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Full Length Research Article

YIELD AND YIELD COMPONENTS OF BAMBARA GROUNDNUT AS INFLUENCED BY POULTRY MANURE RATES, MOISTURE REGIME, AND INOCULATION IN NORTHERN GUINEA SAVANNAH OF NIGERIA

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ABSTRACT
Field trials were conducted in dry season of 2021/2022 to investigate the influence of poultry manure rate, soil moisture regime and inoculation on the yield and yield components of Bambara groundnut 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 levels of poultry manure rates (0.0, 2.0, 4.0, and 6.0 tons ha-1), four levels of soil moisture regimes (25%, 50%, 75%, and 100%), and two levels of inoculation: no inoculation and inoculation. Treatments were factorially combined and laid out in a randomized complete block design (RCBD) and replicated three times. Significant increment was observed due to the poultry manure rate application of 6 tons ha^{-1} on yield parameters like number of pod $plant^{-1}$, number of kernels pod^{-1}, 100 kernels weight (g), number of pods $plot^{-1}$, number of pod ha^{-1}, number of kernels (g) $plot^{-1}$, kernel yield kg ha^{-1} and harvest index over other rates evaluated, while application of 100% moisture regime had a significant effect on parameters like number of pod $plant^{-1}$, number of kernels pod^{-1}, 100 kernels weight (g), of pods $plot^{-1}$, number of pod ha^{-1}, number of kernels (g) $plot^{-1}$, harvest index and kernel yield kg ha^{-1} over other moisture regimes evaluated. Also, Bambara groundnut treated with rhizobium inoculant produced better yield and yield parameters, well over non-inoculated plants. From the result obtained, the combination of 6 tons $ha^{-1}$and 100% moisture regime produced highest Bambara groundnut kernel yield (kg/ha) and other yield components at both location.

Keywords: Bambara groundnut, poultry manure, soil moisture regime, inoculation, growth, yield, yield components, and Nigerian Savannah.

INTRODUCTION

Among the members of leguminous *Fabaceae* family is Bambara groundnut (V*igna subterranean* (L.) Verdc), a hardy tropical annual pulse crop with underground pods that plays a considerable economic role in rural Nigeria, even though it is largely underutilized and underappreciated and is the third most important food grain legume after groundnut (A*rachis* h*ypogea* L.) and cowpea (V*igna* u*nguiculata (*L*).*W*alp*) in semi-arid area of sub-Sahara Africa (Adeyeye *et al*., 2019). It is 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 is used for food, feed and for industrial as well as for medicinal use (Obidiebube *et al*., 2019). Bambara groundnut 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). 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. 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).

This nutrient-dense legume is sometimes termed a “complete food” due to its balanced macronutrient composition. Bambara groundnut contains 64.4% carbohydrate, 23.6% protein, 6.5% fat, and 5.5% fiber and is rich in minerals (Unigwe et al., 2018). It is relatively underutilized when compared with major cash crops and has often been associated with small-scale, subsistence farming, with women being the major producers and processors (Cook., 2017). Bambara groundnut is thought to have its center of origin somewhere between West and Central Africa (Keller., 2014). It is grown widely in sub-Saharan Africa and is also presently at low levels in Thailand, Malaysia, and Indonesia (Alake and Ayo-vaughan.,2017). Higher preference for Bambara groundnut has been observed in dry regions prone to drought (Muzahib et al., 2013). This is possibly linked to its ability to produce reasonable yields under such conditions, hence acting as a safety net for farmers.

The present low yield of Bambara groundnut in Nigeria is less than 1 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. Increasing concerns about prohibitive high cost of chemical fertilizers, its adulteration, its unavailability at the right time and in sufficient quantity and having sometimes negative effect of chemical fertilizers on the soil acidification and environment makes organic (poultry) manure a better and safe alternative (Ibrahim *et al*., 2014). 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. Iheaturu *et al*. (2023) reported that application of different rates of poultry manure lead increase in the yield of Bambara groundnut plant. Farmers sometimes 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.

Water is the source of life, all living things depends on it. Water is essential in the cultivation of Bambara ground nut. The shortage of rainfall in terms of amount, intensity duration leading to drought and sometimes short dry spells as a result of climate change led to poor crop performance (during rainy season) resulting in low or no yield at all. Water shortage at any vegetative / reproductive growth stages in dry season cultivation of Bambara groundnut can have a negative impact on survival and can result in poor germination, poor vegetative growth resulting in poor yield and yield components of Bambara nut. Drought stress negatively influences crop growth and development and has been described as the most damaging climate hazard affecting two-thirds of the global population and threatening food security. The frequency and severity of drought are projected to increase due to decreased precipitation and increased evaporation due to global climate change. Crop responses to drought stress, on the other hand, vary significantly and are dependent on the severity and duration of the drought stress. Most times farmers do not use water judiciously during dry season cultivation of Bambara groundnut but are wasteful, which needs to be addressed during dry season cultivation. 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).

In this trial therefore, varied water regimes will be applied and their attendant consequences examined in Bambara nut cultivation. Therefore, this study was undertaken to investigate the effect of poultry manure, soil moisture regimes and inoculation on performance of yield and yield components of Bambara groundnut in the Nigerian savannah.

MATERIALS AND METHODS

Field trials were conducted during 2021/2022 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 -30cm for analysis, 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, four moisture regimes (25%, 50%, 75% and 100%) and two levels of inoculation; no inoculation and inoculation 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) were drilled 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. Moisture regimes treatment commenced at the onset of the trial. The experimental field was irrigated (immediately after sowing) at 3 days interval for a month to supply moisture to the crop up to 4WAS, there after irrigation was carried out at interval of 5 days as per treatment. 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 yield parameters like number of pod plant^{-1}, number of kernels pod^{-1}, 100 kernels weight (g), number of pods plot^{-1} , number of pod ha^{-1}, number of kernels (g) plot$^{-1,}$ harvest index, and kernel yield kg ha^{-1} at harvest. The data collected were analyzed using analysis of variance (ANOVA) technique, the treatment means were separated using Duncan's Multiple Range Test (Duncan,1955).

RESULTS

The result of soil physical and chemical properties of the experimental sites during the 2021/2022 dry season was presented as Table 1, while the results of the analysis of the poultry manure were presented as Tables 2 respectively. The soil at both Samaru was found to be of sandy loam textural class, while the soil at Mando was loam soil. Total Nitrogen and available Phosphorus

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was moderately low at both locations while organic carbon moderately high for both locations. The exchangeable bases (cmol kg^{-1}) was also low for both locations. The pH of soil at both locations was found to be slightly acidic in water and moderately acidic in $Cacl_2$ solution. The analysis of poultry manure used for the trial indicated high content of total Nitrogen (N) and potassium oxide (k_2O), Medium Organic material and low organic Nitrogen for liquid organic fertilizer. For solid organic fertilizer used, it contains high total organic material, high total Nitrogen (N), low organic Nitrogen and high water soluble potassium oxide.

Table 1: Physical and Chemical Properties of the Soil at Mando and Samaru during 2021/2022 dry Season.

Physical Properties (%)	**Mando**	**Samaru**
Clay	41.0	12
Silt	27.0	31
Sand	32.0	57
Textural Class	Loam	Sandy Loam
Chemical Properties	6.24	6.12
pH (H_2O) 1:2,5	5.86	5.63
pH 0.01 $Mcacl_2$	3.7	4.0
Total Nitrogen (gkg^{-1})	4.65	5.24
Available $Pmgkg^{-1}$	13.67	16.01
Organic Carbon		
Exchangeable	2.59	2.12
Bases ($cmolkg^{-1}$)	0.71	0.80
Calcium Meg/100g	0.01	0.13
Magnesium	0.17	0.61
Meg/100g	3.48	3.64
Potassium Meg/100g		
Sodium Meq/100g		
CEC Meg/100g		

Source: Analytical Laboratory, Department of Agronomy, Ahmadu Bello University, Zaria

Table 2: Nutrient Content of Poultry Manure Used at the Trial Sales 2021/2022 dry Season

Nutrient Content	**Value (%)**
Total Nitrogen	19.29
Available Phosphorus	0.90
Potassium	0.82

Source: Analytical Laboratory, Department of Agronomy, Ahmadu Bello University, Zaria

Table 3: Weather Data for the Experimental Sites during 2021/2022 dry Season

Mando						**Samaru**				
Months	**Rainfall (mm)**	**Temperature ^0C**		**Relative Humidity % 0900hrs**	**Sunshine (hrs)**	**Rainfall (mm)**	**Temperature ^0C**		**Relative Humidity %**	**Sunshine (Hrs)**
		Max	**Min**				**Max**	**Min**		
Oct	10.7	33	23	81	5.4	17.7	32	23	82	3.8
Nov	0.0	30	23	86	3.9	10.5	30	22	81	3.0
Dec	0.0	23	19	91	1.8	0.5	26	20	87	2.1
Jan	0.8	20	18	87	2.3	0.1	29	21	91	1.5
Feb	0.0	26	20	86	3.3	0.7	30	23	90	2.4
Mar	0.6	29	24	85	4.7	0.8	30	23	85	4.5
Apr	5.5	30	21	82	4.1	8.1	31	21	80	6.6
May	15.0	33	21	74	4.1	23.6	33	21	64	7.0
Total	**36.3**					59.44				

Source: Weather station of IAR-Samaru Zaria and Kaduna Aerodrome, International Airport Kaduna

Number of pod $plant^{-1}$

Table 4 showed the effect of poultry manure rate, moisture regime and inoculation on Bambara groundnut number of pod $plant^{-1}$ at Mando and Samaru during 2021/2022 dry season. The effect of poultry manure rates had a significant effect on Bambara groundnut number of pod $plant^{-1}$at both Mando and Samaru where application of 6 tons/ha resulted in highest number of pod $pant^{-1}$ that was statistically similar to plants produced with 4 tons/ha at Mando and zero(0) ton ha^{-1}.produced the least number of pods $plant^{-1}$. Similarly, table 4 further showed that Bambara groundnut number of pod $plant^{-1}$ significantly responded to influence of moisture regimes at both Mando and Samaru, where application of 100 % moisture regime resulted in highest number of pod $pant^{-1}$ that was statistically similar to plants produced with 4 tons/ha at both Mando and Samaru, while 25% moisture regime produced the least number of pods $plant^{-1}$. The effect of inoculation on number of pod $plant^{-1}$ of Bambara groundnut was significant where inoculated plants had more pods $plant^{-1}$ than non-inoculated plants from both locations as shown in table 4. There was no interaction effect between the variables.

Number of kernels pod^{-1}

Table 4 also showed the effect of poultry manure rate, moisture regime and inoculation on Bambara groundnut number of kernels pod^{-1} at Mando and Samaru during 2021/2022 dry season. The application of poultry manure rates had a significant effect on Bambara groundnut number of kernels pod^{-1} at both Mando and Samaru where application of 6 tons/ha resulted in more kernels pod^{-1} that was statistically similar to plants produced with 4 tons/ha at Mando and zero(0) ton ha^{-1}.produced the least number of kernels pod^{-1}. Similarly, table 4 further showed the effect of moisture regimes on Bambara groundnut number of kernels pod^{-1} had a significant effect at both Mando and Samaru, where application of 100 % moisture regime resulted in high number of kernels pod^{-1} that was statistically similar to plants produced with 4 tons/ha at both Mando and Samaru, while 25% moisture regime produced the least number of kernels pod^{-1}. The effect of inoculation on number of pod $plant^{-1}$ of Bambara groundnut was

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significant where inoculated plants had more pods plant^{-1} than non-inoculated plants from both locations as shown in table 4. There was no interaction effect between the variables.

100 kernels weight (g)

100 kernel weight (g) of Bambara groundnut as influenced by poultry manure rate, moisture regime and inoculation solid at Mando and Samaru during 2021/2022 dry season is presented as table 4.

The application of poultry manure rates had a significant effect on Bambara groundnut 100 kernel weight (g) number of kernels pod^{-1} at both Mando and Samaru where application of 6 tons/ha resulted in heavier 100 kernel weight (g) that was statistically similar to those produced with 4 tons/ha at Mando and zero(0) ton ha^{-1}.produced the lightest 100 kernel weight (g). Similarly, table 4 further showed that of application of moisture regimes had a significant effect on Bambara groundnut 100 kernel weight (g)at both Mando and Samaru, where application of 100 % moisture regime resulted in heavier 100 kernel weight (g) that was statistically similar to plants produced with 4 tons/ha at both Mando and Samaru, while 25% moisture regime produced the lightest 100 kernel weight (g). The effect of inoculation on number of pod plant^{-1} of Bambara groundnut was significant where inoculated plants had more pods plant^{-1} than non-inoculated plants from both locations as shown in table 4.

There was interaction effect between poultry manure rate and moisture regime Bambara groundnut 100 kernel weight (g) at Samaru in2021/2022 as shown in Table 5. The heaviest 100 kernel weight (g) was obtained at the combination of 6 ton ha^{-1} and 100% moisture regimes in which 6 and 4 ton ha^{-1} poultry manure rates were statistically similar and 100 and 75% moisture regimes were statistically similar

Table 4: Effect of Poultry manure, Moisture regimes and inoculation on Number of pod plant^{-1}, Number of kernels pod^{-1} and 100 kernels weight (g) of Bambara groundnut during 2021/2022 Dry Season at Mando and Samaru.

	2021/2022					
	Mando			Samaru		
Treatment	Number of kernels pod^{-1}	Number of pod plant^{-1}	100 kernels weight (g)	Number of kernels pod^{-1}	Number of pod plant^{-1}	100 kernels weight(g)
Poultry manure (tha^{-1})						
0	1.94^{c}	47.32^{cd}	214.73^{c}	1.99^{c}	51.95^{cd}	295.20^{c}
2	2.12^{b}	55.98^{c}	311.26^{b}	2.12^{b}	56.33^{c}	342.74^{b}
4	2.13^{ab}	73.39^{ab}	370.06^{ab}	2.17^{ab}	87.62^{ab}	388.81^{ab}
6	2.17^{a}	94.94^{a}	396.62^{a}	2.23^{a}	96.56^{a}	402.53^{a}
SE	0.026	2.435	0.206	0.026	2.898	0.268
Moisture regime (%)						
25	2.00	45.90^{d}	265.55^{c}	2.08^{c}	54.38^{bc}	304.42^{b}
50	2.08	59.63^{c}	297.10^{bc}	2.08^{c}	55.49^{b}	310.13^{b}
75	2.15	67.10^{ab}	322.71^{ab}	2.15^{ab}	68.35^{ab}	371.26^{a}
100	2.24	77.12^{a}	369.38^{a}	2.23^{a}	83.53^{a}	409.92^{a}
SE	0.026	2.435	0.206	0.026	2.898	0.268
Inoculation						
No inoculation	2.04^{b}	69.22^{b}	298.55^{b}	2.05^{b}	73.98^{b}	323.44^{b}
Inoculation	2.20^{a}	87.43^{a}	328.82^{a}	2.21^{a}	91.89^{a}	374.17^{a}
SE	0.018	2.036	0.145	0.018	2.049	0.189
Interaction						
P x I	NS	NS	NS	NS	NS	NS
M x I	NS	NS	NS	NS	NS	NS
P x M	NS	NS	NS	NS	NS	*
P x M x I	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a column of treatment b means 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.

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Table 5: Interaction Effect between Poultry manure and Moisture regimes on 100 kernel weight (g) of Bambara groundnut at Samaru during 2022 dry season.

	100 Kernel weight (g)			
	Moisture regimes (%)			
Poultry manure tha^{-1}	**25**	**50**	**75**	**100**
0.0	75.90g	81.53f	87.87e	96.25d
2.0	96.00d	100.48cd	104.02c	103.60c
4.0	101.00c	111.83b	115.04b	119.85ab
6.0	104.58c		115.09b	128.95a
		114.40b		
SE±				
		1.55		

Means followed by the same letter(s) within a column of treatment b means 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.

Pod yield (g) Plot^{-1}

Table 6 shows the effect of poultry manure rates, moisture regimes and inoculation on pod yield (g) plot^{-1} at Mando and Samaru 2021/2022 dry season. The effect of poultry manure rate on pod yield plot^{-1} of Bambara groundnut was not significant at both locations where the control (0-ton ha^{-1}) produced the lightest pod yield per plot while 6 tha^{-1} produced the heaviest pods weight per plot relative to other poultry manure rates evaluated. Similarly, the effect of moisture regimes on pod yield per plot at both locations was also not significant where 25% moisture regime produced lowest pod yield per plot, while 100% moisture regime produced heaviest pod yield/plot. The response of pod yield (g) plot^{-1} to inoculation was not significant in both locations except at 2021/2022. Inoculated Bambara nut plant had heavier pods per plot than non-inoculated plant. There was no interaction effect between the variables.

Pod yield kg ha^{-1}

Table 6 further shows the effect of poultry manure rate, moisture regimes and inoculation on pod yield kg/ha of Bambara groundnut at Mando and Samaru 2021/2022 dry seasons. The effect of poultry manure rates on pod yield kg/ha was significant at both locations where the control (0 tons/ha) had a lighter pod yield (kg/ha) and 6 tons/ha produced the heaviest pod yield per hectare. Also the effect of moisture regime on pod yield (kg/ ha) of Bambara nut was also significant where 25% moisture availability produced lighter pod yield/ha while 100 percent moisture availability produced higher pods yield (kg) The responses of pod weight kgha^{-1} of Bambara groundnut to inoculation was significant at all locations where inoculated plants had a higher pod yield kgha^{-1} than non -inoculated plants. There was no interaction between the variables.

Kernel yield (g) Plot^{-1}

Table 6 also showed the effect of poultry manure rate, moisture regime and inoculation on kernel yield kg ha^{-1}of Bambara groundnut at Mando and Samaru 2021/2022 dry seasons. The effect of poultry manure rates on kernel yield kg ha^{-1}was significant in both locations where the control (0 tons ha^{-1}) produces lower kernel yield and 6 tha^{-1} produces highest kernel yield relative to other rates evaluated. Similarly, the effect of moisture regimes on kernel yield kg ha^{-1}was also significant in all locations where 25% moisture regime produces lower kernel yield kg ha^{-1} while 100% moisture regime produces highest kernel yield kg ha^{-1}.The response of kernel yield of Bambara groundnut to inoculation during 2021/ 2022 dry season at both locations was significant. 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 Moisture regime on kernel yield kg ha^{-1} of Bambara ground nut at Samaru during 2022warm dry season as presented in Table 7. 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.

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Table 6: Effect of Poultry manure, Moisture regimes and inoculation on Pod yield (g) plot^{-1}, Pod yield kg ha^{-1} and kernel yield (g) plot^{-1}of Bambara groundnut during 2021/2022 Dry Season at Mando and Samaru.

	2021/2022					
	Mando			Samaru		
Treatment	Pod yield (g) Plot^{-1}	Pod yield kg ha^{-1}	Kernel yield (g)Plot^{-1}	Pod yield (g) Plot^{-1}	Pod yield kg ha^{-1}	Kernel yield (g) Plot^{-1}
Poultrymanure tha^{-1}						
0	390.03	618.77^{b}	269.31^{c}	392.11	637.52^{b}	269.64^{c}
2	399.44	707.69^{a}	332.94^{b}	405.66	726.50^{a}	336.99^{b}
4	400.06	739.15^{a}	337.76^{b}	406.77	750.02^{a}	341.28^{ab}
6	436.70	744.59^{a}	346.64^{a}	441.76	758.80^{a}	352.80^{a}
SE	9.010	13.692	2.414	9.003	100.667	1.487
Moisture regime (%)						
25	399.84	605.53^{b}	306.63^{c}	399.98	614.56^{c}	315.79^{c}
50	408.76	712.92^{a}	310.91^{b}	409.44	724.72^{b}	319.33^{b}
75	408.88	747.35^{a}	323.68^{ab}	410.88	765.47^{ab}	327.00^{ab}
100	409.83	749.02^{a}	324.04^{a}	411.23	766.03^{a}	344.11^{a}
SE	9.010	13.922	2.414	9.003	100.667	1.487
Inoculation						
No inoculation	391.57	679.04^{b}	311.89^{b}	395.12^{b}	694.63^{b}	314.74^{b}
Inoculation	422.09	728.37^{a}	329.34^{a}	425.77^{a}	740.76^{a}	335.88a
SE	6.371	9.681	1.707	6.366	9.1189	1.052
Interaction						
P x I	NS	NS	NS	NS	NS	NS
M x I	NS	NS	NS	NS	NS	NS
P x M	NS	NS	NS	NS	NS	*
P x M x I	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a column of treatment b means 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 and Moisture regimes on Kernel yield (g) plot^{-1}of Bambara groundnut at Samaru during 2022 dry season.

	Moisture regimes (%)			
Poultry manure tha^{-1}	**25**	**50**	**75**	**100**
0.0	247.37h	249.12l	257.36h	290.17g
2.0	306.53		340.37cd	351.58bc
4.0	322.42e	328.70e	344.97bc	357.67b
6.0	326.41e	339.70cd	352.13b	371.50a
		342.02c		
SE±				
		2.975		

Means followed by the same letter(s) within a column of treatment b means 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 8 shows the effect of poultry manure rate, moisture regime and inoculation on Kernel yield kg ha^{-1} of Bambara groundnut at Mando and Samaru during 2021 /2022 dry seasons. The effect of poultry manure rate on Kernel yield kg ha^{-1} was significant in all locations in 2021/2022. The control 0 tons ha^{-1} of poultry manure produced Kernel yield kg ha^{-1} while 6 tons ha^{-1} produced the highest Kernel yield kg ha^{-1} values.

The effect of moisture was also significant on Kernel yield kg ha^{-1} of Bambara groundnut in all location where 25 percent moisture regime produced least of Bambara groundnut plant Kernel yield kg ha^{-1} values while 100 percent available moisture produced the

highest Kernel yield kg ha^{-1} values. The response of kernel yield kg ha^{-1}to inoculation was also significant in all locations where inoculated plant had a higher kernel yield kg ha^{-1} values than non-inoculated Bambara nut plants.

There was a significant interaction between poultry manure and moisture regime on kernel yield kg ha^{-1} of Bambara ground nut at Samaru during 2021/2022 dry season as shown in Table 9. The highest kernel yield kg ha^{-1} was obtained at the combination of 6 tons ha^{-1} poultry manure with 100% moisture regime.

Harvest Index

Table 8 further shows the effect of poultry manure rate, moisture regime and inoculation on harvest index of Bambara groundnut at Mando and Samaru during 2021/2022 dry seasons. The effect of poultry manure rate on harvest index was significant in all locations in 2021/2022. The control 0 tons ha^{-1} of poultry manure produced least harvest index values while 6 tons ha^{-1} produced the highest harvest index values.

The effect of moisture regime was also significant in all location in 2021/2022 where 25 percent moisture regime of Bambara groundnut plant produced least harvest index values while 100 percent available moisture produced the highest harvest index values. The response of harvest index to inoculation was also significant in all locations where inoculated plant had a higher harvest index values than non-inoculated Bambara nut plants.

There was a significant interaction between poultry manure and moisture regime on harvest index of Bambara ground nut at Samaru during 2021/2022 dry season as shown in Table 10. The highest harvest index was obtained at the combination of 6 tons ha^{-1} poultry manure with 100% moisture regime.

Table 8: Effect of Poultry manure, Moisture regimes and inoculation on kernel yield kg ha^{-1} and Harvest index of Bambara groundnut during 2021/2022 Dry Season at Mando and Samaru.

	2021/2022			
	Mando		Samaru	
Treatment	Kernel yield kg ha^{-1}	Harvest Index	Kernel yield kg ha^{-1}	Harvest index
Poultrymanure tha^{-1}				
0	442.18^{c}	62.06^{c}	449.43^{c}	63.46^{c}
2	554.91^{b}	63.52^{b}	561.65^{b}	64.77^{b}
4	562.94^{ab}	64.87^{ab}	568.82^{ab}	65.19^{ab}
6	577.73^{a}	66.86^{a}	588.00^{a}	68.12^{a}
SE	4.024	0.096	2.479	0.102
Moisture regime (%)				
25	511.04^{c}	63.33^{c}	526.32^{c}	63.45^{c}
50	518.19^{b}	64.30^{b}	523.89^{b}	64.54^{b}
75	539.46^{ab}	65.55^{ab}	545.01^{ab}	65.89^{ab}
100	570.06^{a}	67.29^{a}	573.53^{a}	67.54^{a}
SE	4.024	0.096	2.479	0.102
Inoculation				
No inoculation	519.82^{b}	64.19^{b}	524.57^{b}	64.23^{b}
Inoculation	549.56^{a}	66.04^{a}	559.80^{a}	66.48a
SE	2.851	0.068	1.753	0.072
Interaction				
P x I	NS	NS	NS	NS
M x I	NS	NS	NS	NS
P x M	NS	NS	*	*
P x M x I	NS	NS	NS	NS

Means followed by the same letter(s) within a column of treatment b means 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.

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Table 9: Interaction Effect between Poultry manure and Moisture regimes on Kernel yield kg ha^{-1}of Bambara groundnut at Samaru during 2022 dry season.

	Moisture regimes (%)			
Poultry manure tha^{-1}	**25**	**50**	**75**	**100**
0.0	401.94h	403.19l	431.86l	483.61h
2.0	510.89g	547.83f	567.27de	595.22b
4.0	539.03f	568.36e	586.61bc	596.11b
6.0	562.36e	576.17cd	594.31b	619.17a
SE±		4.975		

Means followed by the same letter(s) within a column of treatment b means 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 and Moisture regimes on Harvest index of Bambara groundnut at Samaru during 2022 dry season.

	Moisture regimes (%)			
Poultry manure tha^{-1}	**25**	**50**	**75**	**100**
0.0	247.37h	249.12l	257.36h	290.17g
2.0	306.53	328.70e	340.37cd	351.58bc
4.0	322.42e	339.70cd	344.97bc	357.67b
6.0	326.41e	342.02c	352.13b	371.50a
SE±		2.975		

Means followed by the same letter(s) within a column of treatment b means 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.

DISCUSSION

The results of soil, poultry manure analysis and weather data for both locations (tables 1, 2 and 3 respectively) indicate that the soil textural class was sandy loam at Samaru while loam soil was obtained at Mando locations. Sandy loam soil is almost ideal for growth and yield of Bambara groundnut plant in the savannah agro ecology according to Olayinka *et al,* (2016). This type of soil enhances better root growth and development while maintaining adequate soil aeration which encourage good soil microbial activities. It also allows for good water retention capacity of the soil while maintaining adequate drainage. Table 4 showed That the mean minimum and maximum daily temperature, relative humidity and sunshine hours were optimal in 2021/2022 dry season and particularly during flowering, pod formation and kernel filling stages as reported by Gerranno *et al*., (2021), which favored good yield performance of the crop at Samaru than Mando This probably explains why the performance of the Bambara groundnut is better in terms of growth, yield and yield parameters at Samaru than those of Mando.

It was observed that the application of 6 t ha^{-1}poultry manure and 100% moisture regimes significantly increased the growth, yield and yield parameters of inoculated Bambara groundnut over non-inoculated Bambara groundnut plants in these trials. The positive response of some yield and yield components such as like number of pod plant^{-1}, number of kernels pod^{-1}, 100 kernels weight (g),number of pods plot^{-1} ,number of pod ha^{-1},number of kernels (g) plot^{-1}, kernel yield kg ha^{-1} and harvest index of Bambara groundnut at Samaru could be attributed to the role higher poultry manure rate over other rates evaluated play in slowly releasing nutrients to the plants over a long period of time, also maintaining soil organic matter level, productivity and aggregate stability. This is in line with the report of Wamba *et al*., (2012) who stated that organic matter improves soil aggregate stability and allows crop plants take up nutrients easily thus better growth and yield in growing Bambara ground nut plant. Adeyeye *et al* (2019) further affirmed that the increase in yield and yield components of Bambara groundnut with higher rate of poultry manure application shows that organic manures improves the microbial level as well as solid organic matter which in turn produces organic acids, those organic acids enhance the promotive effect of auxins which has the direct effect on plant growth. The increase in number of pod plant^{-1}, number of kernels pod^{-1}, 100 kernels weight (g),number of pods plot^{-1} ,number of pod ha^{-1},number of kernels (g) plot^{-1}, kernel yield kg ha^{-1} and harvest index of Bambara groundnut with increased application of moisture regimes was also evident in this trial. The growth, yield and yield parameters responses of Bambara groundnut to water sufficiency would most certainly encourage the utilization of resource needed for growth and development, yield and yield components to the maximum. Bambara groundnut would utilize such resource maximizing in all growth indices like plant length, number of leaves, number of branches, canopy spread, LAI, CGR, RGR and NAR and higher amount of dry matter would be recorded. Thus bigger and better response would be evident as observed in yield and yield components like number of pod plant^{-1}, number of kernels pod^{-1}, 100 kernels weight (g),number of pods plot^{-1} ,number of pod ha^{-1},number of kernels (g) plot^{-1}, kernel yield kg ha^{-1} and harvest index of Bambara groundnut. This result agrees with the report of Vurayai *et al*., (2011), and Ngwako *et al*, (2013) reported that water sufficiency (100% water regime) increased Bambara groundnut growth, yield and yield parameters.

The increase in number of pod plant^{-1}, number of kernels pod^{-1}, 100 kernels weight (g),number of pods plot^{-1} ,number of pod ha^{-1},number of kernels (g) plot^{-1}, kernel yield kg ha^{-1} and harvest index of Bambara groundnut due to inoculation could be as a result of microbial inoculation of the crop which possibly enhanced and boost the crops vigor through increased nodulation, thus increased atmospheric N fixation which improved the soil fertility around the root zone of the crop that probably improved the crops nutrients uptake from the soil as well as encourage an improved the microbial activities in the soil. This is in accordance with an experiment conducted by Singh *et al.* (2022) which concluded that inoculation of beneficial microbes enhances plant acquisition of macro nutrients and micronutrients in legumes for higher yield and yield parameters performance. This confirmed the finding of Muhammed. (2011) and Yandav and Sarkar. (2019) that inoculating Bambara groundnut and soya bean with bradyrhizoidal significantly increased pod and seed number, the number of effective noodles per plant increased with the application of inoculants.

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 yield and yield indices, followed by the 4 tons ha^{-1}, 2 tons ha^{-1} and lastly the control, 0 tons ha^{-1} in that order. Application of 100% moisture regime also gave the highest values in terms of growth and yield characters of Bambara ground nut over other moisture regimes evaluated. 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, a combination of 6 t ha^{-1} with 100% moisture regime on inoculated Bambara groundnut could be considered for better performance of yield and yield parameters of Bambara groundnut at Mando and Samaru both in Kaduna State of Nigeria.

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