowest seed weight (2,270 kg ha^{-1}) in 2017 and 2018 respectively. The analysis revealed a significant difference ($p<0.05$) between the treatment means. The application of phosphorus at different rates also produced the highest yield (3,304 kg ha^{-1}) when 40 kg ha^{-1} of P was applied while the control plot produced the lowest seed weight per hectare (1747.20 kg). The statistical analysis revealed significant differences ($p<0.05$) between the treatment means. In addition, there was a significant tillage and phosphorus interaction ($p<0.05$) at the two years of study.

DISCUSSION

The nutrient status of the experimental site was enhanced at the end of the 2015 cropping season due to nitrogen fixation by the crop (Karunaratne, 2009).This tremendous increase in the nitrogen contents was also reenacted in the individual plots at the end of the cropping season in 2016.This further re-affirms the use of legume in the management of fallows especially in impoverished soils. The tillage methods used had similar soil pH values and this is in agreement with the report of Rasmussen (1999) but contrary to Rahman et al. (2008) and Lal (1997). The nurients composition (Exchangeable K, Mg and Ca) in the zero tillage were higher than that of the deep and shallow tillage due to plant debris which were left on the soil surface that acted as mulch, prevented erosion and on decomposition acted as organic inputs and increased the population of macro-organisms such as earthworms which created tunnels, increased the soil porosity and this is in consonance with the findings of Rahman et al. (2008).The result of the study showed that in the first year, the deep tillage had higher porosity which increased infiltration for some time but in the second year, the zero tillage had porosity due to repackaging of the soil aggregates in the deep tillage plots (Martinez et al., 2008). Shukla et al. (2003) had reported that zero tillage had higher infiltration rates due to the organic matter content and hence the protection of the soil surface from the vagaries of weather. Pagliai (2004) also reported that minimum tillage improved the soil pore spaces by increasing the storage pores hence increase in the water content in soil, an increase of available water for plants. Voorhees & Lindstrom (1984) also reported that reduced tillage produced better soil porosity and overall soil quality (tilth), but three to four years of reduced tillage were required for these changes to take full effect. They further reinterated that zero tillage maybe slow to show its full benefits, but after a few years will show improvement over conventional tillage (Franzluebbers, 2002).The zero tillage had highest bulk density at the three sampling periods in the first year but lowest bulk density in the second year of the study. Also the zero tillage had high water holding capacity which could be attributed to its organic matter content due to debris accumulation on the soil surface which on decomposition increased the activities of macro and microorganisms such as earthworms which created tunnels hence higher porosity and better soil aeration during the period of the study. This is in agreement with the findings of Hernanz et al. (2002) Meyer & Mannering (1961) who reported that zero tillage results in increased organic matter and more water-stable aggregates near the soil surface over time, along with higher bulk densities as compared to conventional tillage. Similar result was also found by Ghosh et al. (2006), Shukla, Lal, Owens & Unkefer (2003) who also reported that Infiltration in no-tillage soils is deemed higher as a result of less compacted, rougher soil, and better soil aeration .Mosaddeghi et al (2009) had reported that tillage methods affects the physical properties of soil and crop growth. There was an increase of 3.65% in yield in the zero tillage plots over the conventional tillage and 17.54% over the traditional tillage in the first cropping season. A similar trend was followed in the second cropping season. This was in conformity with the findings of Pendersen & Lauer (2003) and Yusuff et al. (1999). The yield differential could be adduced to the higher organic matter content of the zero tillage plot. The results showed that the application of phosphorus enhanced all the parameters tested on legume grains and that their responses to phosphorus differs. This result confirms the observation of Weber (1996) that in the southern Guinea savannah zone of Nigeria, legumes require about 30kgPha^{-1} for optimal growth and nitrogen fixation but due to the depletion in savannah soils, 40kgPha^{-1} could be recommended. The increase of the whole plant growth and plant nitrogen concentration in response to increased soil phosphorus supply has been noted for several leguminous species including groundnut (Rebafka et al., 2003) soybean (Kwari, 2005) and cowpea (Uzoma, et al., 2006). However, Tsvetkova & Georgiev (2003) observed that excess phosphorus application can cause decrease in plant growth and reduction in nodulation. The yield difference with respect to tillage can be adduced to different moisture level at the root zone particularly during the period of pod formation and pod filling (Collinson et al., 2000). The higher yield (3040 kg/ha)obtained in the zero tillage plots could be attributed the increase in organic matter content and higher moisture retention and the 3304 kg ha^{-1} obtained in the 40 kgha^{-1} plot was in the range of what was reported by Collinson et al.(2000) who asserted a yield range of 3.0 – 3.8t/ha under favourable conditions but lower than 4.8t/ha reported by Kouassi & Zorro (2010).This is in line with observation of Kargas et al. (2012) who reported that zero tillage is an effective way of reducing soil and residue disturbance, moderating evaporation and minimizing erosion losses. Pedersen & Lauer (2004) observed a 6% greater yield in soybean planted in a no-tillage system compared to a conventional tillage system. Similarly, in Alabama, Edwards et al. (1988) showed a soybean yield advantage of 736 kg ha^{-1} in a no-tillage system than in a conventional tillage system in three out of four years. Fertility study in Illinois also showed that soybean planted in a no-tillage system was observed to yield less than soybean planted under other various tillage practices (Vasilas et al., 1988). The similarity in the seed compositions with respect to tillage and rate of phosphorus in the experiment could be attributed to genetic makeup of the seed since nutrients composition of a seed is mainly dependent on the seed genetic traits. The protein content of the seeds were within the range of 16 – 26% as reported (Onimawo et al., 1999; Linneman & Azam- Ali, 1993). The carbohydrate content was also in the range of (53 – 60%) as reported (Onimawo et al., 1999). The crude fat was (7 – 8.5%); this was lower than what was reported by Onimawo et al. (1999). This therefore suggest that nutrient composition of the seeds is superior to other legumes (Linneman & Azam – Ali, 1993). Balole et al. (2003) had reported that mounding a form of deep tillage had negative effect on flowering and hence yield. Boone & Veen (1994) opined that tillage had a positive effect on crop yield due to its effect on root growth, water and nutrient use (Davies, 1994) and agronomic yield (Lal, 1993). However, Malhi & Lemke (2007) reported an increase of 22% in root mass under zero tillage compared to deep tillage due to the formation channels and air spaces created by earthworms and higher number of biosperes (Francis & Knight, 1993) which assists in root elongation and increase in the number of roots that will aid in nutrient absorption.

CONCLUSION

This study shows the importance of zero tillage over conventional tillage and traditional tillage and also the importance of phosphorus at low rates (40 kgha^{-1}) in increasing the yield of bambara groundnut. There was also an advantage in increasing the organic matter content of the soil and yield. The herbicide used posed no threat to the environment because it can readily decompose (by photo decomposition and microorganisms) compared to other methods. This means that the cultivation of bambara groundnut in this area can be done without yield losses as was demonstrated in this study.

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