FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 9 No. 6, June, 2025, pp 118 – 126
DOI: https://doi.org/10.33003/fjs-2025-0906-3720

GROWTH AND YIELD OF BAMBARA GROUNDNUT AS INFLUENCED BY POULTRY MANURE RATES AND INOCULATION IN NORTHERN GUINEA SAVANNAH OF NIGERIA

***[1]Kabir Muhammad Ladan [2]Habu Nasiru Kura and [2]Abdul Bamidele Lawal**

[1]Department of Agronomy, Faculty of Agriculture Federal University, Dutsin-Ma, Katsina State
[2]Department of Agronomy, Faculty of Agriculture, Ahmadu Bello University, Zaria

*Corresponding authors' email: Ladanoladan@gmail.com

ABSTRACT
Bambara ground nut is a nutrient-dense legume termed a "complete food" due to its balanced macronutrient composition, however poor soil fertility is one of the most important biophysical constraints to its productivity. Also, combination of nutrient demand with supply is critical for plant growth, development and yield. Therefore, this study was conducted to evaluate the effect of poultry manure and inoculation on growth and yield of Bambara groundnut during the dry season of 2020/2021 cropping season at irrigation farm of Institute for Agricultural Research IAR, A.B.U., Samaru- Zaria and College of Agriculture and Animal Science, Irrigation Farm Mando, Kaduna both located in the Northern Guinea Savannah Ecological Zone of Nigeria respectively. Treatments consisted of four rates of poultry manure (0.0, 2.0, 4.0 and 6.0) tons ha-1 and two levels of rhizobium inoculation; no inoculation and inoculation. Treatment were factorially combined in a randomized complete block design (RCBD) and replicated three times. Data on growth parameter were collected on plant height (cm), leaf Area index (LAI), Crop growth rate (CGR) Relative Growth Rate (RGR) and kernel yield kg ha-1 were collected. Results showed that 6 tons/ha poultry manure recorded significantly higher values of growth parameters like plant height (cm), leaf Area index (LAI),crop growth rate (CGR) Relative Growth Rate (RGR) and kernel yield kg ha-1 of Bambara groundnut over other rates evaluated at both locations. While inoculation of Bambara groundnut significantly resulted in higher performance in both growth and yield parameters evaluated over non-inoculated Bambara groundnut plants at both locations. From the results obtained, the combination of 6.0 ton ha-1 poultry manure and Bambara ground nut inoculated with rhizobium inoculant produced better performance on growth and yield of inoculated Bambara groundnut at both locations.

Keywords: Bambara groundnut, Growth, Inoculation, Nigerian Savannah, Poultry manure, Yield

INTRODUCTION

Bambara groundnut (V*igna subterranean* (L.) Verdc), a member of the Fabaceae family is a tropical annual pulse crop with underground pods and is the third most important food grain legume after groundnut (A*rachis* h*ypogea* L.) and cowpea (V*igna u*n*guiculata (*L*).*W*alp*) in semi-arid area of sub-Sahara Africa (Adeyeye *et al*., 2019). It is also a drought tolerant, sustainable, low-cost source of complex carbohydrates, plant-based protein, unsaturated fatty acids, and essential minerals (magnesium, iron, zinc, and potassium), especially for those living in arid and semi-arid regions; it is resilient to adverse environmental conditions and can yield reasonably well on poor soil (Obidiebube *et al.,* 2022,Tan *et al*., 2020).

Bambara groundnut also known as Bambara nut is an important source of protein in the diets of a large percentage of the population, particularly the resource poor rural people who cannot afford expensive animal protein (Emilia and Agbachi, 2018). Bambara groundnut is used for food, feed and for industrial as well as for medicinal use (Obidiebube *et al*., 2019). As a legume, it fixes atmospheric nitrogen through root nodules which contributes to improving soil fertility (Sprent *et al*., 2010), in addition to being an agronomically and nutritionally good complement to cereal crops (Halimi *et al.,* 2019). It is one of the underutilized (orphaned) leguminous crops that could be an important future crop to cushion global food demand and ensure food security especially in Africa and the Asian continent (Khan *et al*., 2020). Production is primarily at subsistence level, and only the surplus is sold. In Nigeria production of Bambara groundnut was mostly carried out at semi-arid areas of Northern Nigeria, where there is low moisture availability coupled with low soil fertility. For Africa, the crop offers various benefits, being an ideal subsistence crop, a good rotation crop, a good backstop for hungry times, and a promising commercial resource (Gerrano *et al*., 2021).

In Nigeria, the fresh pods are boiled with salt and eaten as a snack. Additionally, the dry seeds are ground and made into a dough paste delicacy (popularly known as 'okpa') wrapped in banana leaves before cooking which can be consumed for breakfast, lunch or supper by families with average income, although it is generally enjoyed by many. Caroline (2003) and Omoikhoje (2008) described nutritional value of Bambara groundnut as follows: carbohydrates (54.4-69.3%), protein (17-24.6%), and fat (5.3 -7.8%), while calories are 367 - 414 cal per 100g. It is a good source of fiber, calcium, iron and potassium; usually high in methionine. Application poultry manure to the soil improves the growth and yield performance of Bambara groundnut (Ibrahim, 2015), through adding organic matter to the soil which improves the soil structure, enhance uptake of plant nutrients. Poultry manure also ensures adequate supply of nitrogen which is beneficial for carbohydrate and protein metabolism, promoting cell division and enlargement in Bambara groundnut (Ikhajiagbe *et al.,* 2021). Poultry manure also enhances the activities of soil macro and microorganisms and also increased the water holding capacity of the soil leading to adequate crop growth and development.

The present low yield of Bambara groundnut in Nigeria is between 0.4- 0.75 ton/ha despite having a potential yield of up to 3 ton/ha (Majola *et al.,* 2021). The current low yield obtained from Bambara groundnut in Nigeria as reported by farmers has been attributed to a number of factors, among which are non-adherence to proper agronomic practices in its

cultivation by farmers like; the use of local unimproved accessions with low productive potential in place of improved cultivars, coupled with poor soil fertility and biotic /abiotic (stress) factors among others. Growing concerns about prohibitive high cost of chemical fertilizers, its adulteration, its unavailability at the right time and in sufficient quantity and sometimes having negative effect of chemical fertilizers on the soil acidification and environment makes organic (poultry) manure a better and safe alternative (Ibrahim *et al*., 2014). As a legume, Bambara ground nut contributes to soil fertility by fixing atmospheric nitrogen through nodulation. In most savannah soils, the nodule bacteria (indigenous rhizobia) are not adequate for aiding proper nodulation, it is necessary to inoculate the seed or the soil with highly effective strain rhizobia for higher and better productivity in Bambara groundnut cultivation (Sprent *et al*., 2010).

The use of poultry manure as an alternative is a hub of both macro and micro source of plant nutrients is relatively available and cheap in place of chemical/inorganic fertilizers. Farmers arbitrarily apply poultry manure without proper quantification in most rural areas to their farms in Nigeria, thus effect of rates might not be fully observed. In this trial, varying rates of poultry manure will be applied and their effect will be examined as well as the use of inoculant may be looked into in order to improve the performance of Bambara groundnut in terms of growth and yield of Bambara groundnut. Therefore, this study was undertaken to investigate the effect of poultry manure rates and inoculation on growth and yield of Bambara groundnut in the Nigerian savannah.

MATERIALS AND METHODS

Field trials were conducted during 2020/2021 dry season at Institute for Agricultural Research (IAR) Savannah Research Farm (Lat $11^0$11'N, $07^0$3'E, 686m above sea level) Samaru-Zaria and College of Agriculture and Animal Science, Irrigation Farm Mando, Kaduna (Lat 10^o43'N, Long 06^o34'E 500m above sea level) both located in the Northern Guinea Savannah Ecological Zone of Nigeria respectively. Soil sample collected at 0-15cm, 15-30cm from each location and poultry manure samples were collected for analysis at Analytical laboratory of department of Agronomy, Ahmadu Bello University Zaria before planting, while the weather data for the two locations were monitored throughout the duration of the trials. The Bambara groundnut Landrace used was a local variety called Giwa-white as described by Tanimu,(1996) obtained from Samaru seeds dealers. It's of medium duration with profuse branching/ spreading habit, which matures between 100-110 days and has a potential seed yield of 3tha^{-1} (Majola *et al.,* 2021).

The treatment consisted of a factorial combination of four levels poultry manure rates at 0, 2, 4 and 6 tons ha^{-1} and two levels of inoculation; no inoculation and inoculation, were laid out in a randomized complete block design (RCBD) with three replications. The gross and net plot sizes were 4m by 4.5m = 18m^2 and 4m x 3m = 12m^2 made up of 6 rows (gross) and four inner rows for net plots. The land was ploughed, harrowed twice and their ridges made of 75m apart then plots and border areas were laid out which were separated by 1m and 0.5m paths respectively. Two seeds were manually sown 15cm apart along the ridges on 27th Feb 2021 at Samaru and 5th Mar 2021 at Mando respectively. Thinning was carried out at 2 WAS to 2 plants par stand.

The poultry manure (0, 2, 4 and 6 t/ha) as par treatment were drilled and incorporated into the soil along the side of the ridge two weeks before sowing while inoculation was carried out at planting with a commercial inoculant (Nodumax) according to the manufactures specification as described by Famawanga *et al*. 2022. Weed control was conducted prior to land preparation with glyphosate sprayed at the rate of 1.4 a.i kg/ha to keep the land weed free and this was followed by manual hoe weeding at 3 and 6 WAS. The ridges were molded up at 12 WAS. Karate (Lambdacyhalothrin) at the rate of 0.8 litre ha-^{1} along with Benlate (benomyl) at the rate of 11kga.i ha^{-1} were applied 3 times using CP-15 knapsack starting from 8WAS, 10 WAS and 12 WAS as a routine preventive measure against pest and disease incidence. The matured Bambara groundnut plants were harvested at physiological maturely (on 26 May, 2021 at Samaru and 8th June 2021 at Mando respectively (while plant parts are still green and pods are easily remove from soft moist ground). The plants in net plot were harvested by carefully digging up whole plant along with the pods with a hoe and picking up the remaining pods from the soil. Thereafter, kernels were separated from the plants and haulms were weighed and allowed to dry for seven days under the sun. The dried pods and haulm from each net plot were then re-weighed using mettle's balance (model E200D) and the value recorded on per plot basis and later computed on per hectare basis. Data were collected at 4, 8, and 12 WAS on growth parameters like plant height (cm), leaf area index, crop growth rate, relative growth rates, data was also collected on kernel yield (kg) per hectare at harvest. The data collected were analyzed using analysis of variance (ANOVA) technique, the treatment means were separated using Duncan's Multiple Range Test (Dunca,1955).

RESULTS AND DISCUSSION

Results

Details of the soil physical and chemical properties of the experimental sites were presented as table 1, likewise the details of the nutrient content of the poultry manure used as presented as table 2. The soil at Samaru was found to be of sandy loam textural class while that of Mando is of loam textural class. The soil at Samaru had a moderate N content, low level of available phosphorus (P), potassium (K) and Cathion exchange capacity (CEC). The soil from Samaru had a moderate level of Organic carbon, calcium, magnesium and sodium with a slightly acidic pH in water and moderately acidic in calcium chloride solution ($Cacl_2$). The soil at Mando has a moderate N and P content with moderate calcium, magnesium and sodium content, also low level of organic carbon, potassium and CEC were observed. PH was slightly acidic in both water and $cacl_2$ solution.

The analysis of poultry manure used during this trial for both Samaru and Mando are presented in Table 2 indicated that it contain high total nitrogen (N) content, low available phosphorous and potassium contents were 2.28%, 0.90% and 0.82% respectively.

Table 1: Physical and Chemical Properties of the Soil at Both Mando and Samaru During 2020/2021 Dry Season

	Mando	Samaru
Physical Properties gkg^{-1}		
Clay	210.0	120.0
Silt	270.0	390.0
Sand	620.0	570.0
Textural Class	Loam	Sandy Loam
Chemical Properties		
PH (H_2O) 1:2,5	6.24	6.12
PH 0.01m $CaCl_2$	5.86	5.63
Total Nitrogen (gkg^{-1})	3.7	4.0
Available Pmg Kg^{-1}	1.65	5.24
Organic Carbon	1.67	1.01
Exchangeable Bases (Cmol Kg^{-1})		
Calcium Meq/100g	2.59	2.12
Magnesium Meq/100g	0.71	0.80
Potassium Meq/100g	0.01	0.13
Sodium Meq/100g	0.17	0.61
CEC Meq/100g	3.48	3.64

Source: Analytical Lab of department of Agronomy, ABU Zaria

Table 2: Nutrient Content of Poultry Manure used at the Experimental Sites during 2020/2021

Nutrient Contents	Value (%)
Total Nitrogen	2.29
Available Phosphorus	0.90
Potassium	0.82

Source: Analytical Lab of department of Agronomy, ABU Zaria

Plant Height (cm)

The effect of poultry manure rate and inoculation on plant height (cm) of Bambara groundnut at 4, 8, and 12 during 2021 dry seasons at Samaru and Mando is presented on Table 3. The effect of poultry manure rates in Samaru on plant height of Bambara groundnut was significant ($p \leq 0.05$) at all sampling periods. Application of 6 tons ha^{-1} of poultry manure was found to produce the tallest Bambara ground nut plants which were statistically similar to application of 4 tons and 2 tons of poultry manure hectare^{-1} at 8 and 12 WAS at both Samaru and Mando in 2021. While the untreated control (0 tons ha^{-1}) produced shorter plants which increased in height with increased poultry manure application up to 6 tons ha^{-1}. Bambara groundnut response to inoculation was significant ($p \leq 0.05$) in both locations at all sampling periods in 2021 where inoculated Bambara groundnut plants were taller compared to non- inoculated plants at both locations. There was no significant interaction between the variables

Table 3: Effect of Poultry Manure rate and Inoculation on Plant Height (cm) Of Bambara Groundnut at Samaru and Mando During 2020/2021 Dry Season

Treatment	Plant Height (cm)					
	Samaru			Mando		
	Weeks after Sowing (WAS)			Weeks after Sowing (WAS)		
	4	8	12	4	8	12
Poultry manure t/ha						
0.0	8.66d	15.33c	21.93c	8.23d	14.44c	22.31c
2.0	9.74c	17.12b	22.42bc	9.27c	15.48b	22.75b
4.0	10.92b	17.28ab	22.89ab	10.08b	17.63ab	23.76ab
6.0	12.45a	18.34a	23.13ab	11.16a	18.40a	23.98a
SE±	0.152	0.253	0.322	0.179	0.261	0.239
Inoculation						
Non- inoculated	9.90b	16.33b	21.93b	9.80b	15.04b	22.24b
Inoculated	11.10a	17.82a	23.74a	10.35a	16.38a	23.73a
SE±	0.107	0.179	0.228	0.127	0.184	0.169
Interaction						
P x I	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a column and treatment are significant at 1% and 5% level of probability (DMRT). NS – Not Significant. * Significant at 5% level of probability, ** highly significant at 1% level of probability.

Table 4 showed the effect of poultry manure rate and inoculation on leaf area index of Bambara groundnut at 4, 8 and 12WAS at Samaru and Mando during 2021 dry seasons. The effect of poultry manure rates in both locations in 2021 on leaf area index of Bambara nut was significant ($P \leq 0.05$) at all sampling periods. The result showed that increased poultry manure rate application result in successive increase in LAI in both location except at 12 WAS in 2021 at Samaru where 6 and 4 ton/ha poultry manure rates were statistically similar. The inoculated Bambara groundnut had a much higher value of LAI than those not inoculated at both locations in 2021.

There was a significant interaction between poultry manure and inoculation at 12 WAS at Samaru during 2021 warm dry

season (Table 5). Inoculated plants had leaf area index values that were higher than non-inoculated plants. Furthermore, increasing the application of moisture from 25% to 100% for inoculated Bambara groundnut plants had the highest LAI values and further increase resulted in increased LAI values

Table 4: Effect of Poultry Manure rate and Inoculation on Leaf Area Index of Bambara Groundnut at Samaru and Mando During 2021 Dry Season.

Treatment	Leaf Area Index (LAI)					
	Samaru			Mando		
	Weeks after Sowing (WAS)			Weeks after Sowing (WAS)		
	4	8	12	4	8	12
Poultry manure t/ha						
0.0	0.07c	0.38d	0.82c	0.44c	0.48d	0.85c
2.0	0.08c	0.43c	0.89b	0.51c	0.54c	0.91bc
4.0	0.12b	0.51c	0.95ab	0.13b	0.59b	0.96b
6.0	0.14a	0.79a	0.99a	0.15a	0.85a	1.01a
SE±	0.004	0.011	0.005	0.004	0.004	0.003
Significance	NS	NS	NS	NS	NS	NS
Inoculation						
Non-inoculated	0.10a	0.516	0.93b	0.13a	0.56b	0.94b
Inoculated	0.11a	0.55a	1.37a	0.16a	0.61a	1.22a
SE±	0.002	0.008	0.004	0.003	0.003	0.002
Interaction						
P x I	NS	NS	*	NS	NS	NS

Means followed by the same letter(s) within a column and treatment are significant at 1% and 5% level of probability (DMRT). NS – Not Significant. * Significant at 5% level of probability, ** highly significant at 1% level of probability.

Table 5: Interaction Effect Between Poultry Manure Rate and Inoculation on Leaf Area Index (LAI) at 12 WAS at Samaru During 2021 dry Season

	Leaf Area Index (LAI)			
	Poultry manure rate t/ha			
Inoculation	**0**	**2**	**4**	**6**
No-Inoculation	0.81f	0.89d	0.95c	0.97b
Inoculation	0.85e	0.89d	0.96c	0.98a
SE		0.002		

Means followed by the same letter(s) within a column of treatments means are significant at 5% level of probability and 1% level of probability. NS: not significant.

Crop Growth Rate (CGR) ($g^{-1}cm^{-2}wk^{-1}$)

Table 6 presents the effect of poultry manure rate and inoculation on crop growth rate (CGR) of Bambara groundnut at 8-10 and 10-12 WAS at Samaru during 2021 dry seasons. The effect of poultry manure rates in both locations in 2021 on crop growth rate (CGR) of Bambara groundnut was also significant ($P \leq 0.05$) at all sampling periods where the control 0 tons ha^{-1} produce plants with lower CGR value which increased with increase in poultry manure rates application up to 6 tons ha^{-1} that produces higher CGR values. Application of 6 tons ha^{-1} of poultry manure rate was found to be statistically similar to 4 tons ha^{-1} at Samaru at 8-10WAS in 2021. The crop growth rates of Bambara groundnut's response to inoculation was significant ($P \leq 0.05$) at all sampling periods in both locations and sampling periods except at 8-10WAS at Samaru (2021), the significant response by inoculated plants produced a higher value of crop growth rate than non-inoculated plants. There was a significant interaction between poultry manure and inoculation at 4-8WAS at Samaru in 2021 warm dry season (Table 7), where inoculated Bambara ground nut plants had a higher CGR values over non inoculated plants.

Table 6: Effect of Poultry Manure Rate And Inoculation on Crop Growth Rate (CGR) of Bambara Groundnut at Samaru and Mando During 2021 Dry Season

Treatment	Crop Growth Rate (CGR)					
	Samaru			Mando		
	Weeks after Sowing (WAS)			Weeks after Sowing (WAS)		
	4-8	8-10	10-12	4-8	8-10	10-12
Poultry manure t/ha						
0.0	2.14b	4.06b	3.38b	2.30a	3.58b	2.41c
2.0	2.15b	4.11b	3.27bc	2.31a	3.62b	2.71bc
4.0	2.89a	3.77c	3.134c	2.35a	3.64b	3.25ab
6.0	2.35a	4.68a	4.41a	2.39a	4.81a	3.86a
SE±	0.047	0.079	0.063	0.070	0.168	0.224
Significance	NS	NS	NS	NS	NS	NS
Inoculation						
Non-inoculated	2.22b	4.03b	3.46b	2.30b	3.76b	3.067b
Inoculated	2.25a	4.26a	3.63a	2.37a	4.06a	3.068a

SE±	0.033	0.056	0.044	0.049	0.119	0.158
Interaction						
P x I	*	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a column and treatment are significant at 1% and 5% level of probability (DMRT). NS – Not Significant. * Significant at 5% level of probability, ** highly significant at 1% level of probability

Table 7: Interaction Effect Between Poultry Manure rate and Inoculation on Crop Growth Rate at Samaru During 2021 Dry Season

	Crop Growth Rate (CGR)			
	Poultry manure rate t/ha			
Inoculation	**0**	**2**	**4**	**6**
No-Inoculation	3.22c	3.19c	3.35c	3.61b
Inoculation	3.28c	3.72b	4.00a	4.09[a]
SE		0.115		

Means followed by the same letter(s) within a column of treatments means are significant at 5% level of probability and 1% level of probability. NS: not significant.

Relative Growth Rate (RGR) (g.g.wk^{-1})

Table 8 shows the effect of poultry manure rate and inoculation on relative growth rate (RGR) of Bambara groundnut at 8 – 10 and 10 - 12 WAS at Samaru and Mando during 2021 dry seasons. The effect of poultry manure rate on relative growth rate (RGR) of Bambara groundnut in both locations in 2021 was significant ($P \leq 0.05$) at all sampling periods, where 6 tons ha^{-1} poultry manure produce higher RGR values which was statistically similar to 4 tons ha^{-1} in most cases at Samaru in 2021 (8 – 10 and 10 – 12 WAS). However, 6 tons ha^{-1} was statistically similar to 4 tons ha^{-1} in terms of RGR values at 10 – 12 WAS in 2021 at Samaru.

Relative growth rate (RGR) of Bambara groundnut response to inoculation was significant ($P \leq 0.05$) in both location at all sampling periods in both 2021 except at 10 – 12 WAS at Mando in 2021. Inoculated plant had a higher RGR values than non-inoculated plants.

Table 8: Effect of Poultry Manure Rate and Inoculation on Relative Growth Rate (CGR) of Bambara Groundnut at Samaru and Mando During 2021 Dry Season

Treatment	Relative Growth Rate (RGR)					
	Samaru			Mando		
	Weeks after Sowing (WAS)			Weeks after Sowing (WAS)		
	4-8	**8-10**	**10-12**	**4-8**	**8-10**	**10-12**
Poultry manure t/ha						
0.0	0.22b	0.20b	0.11c	0.24b	0.19b	0.10c
2.0	0.22b	0.21b	0.13b	0.24b	0.21b	0.11bc
4.0	0.27a	0.24a	0.14a	0.27a	0.21b	0.13ab
6.0	0.28a	0.24a	0.14a	0.28a	0.24a	0.14a
SE±	0.005	0.002	0.002	0.008	0.010	0.008
Significance	NS	NS	NS	NS	NS	NS
Inoculation						
Non-inoculated	0.22b	0.22b	0.30b	0.20b	0.21b	0.12
Inoculated	0.27a	0.23a	0.38a	0.25a	0.23a	0.13
SE±	0.004	0.003	0.002	0.006	0.007	0.006
Interaction						
P x I	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a column and treatment are significant at 1% and 5% level of probability (DMRT). NS – Not Significant. * Significant at 5% level of probability, ** highly significant at 1% level of probability

Kernel Yield kg ha^{-1}

Table 9 showed the effect of poultry manure rate and inoculation on kernel yield kg ha^{-1}of Bambara groundnut at Samaru, Mando and combined during 2021 dry seasons. The effect of poultry manure rates on kernel yield kg ha^{-1}was also significant (<0.05) in both years, locations and combined where the control (0 tons ha^{-1}) produces lower kernel yield and 6 t ha^{-1} produces highest kernel yield relative to other rates evaluated. The response of kernel yield of Bambara groundnut to inoculation during 2021 dry season at both locations and combined in 2021 was significant ($P \leq 0.05$). Inoculated Bambara nut plants had a higher kernel yield kg ha^{-1} than non- inoculated plants.

There was a significant interaction between poultry manure and Inoculation on Bambara ground nut at Samaru during 2021 warm dry season as presented in Table 10. The highest kernel yield kg ha^{-1} was obtained at the combination of 6 tons ha^{-1} poultry manure which was statistically similar with 4, and 2 tons ha^{-1} with inoculated plants.

Table 9: Effect of Poultry Manure Rate and Inoculation on Kernel Yield kg/ha of Bambara Groundnut at Samaru and Mando During 2021 Dry Season

Treatment	Kernel yield kg/ha at Harvest	
	Samaru	Mando
Poultry manure t/ha		
0.0	388.92d	379.85c
2.0	404.96c	413.21b
4.0	447.85b	435.85a
6.0	467.76a	445.97a
SE±	3.722	5.792
Significance	NS	NS
Inoculation		
Non-inoculated	400.31b	404.43b
Inoculated	442.91a	432.45a
SE±	2.218	4.095
Interaction		
P x I	NS	*

Means followed by the same letter(s) within a column and treatment are significant at 1% and 5% level of probability (DMRT). NS – Not Significant. * Significant at 5% level of probability, ** highly significant at 1% level of probability.

Table 10: Interaction Effect Between Poultry Manure Rate and Inoculation on Kernel yield kg/ha at Mando During 2021 Dry Season

	Kernel yield kg/ha			
	Poultry manure t/ha			
Inoculation	**0**	**2**	**4**	**6**
Non-inoculated	268.11^{c}	287.45^{bc}	297.91^{bc}	307.37^{b}
Inoculated	278.51^{c}	312.69^{bc}	324.41^{ab}	347.57^{a}
SE		21.994		

Means followed by the same letter(s) within a column of treatments means are significant at 5% level of probability and 1% level of probability. NS: not significant.

Discussion

Generally, the performance of Bambara Groundnut depends largely on environmental factors which comprises of soil type and fertility, climate (favorable temperature, sunshine hours and relative humidity). These factors influence the crops growth and development which effectively improve the yield potentials of the crop. Sandy loam soil (at Samaru) encourages better growth performance in Bambara groundnut than clayed-loamy soil (at Mando) and as was seen in the performance of the crop in Samaru was better than at Mando during 2021 dry season. This could possibly be due to better enhancement of sandy soil at Samaru that encourages growth avenues like providing better drainage capability for better soil aeration enhancing soil microbial activities than clay soil at Mando. This is in line with the report of Brink (1999) and Olayinka *et al,* (2016) which states that growth and yield attribute of Bambara groundnut were found to be highest in sandy loamy soil than in loam soil. This is further corroborated by Nyau *et al, (*2017) who reported that Bambara groundnut grows well on well drained sandy-loam soil and sandy soil development of pod in the soil easy as well as easy harvesting than other soil. The mean minimum and maximum daily temperature, relative humidity and sunshine hours (Appendix I & II) were optimal in 2021 and particularly during flowering, pod formation and kernel filling stages which favored good performance of the crop at Samaru than Mando. The optimum temperature for seed germination is between 30 – 35^{o}C and optimum day temperature is between 20-28 ^{o}C. Very low temperature can cause chilling injury and very high temperature above 38^{o}C results in arrested development (Gerranno *et al*., 2021). Poultry manure application to Bambara ground nut enriches the soil with higher N (due to N fixation), high organic carbon and available phosphorus for the growing plant, thus are better in terms of growth as exemplified by the plant having more leaves on taller plants with larger leaf area index, more dry matter production than plots with zero poultry manure application. This could be attributed to the increases in the amount of N fixed by the crop and quantity of N and P derived from the decomposed poultry manure for use by the crop as reported by Wamba *et al*.,(2012), Thus higher values of growth parameters obtained resulted in higher and better yield components and yield was recorded in 2021 dry seasons at both locations.

In this study, application of poultry manure rates (2, 4 & 6 tha^{-1},) had significant effect on Bambara groundnut growth attributes like plant height, Leaf area index, Crop growth rate, Relative growth rate and kernel yield kg ha^{-1}. Application of six (6) t ha^{-1} of poultry manure recorded the tallest plants which were statically similar to 4 tons hectare^{-1} followed by 2 tons hectare^{-1} and lastly the control (0 ton/ha). The greater plant height produced by application of 6 tons/ha might be attributed to the increased potential of the plant to exhibit better competition for capturing and utilizing solar radiation due to probably the gradual release of more nutrient by the poultry manure to the growing Bambara ground nut plant for better growth and development as reported by Ahmad and Arain (2021) that the higher mean value of plant height was produced by application of 5tha^{-1}while the control produced shorter plants. Adeyeye *et al*., (2019) reported that application of 10 tons of poultry manure to Bambara groundnut results in having tallest plants while the control produced shortest plants. Wamba *et al*, (2012) further corroborated above findings by stating that higher amount poultry manure fertilizer application is the energy source for soil fauna and microorganism, which are primary agents that manipulate the decomposition and release of mineral nutrients in the soil ecosystem for better growth and development of Bambara groundnut.

The higher growth attributes recorded such as plant height, leaf area index (LAI), Crop Growth Rate (CGR), Relative Growth Rate (RGR) and total dry matter produced exhibited by the application of highest amount of poultry manure (6 tha^{-1}) to the Bambara groundnut plant could be due to slow released (high content of nutrients released) into the soil of nutrients like Nitrogen, Phosphorous, potassium and calcium in poultry manure which in turn stimulates vegetable growth, development and the resultant effect led to accumulation of greater dry matter produced, thus increasing crop total dry matter, crop growth rate, relative growth rate and net assimilation rates. Increasing rates of poultry manure led to a significant increase in leaf area and leaf area index which was as a result of increased number of leaves, branches with wider canopy. This in turn allowed for greater light interception which is of greater benefit for photosynthesis and other processes leading to better growth and development for greater yield and yield component of Bambara groundnut. Similar observation was made by Dwyer and Stewart (1986). From the result of this study, higher values of kernel yield ha^{-1}, were recorded with increase application of poultry manure rates from 2, 4 and 6 tons/ha over the control with least values of yield parameters. These showed that poultry manure's ability to slowly release the much-needed essential nutrients that promote good growth, development, yield component and yield of Bambara groundnut (Babu *et al*.,2021).

Application of microbial inoculant significantly improved the growth, yield and yield parameters of Bambara groundnut, thus improving the crops productivity. The increase in growth attributes such as plant height, number of leaves, leaf area index, crop growth rate, relative growth rate, net assimilation rate and total dray matter produced could be as a result of microbial inoculation of the crop which possibly enhanced and boost the crops vigor that probably improved the crops nutrients uptake from the soil as well as encouraged an improved the microbial activities in the soil. Microbial inoculation helps in increasing nodulation, thus increased atmospheric N fixation. This is in line with the report of (Fasasi and Babalola 2021), who reported that addition to applying poultry manure which supplies adequate nutrients to the inoculated growing plants hence boosting and improving plant growth, reducing heavy metal contamination, and controlling phytopathogens which enhances sustainable agriculture. Kyei-Boahen *et al,* (2017) reported that the successful field rhizobia inoculation serves as a vigor boost to the growing plant which possibly contributed to better plant growth, development and kernel yield when compared with non-inoculation plants. Oburger and Schmidt, (2016) corroborated that the microbes in the soil helps in decomposition of organic matter, transformation of nutrients and regulation of soil productivity for an improved plant growth, development and production of high kernel yield. The significant effect of inoculation on Bambara groundnut plant height, number of leaves, leaf area index, crop growth rate, relative growth rate and kernel yield kg ha^{-1} could probably be due to inoculation rhizobia which may complement the little or no indigenous rhizobia available in the soil. The differences in the impact of inoculation recorded on the growth parameters and yield of inoculated Bambara groundnut plants over non-inoculated plants was significant. The increase in plant height and other growth attributes of Bambara nut could lead to increase in shoot dry matter due to inoculations positive effect on stem girth, width and ability of the inoculation to significantly influence modulation. This agrees with the result of Glick (2020); Babalola *et al,* (2022) who states that positive response to inoculation is likely to occur when indigenous rhizobia population is less than 5 or 10 rhizobia cells g^{-1} soil with high degree adaptability to the environment than non-inoculated plants, furthermore, significant difference observed in the kernel yield in this trial shows that microbial inoculation enhances biomass yield over non-inoculated plant thus better growth and higher yield production. Similar findings was observed by Solomon *et al,* (2012) who reported that the effect of inoculation of rhizobia strains significantly influence dry matter production at mid flowering resulting in higher yield produced. Caliskan (2007) and Amani (2020) also reported that plant height of soya bean increased with application of inoculations, number of leaves, number of branches as well as wideness of the canopy also increased resulting in higher yield in the inoculated plants over non inoculated plants. This agrees with the report of Mohammed *et al,* (2011) who stated that maximum leaves, branches and final yield in inoculated plants may be attributed to symbiotic relationship of rhizobium (bacteria) with the root of leguminous crops, which fixes atmospheric nitrogen into the roots of groundnut and thus the number of leaves per plant was increased. The significant difference observed due to inoculation may also be due to efficient nitrogen fixation by the crop by the nitrogen fixing bacteria in the plants root nodules.

Increase in crop physiological indices like crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR) , leaf area index (LAI) and kernel yield of Bambara groundnut plants over non inoculated plant may possibly be as a result of good symbiosis between the rhizobium inoculation, good environmental conditions (adequate temperature, humidity and sunshine hours) and proper crop management. This is in line with the work of Woomer *et al,* (2014) who stated that the success of rhizobium inoculation primarily depends on the rhizobium strain, the legume genotype, the environmental condition and the crop management. There was a significant and positive response on application of inoculants on Bambara ground nut's number of pods/plant, pod yield ha^{-1} and kernel yield ha^{-1}.

CONCLUSION

From the result of this study, it can be concluded that Application of 6 tons ha^{-1} poultry manure rate had highest values of growth and yield indices, followed the 4 tons ha^{-1}, 2 tons ha^{-1} and lastly the control, 0 tons ha^{-1} in that order.. Inoculation of Bambara groundnut could be considered as it produced a better performance in terms of both growth, and yield of the crop which is beneficial for food, feed and for income generation in this trial. Therefore, 100% moisture regime on inoculated Bambara groundnut could be considered for better performance of growth and yield of Bambara groundnut at Samaru and Mando both in Kaduna State of Nigeria.

REFERENCES

Adeyeye, A.S., Dima, A.E., Olalekan, K.K., Lamidi, W.A., Othman, H.J., and Ishaku, M.A. (2019). The effect of organic and inorganic nutrient sources on the growth and seed yield of bambara nut (Vigna subterranean L. verdc) variety. *World Journal of Agriculture and soil Science.* https://doi.org/10.33552/WJASS.2019.02.000537.2(3).

Ahmad, A.Y., and arain M.A (2021). Repsonse of Common Bean (Phaseolos volgaris L.) to different levels of organic and inorganic fertilizer. *International Journal of Life Scienceand biotechnology* 4(3): 439 – 450.

Amani, A.B (2020). Effect of plant density and urea foliar application on yield and yield component of chik pea (*Cicer*

arietium L). *Research Journal of Agricultural and Biological Science* 3(4): 220 – 223.

Babalola, O.O., Oyatomi, O., and Abberlon M. (2022). Effect of Brady RhizobiumJapomce Strain and inorganic Nitrogen fetilzier on the growth and yield of Bambara Nut (rising subte) accession.

Babu, A., Singh, U., Meena, R. Dadarwal, B. and Jakhar (2021). The Use of Poultry Manure as Organic Fertilizer in Different Crops. *The Agricultural Magazine* 1, 14-15.

Brink, M. (1999). Development, growth and dry matter partitioning in bambara groundnut (Vigna Subtteranea (L.) verdc) and influenced by photoperiod and shading. *Journal of Agriculture Science,* 133; 159- 169.

Caliskan, S., Arslan M Uremis, I. and CaliskanM.E (2007). The Effect of row spacing on yield and yield components of full season and double cropped soya bean. *Turkey journal of Agricultural and Forestry.* 31 147 – 154.

Caroline, de Kock. (2003). 'Bambara Groundnut (*Vigna subterranean L. verdc*). Specialty Foods of Africa' Pvt Ltd., *Zimbabwe journal od Agriculture*.23(2):1 – 6

Duncan, J.B. (1955). Multiple Range Multiple F Test Biometrics, 11:1-42,

Dwyer, L. M. and D.W Stewart (1986). Leaf area development in field grown maize. *Agronomic Journal*, 78:334 – 343.

Emilia, T.J., and Agbachi,I.,(2018). Productivity of maize/bambara groundnut intercrop with poultry manure rates. *Journal of Biology, Agriculture and Healthcare*, 8(4).
Fasasi O.A, Cruz, C. and Babalola O.O (2021). Agricultural sustainability: microbial bio-fertilizer in rhizosphere management. *Agriculture* 11.163 https://doi.org/10.3309/agriculture 11020163.

George McRobie (1998) Tools for organic farming, its manual of appropriate equipment and treatment. *International technology publication*. UK Pp. 77.

Gerano A.S. El-fendy K., Labuschange, M and Hassen Ahmed Ions (2021). Production practices of Bambara groundnut. (*Vigna Subterranea* L. Verdc.) Researchgate https://www.researchgate.net/publication/355121398. https://doi.org/10.1007/978-3-73920-1-2.

Glick, B.R (2020). Introduction to Plant Growth promoting bacteria beneficial to plant – bacterial interaction, New York City sprungers, 1 – 37.

Halimi, R.A., Barkla, B.J., Mayer, S., and King G.j (2019). The potential of the underutilized pulse Bambara groundnut (Vignasubtarance (L) VERDC) for nutritional food security.

Journal of food composition. Anal 77, 47 – 59.
Ibrahim U. (2015). Influence of poultry manure and weed control method on the performance of groundnut (Arachis hypogea L.) varieties under rainfall and irrigated conditions. Unpublished Ph.D thesis. Department of Agronomy, Faculty of Agriculture, Ahmadu Bello University Zaria. Pp 27.

Ibrahim, U., Mukhtar, A.A., Babaji, B.A., and Adekpe, D.I. (2014). Effect of poultry manure and weed control methods on growth and yield of three groundnut varieties (*Arachis hypogea* L.) varieties at -Zaria. *Nigerian Journal of Agriculture, Food and Environment, 10,* 18-22.

Ikhajiagbe, B., Ogwu, M. C., Ogochukwu, O. F., Odozi, E. B., Adekunle, I. J., & Omage, Z. E. (2021). The place of neglected and underutilized legumes in human nutrition and protein security in Nigeria. *Critical Reviews in Food Science and Nutrition*, 62(14), 3930–3938. https://doi.org/10.1080/10408398.2020.1871319.

Khan, M. H., Rafii, M. Y., Ramlee, S. I., Jusoh, M., and Mamun, A. (2020). Genetic Variability , Heritability , and Clustering Pattern Exploration of Bambara Groundnut (Vigna subterranea L . Verdc) Accessions for the Perfection of Yield and Yield Related Traits. 2020

Kyei-Boahen, S., Savala, C.E., Chikoye, D., and Abaidoo, R. (2017). Growth and yield responses cowpea to inoculation and phosphors fertilization in different environment. *Journal front, plant science* 8,646.

Majola, N.G.; Gerrano, A.S.; Shimelis, H. (2021).Bambara Groundnut (Vigna subterranea [L.] Verdc.) Production, Utilisation and Genetic Improvement in Sub-Saharan Africa. *Agronomy,* 11, 1345. https://doi.org/10.3390/agronomy11071345

Muhammed. S.B., Abdorrab., F.W.F., and sayed N.M (2011). Influence of rhizobium inoculation on growth and yield of Bambara groundnut (Vigna subterranea (L) Verdc) cultivation.

Nyau V, Prakash, S; Rodrigves J. Farraut J. (2017) Antioxidant activities of Bambara groundnut and assessed by FRAP and DPPH assays. *Journal of Food Nutrition Discord*. 3,: 7 – 11.

Obidiebube E. A , Akparaobi S.O , Eruotor P. G. , Okolie H. , Obasi C. C and Iwuagwu C. C.(2022) Response of Bambara Groundnut (Vigna Subterranea (L) Verdc.) Varieties to Plant Spacing in South Eastern Zone of Anambra State. *International Journal of Research and Innovation in Applied Science (IJRIAS)* |Volume VII, Issue III, March 2022|ISSN 2454-6194.

Obidiebube E. A , Akparaobi S.O , Eruotor P. G. , Okolie H. , Obasi C. C and Iwuagwu C. C.(2019) Response of Bambara Groundnut (Vigna Subterranea (L) Verdc.) Varieties to Plant Spacing in South Eastern Zone of Anambra State. *International Journal of Research and Innovation in Applied Science (IJRIAS)* |Volume VII, Issue III, March 2022|ISSN 2454-6194.

Oburger, E. and Schmitd H. (2016). New methods to unravel rhizosphere processes. *Journal Trends in Plant Science*. 21, 243 – 245.

Olayinka. B. U, Afolayan. S.S, Mohammed, RT, Abinde, O.O and Etejere, E.o (2016). Biology yield and proximate composition of Bambara groundnut (Vigna subtteranea (L.) verdc) and influenced by sowing depths and soil types Annals of West University of Timisoara, Ser. *Biology*, 2016. Vol 19(2), pp 177 – 186.

Omoikhoje, S.O. (2008) 'Assessment of the Nutritional value of Bambara Groundnut (*Vigna subterranea* (L) Verdc) as Influenced by Cooking Time', Livestock Research for Rural Development 20 (4): 1-4.ss

Solomon, T., pant L. M., and Angaw T (2012). Effect of inoculation by Brady rhizobium Japoricum strain on inoculation, Nitrogen fixation and yield of soya bean (Glycine Max L. Merill) values on nitisols of Bako western Ethiopia. International scholar research notice 2012, 475

Sprent J.I, Odee D.W, Dakora F.D (2010). African legumes: a vital but under-utilized resource. *Journal Exp Bot* 61(5):1257–1265.

Tan XL, Azam-Ali S, Goh EV, Mustafa M, Chai HH, Ho WK, Mayes S, Mabhaudhi T, Azam-Ali S and Massawe F (2020). Bambara Groundnut (*Vigna subterranea* (L) Verdc): An Underutilized Leguminous Crop for Global Food Security and Nutrition. Front. *Nutr*. 7:601496. https://doi.org/10.3389/fnut.2020.601496

Tanimu, B. (1996). Effect of sowing date, fertilizer level and intra-row spacing on the agronomic characters and yield of Bambara groundnut (*Vigna substerranea L. verdc*). (An unpublished dissertation). Ahmadu Bello University, Zaria.

Wamba, O.F., Taffovo, V.D., Yombi, E., Ngwevie, B., and Amougou, A. (2012). Effect of organic and inorganic nutrients sources on the growth, total chlorophyll and yield of three Bambara groundnut landraces (Vigna subterranea (L) Verdc) in coastal region of Cameroon. *Journal of Agronomy,* 11, 31-42.

Woomer, P.L, Huising J. and Giller, K.E (2014). N2 Africa Final Report of the First Phase 2009 – 2013 available at https://www.N2africa.org/28