Journal of Agricultural Science and Practice
Volume 5(1), pages 8-19, February 2020
Article Number: 201184B02
ISSN: 2536-7072
https://doi.org/10.31248/JASP2019.178
https://integrityresjournals.org/journal/JASP

Full Length Research

Effects of multilocation on intra-row spacing and nitrogen rate on growth and yield of Bambara groundnut (*Vigna subterranea* (L.) *Verdc.*) in North Eastern Nigeria

M. M. Tyoakoso[1], M. D. Toungos[1*] and M. Babayola[2]

[1]Department of Crop Production and Horticulture, Modibbo Adama University of Technology, Yola, Nigeria.
[2]Department of Crop Science, Faculty of Agriculture, Adamawa State University, Mubi, Nigeria.

*Corresponding author. Email: toungosm@mautech.edu.ng; dahiru.toungos@gmail.com; Tel: +2348034392406.

Received 7th December, 2019; Accepted 28th December, 2019

ABSTRACT: Field experiments were conducted in 2015 rainy season at Teaching and Research Farms of Department of Crop Production and Horticulture, Modibbo Adama University of Technology, Yola and Department of Crop Science, Taraba State College of Agriculture, Jalingo to investigate the effect of multilocation on intra-row spacing and nitrogen rates on the growth and yield of Bambara groundnut (*Vigna subterranean* (L.) Verdc) in Northern Nigeria. The experiments were laid out in split-plot design with three replications and three nitrogen rate, 20, 25 and 30 kgNha^{-1} as main plot treatment while four intra-row spacing, 20, 25, 30 and 35 cm as the sub plot treatment. The sub plot size was 3 m x 2 m (6 m^2). The nitrogen rate doses were applied a week after emergence of the seedlings. Data collected were, percentage seedlings emergence, number of leaves per plant, number of branches plant, plant height, number of nodules per plant, number of effective nodules per plant, number of non-effective nodules per plant, days to 50% flowering, days to 95% maturity, number of pods per plant, number of seeds per plant, 100 seeds weight, grain yield per plot and grain yield per ha. Data collected were subjected to Analysis of Variance (ANOVA), means were separated using Least Significant Difference (LSD). The results showed that nitrogen rate applied had no significant influence on growth and yield characters in both trial locations. However, significant influence was recorded of intra-row spacing on number of leaves per plant and number of branches per plant at 6 WAS at Jalingo trial location with the mean values of 48.24 at 35 cm and 16.80 at 35 cm respectively. Intra-row spacing, 25 cm gave the highest mean number (3.14) of non-effective nodules per plant at 30 DAS at Yola trial location while at Jalingo, 25 cm gave the highest number of days to 50% flowering. The result of the interaction revealed that there were significant interaction between Nitrogen rates and intra-row spacing on the number of leaves at 3 WAS at Jalingo location, 6 WAS at both locations, number of nodules and number of non-effective nodules at 30 DAS at Yola trial location. It is recommended that nitrogen rate of 20 kgNha^{-1} and intra-row spacing of 35 cm be adopted in the study areas for higher yield to the farmers.

Keywords: Bambara groundnuts, Nitrogen, nodules, yield.

INTRODUCTION

Bambara groundnut (*Vigna subterranea* (L.) Verdc) is one of the few indigenous tropical Africa crops which have wide distribution as a crop plant in Far East, India, Madagascar, Africa, South of the Sahara and South America (Hepper, 1970). The average day temperature ideal for the crop production as stated by Bamshaiye et al. (2011) is from 20 to 28^{0}C and the optimum temperature for germination of Bambara groundnut seed is 30 to 35^{0}C. Extreme temperatures cause dying of the leaves, resulting in the reduction of the biomass yield. They indicated that cool temperatures are conducive to longer seed filling periods and as a result increased yield in grain crops. The crop requires an average rainfall of about 600 to 700 mm during the growing season. Anonymous (2011) reported that, it requires a frost-free period of at least 3 to 5 months, can tolerate short duration drought and is a typical short-day plant. It also requires an altitude of 1,600 m above sea level.

Bambara groundnut will grow on soils ranging from sandy loamy to clay loam with good drainage but prefers light sandy loams with pH of 5.0 to 6.5. It does well on poor soil which is low in nutrients. However, it can be successfully grown on a wide variety of soils with appropriate soil management, fertilization and appropriate moisture control practices (Anonymous, 2011; Swanevelder, 1998).

In Nigeria, it features predominantly in the traditional farming system as an inter-crop with grain cereals (maize, sorghum, and millet), yam and cowpea and it can be singly cultivated (Hueze and Tran, 2013; Mkandiwire and Sibuga, 2002). Asiwe and Kutu (2007) pointed out that, the crop is inter-cropped with grain cereals to reduce risk of crop failure due to drought since it is more tolerant than other companion crops. For this reason, Bambara groundnut is grown on marginal soils with low moisture and fertility status. Egbe et al. (2013) stated that Bambara groundnut fixes atmospheric nitrogen through symbiosis with Rhizobium bacteria, therefore beneficial in rotation and intercropping. Still on the farming system, Hillocks et al. (2012) stated that, it is suitable for intercropping with other crops for it does not take up areas of land that could be used for other crops considered more important and lucrative.

Bambara groundnut is a pulse of immense potential in enhancing food security especially in drought prone agricultural system. Its drought tolerance makes it ideal for production by resource poor farmers especially in communal and resettlement areas. As a result, it can grow well in communal areas where pest and disease control are not given serious attention. It can produce under high temperature where other pulses fail to survive (Vasamuzi, 1992; Akpalu et al., 2013).

In Nigeria, the leading producing states are Kano, Bauchi, Adamawa, Benue, Plateau, Nassarawa, and Gombe (Elijah, 2011). In these areas, the crop is planted between June and August (Tanimu, 1997). The problem of production is acute and will become more critical with each passing year. Although the world is increasing its food supply, population growth is now outstripping food production in all underdeveloped countries.

The use of optimum spacing is essential for seed yield, since this would ensure early and good ground cover and smothering of weeds. In Nigeria, Linnemann (1988) reported that spacing is closely related to cultivation methods. He also found that farmers who plant Bambara groundnut on flat lands use closer spacing than those who plant the crop on ridges. The average spacing on flat land is approximately 35 cm x 35 cm; with the closest spacing being 20 cm x 20 cm and the widest is 40 cm x 40 cm. Farmers planting on ridges generally use a distance of 70 to 75 cm between ridges and 30 to 35 cm between plants on the ridge. In some instances, farmers plant Bambara groundnut in double or triple rows on beds at a spacing of 15 cm between the rows on the ridges with 20 cm distance between plants in the row. In Sudan, El Wakeel and Osman (1992) reported that a high plant population is essential for good yield and crop should be planted in rows to assist subsequent cultivation. They further stated that planting on flat rows is spaced most commonly about 30 cm × 30 cm and the range of plant spacing is 20 to 50 cm × 15 to 30 cm.

With the inconsistency in the plant spacing as essential factor for optimum yield couple with the status of the soil on which Bambara groundnut is grown in North Eastern Nigeria, warrants the need to study the effects of intra-row spacing and Nitrogen fertilizer (Urea) on growth and yield of Bambara groundnut (*Vigna subterranea* (L) verdc.) in Yola and Jalingo. Therefore, the aim of this study is to determine the effect of intra-row spacing on the growth and yield of Bambara groundnut and to determine the effect of nitrogen rate on the growth and yield of the crop.

MATERIALS AND METHODS

The experiment was conducted in two locations during the 2015 cropping seasons. The first location was at the Teaching and Research Farm of the Department of Crop Production and Horticulture, Modibbo Adama University of Technology, Yola which is located within latitude $9^0 19''$N and longitude $12^0 28''$E, at an altitude 185.9 m above sea level and lies within the Northern Guinea Savanna of Nigeria. The annual rainfall of Yola ranges from 900 to 1100 mm and the length of the rainy season ranges from 150 to 160 days, mostly from May to October (Adebayo and Tukur, 1999). The second location was at the Teaching and Research Farm of Department of Crop Science, Taraba State College of Agriculture, Jalingo which is located within latitude $8^0 56''$N and longitude $11^0 50''$E at altitude 1600 m above sea level in Southern Guinea Savanna. Jalingo experience wet and dry tropical climate with rainy season from May to October with mean annual rainfall of 750 to 1000 mm while the dry season commences in November and ends in March or April (TADP, 2012).

Treatment and experimental design

The treatments consisted of four (4) intra-row spacing (20, 25, 30 and 35 cm) and three (3) Nitrogen (urea 46% N) rates (20, 25 and 30 $kgha^{-1}$). The treatments were laid out in a split plot design with nitrogen rate assigned to the main plot whereas intro-row spacing at the sub plot. The treatments were replicated three times. The keys for the main plot treatments, N_1, N_2, N_3 and the sub plot treatments, S_1, S2, S3 and S_4 were written on pieces of papers, squeezed, put in a container and shook-up. The papers were picked at random and used to design the plots. The sub-plot size was 3 m x 2 m (6 m^2).

Agronomic practices

Land preparation

The field was cleared to remove stubbles at the onset of the rainy season. A tractor was used to plough, disc harrowed and the field was leveled manually by the use of hand hoe to produce fine seedbed for good germination and crop establishment. The plots were laid out using rope, pegs, hoes and measuring tape for demarcation accuracy.

Seed selections

A local cultivar Yar Shelleng was used for the experiment which was obtained from Jalingo market. The seeds were visually examined for purity and seeds of uniform sizes and color were selected which were later tested in the laboratory to determine the viability using the germinator.

Seed dressing

Prior to planting, seeds were dressed using seed dressing chemical, Apron plus 50DS at the rate of 10g (1sachet) for 1 to 2 kg in order to protect the crop from infestation of soil-borne pests and diseases.

Sowing date

The sowing date was on the 30th June, 2015 in Jalingo location and on the 28th July, 2015 in Yola location. This was when the rain was well established in the two (2) locations.

Sowing method

Seeds were dibbled in the soil with the use of a hand hoe.

Sowing rate and depth

The seeds were sown at the rate of 2 to 3 seeds per hole and later thinned to 1 plant per hill. The seeds were sown 2.5 to 3.0 cm deep depending on the location.

Weed control

Weeds were controlled manually with the use of hoe first at 2 weeks after sowing and secondly at 4 to 5 weeks after sowing. Weeds were controlled manually throughout the experiment as the use of herbicide may interfere with nodule formation.

Data collection

Percentage seedlings emergence

The proportion of seedlings that emerged to total seeds sown was expressed as percentage seedlings at 2 weeks after sowing (2 WAS).

$$\mathrm{PE} = \frac{\text{Seedling that emerged}}{\text{Total seeds planted}} \text{ x } 100$$

Number of leaves per plant

Five (5) plants were randomly tagged per plot and the number of leaves per plant was counted at 3, 6 and 9 weeks after sowing and the mean number was recorded per plant.

Number of branches per plant

Five (5) plants were randomly tagged per plot and the number of branches per plant was counted at 3, 6 and 9 WAS and the mean number was recorded per plant.

Plant height

Five (5) plants were randomly tagged in each plot and their heights were measured from ground level to tip of the plant at 3, 6 and 9 WAS and the mean was recorded.

Total Number of nodules per plant

The number of nodules was counted at 15 and 30 days after sowing (DAS). Three plants were randomly dug out (root out together with boll of earth) in order not to lose the nodules. These were carefully washed for the nodules to be seen clearly. The nodules were counted and the mean number was recorded.

Number of effective and non-effective nodules

The number of effective nodules was determined by slicing the nodules into two by the use of a new Razor blade. A pinkish color indicated that the nodules were effective while whitish color indicated non-effectiveness of the nodules and the means were recorded.

Days to 50% flowering

This was done by examining each plot periodically to note when 50% of the plants formed flowers.

Days to 95% maturity

This was done by physically observing when 95% of the plant population turned yellowish in each plot signifying plant maturity.

Number of pods per plant

Five (5) plants were randomly harvested in each plot at maturity and the number of pods were counted and divided by five to obtain the mean number of seeds per plant.

Number of seeds per plant

The pods of the five randomly harvested plants in each plot were shelled and the seeds were divided by five to obtain the mean number of seeds per plant.

100 Seeds weight (grams)

100 seeds were randomly taken from each plot and their weight measured using electric top loading balance and their values recorded.

Grain yield per ha-1

The seeds obtained from the dried pods of the plots were weighed on an electric top loading balance to determine the yield per each plot, which was then converted to yield per hectare in kilogram as follows:

$$\frac{\text{Yield}}{\text{ha}} = \frac{\text{Grain yield per plot (kg)}}{\text{Plot size }(6\text{m}^2)}\ x\ 10{,}000\text{m}^2$$

Statistical analysis

All the data collected from the experiments were subjected to Analysis of Variance (ANOVA) appropriate to split plot design and means were separated using Least Significance Difference (LSD) at 5% level of significance as described by Gomez and Gomez (1984). The package used was GENSTAT, 4th Edition.

RESULTS AND DISCUSION

Effects of intra-row spacing and nitrogen rate on percentage seedling emergence of Bambara groundnut

The effect of intra-row spacing and nitrogen rate on percentage seedlings emergence in Jalingo and Yola locations is presented on Table 1. In Jalingo location, there was no significant ($p \leq 0.05$) difference between nitrogen rates on percentage seedlings emergence. The same trend was observed in Yola location. This is due to the application nitrogen which reduces the activities Rhizobia and nitrogen fixing bacteria. This agrees with the work of Onwueme and Sinha (1991), who stated that it is generally advisable to apply a small amount of nitrogen to the legumes at planting time to ensure that the young seedlings will have adequate supply until the Rhizobia becomes established on their roots. Application of nitrogen, however, reduces the activity of *Rhizobia* and is therefore uneconomical. Davis et al. (2015) also stated that, excess nitrogen promotes lush vegetative growth, delays maturity and may reduce seed yield and may suppress nitrogen fixation.

Effects of intra-row spacing and nitrogen rate on number of leaves per plant at 3, 6 and 9 weeks after sowing

The effects of Intra-row spacing and nitrogen rate on number of leaves per plant at 3, 6 and 9 weeks after sowing (WAS) in Jalingo and Yola trial locations are presented in Table 1. There were no significant ($p \leq 0.05$) effects of nitrogen rate and intra-row spacing on number of leaves per plant at 3 WAS in Jalingo trial location. Similar result was obtained in Yola trial location. There were neither significant ($p \leq 0.05$) effects of nitrogen rate nor spacing on number of leaves per plant at 3 WAS. The effects of nitrogen rates on number of leaves per plant in Jalingo trial location was not significant at 6 WAS. Highly significant ($p \leq 0.01$) difference on number of leaves/plant were recorded in intra-row spacing with 35 cm having the highest mean value (48.24) while 20 cm gave the lowest mean (41.96) number of leaves per plant. In Yola, neither nitrogen nor spacing had significant ($p \leq 0.05$) influence on number of leaves per plant at 6 WAS. There were no significant effect of both nitrogen rate and intra-row spacing on number of leaves at 9 WAS in both Jalingo and Yola trial locations. This may be due to the application of nitrogen a week after emergence which could not have influence on it. This suggests that when conditions for germination are favorable, seeds would germinate and emerge even if the nutrient status of the soil is poor. This agrees with the report of Madukwe et al. (2010) that nitrogen fertilizer had no significant effect on germinability of Bambara groundnut seeds.

Interaction between intra-row spacing and nitrogen rate on number of leaves per plants at 3 weeks after sowing

Table 2 shows the interaction between intra-row spacing and nitrogen rate on number of leaves per plant at 3 WAS

Table 1. Effects of intra-row spacing and nitrogen rate on percentage emergence of seedlings and number of leaves per plant of Bambara groundnut in Jalingo and Yola in 2015 cropping season.

Treatment	% Seedlings Emergence		Number of Leaves 3WAS		Number of Leaves 6WAS		Number of Leaves 9WAS	
	Jalingo	**Yola**	**Jalingo**	**Yola**	**Jalingo**	**Yola**	**Jalingo**	**Yola**
Nitrogen Rates ($kgha^{-1}$)								
20	99.54	99.44	6.22	6.60	50.13	30.02	120.30	62.20
25	99.28	98.84	5.90	6.07	45.28	32.30	117.60	63.80
30	99.09	98.40	6.20	6.22	43.07	28.87	108.90	69.70
LSD	0.48	1.80	0.29	1.30	9.29	16.45	17.25	14.30
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Spacing (cm)								
20	99.43	99.24	6.20	6.80	41.96	30.73	111.20	63.00
25	99.30	99.53	6.02	6.09	43.31	29.73	109.30	70.50
30	99.17	98.89	5.96	5.78	47.13	30.87	119.10	70.10
35	99.31	97.92	6.22	6.51	48.24	30.24	122.90	57.30
LSD	1.13	1.77	6.43	0.89	2.84	3.05	14.78	14.56
Significance	NS	NS	NS	NS	**	NS	NS	NS
Interaction (NXS)	NS	NS	*	NS	**	*	NS	NS

WAS= Weeks after sowing; NS = Not significant; * = significant ($p \leq 0.05$); ** = highly significant ($p \leq 0.0$).

for Jalingo trial location. Interaction between intra-row spacing and nitrogen rate had a significant ($p \leq 0.05$) effect on number of leaves per plant at 3 WAS. The response of different levels of nitrogen with increasing intra-row spacing was similar. However, within each intra-row spacing, the response of nitrogen levels gave different trends. The best interaction was registered when 30 $kgNha^{-1}$ was applied at an intra-row spacing of 35 cm with a mean value of 6.67 number of leaves per plant. Furthermore, the least interaction was recorded when 25 $kgNha^{-1}$ was applied to Bambara groundnut at a spacing of 25 cm recording a mean value of 5.53 number of leaves/plant. This might not be unrelated with the peak of demand of nutrients by the crop at 3 WAS since the stored food reserve in the seed might have been exhausted at that period. This is in line with the findings of Madukwe et al. (2010), Iliya (2010) and Kamithi et al. (2009) who conducted their research on bambara groundnut and chickpea in Owerri, Mubi and Kenya respectively.

Interaction between intra-row spacing and nitrogen rate on number of leaves per plant at 6 WAS

Table 3 shows the interaction between intra-row spacing and nitrogen rate on number of leaves per plant at 6WAS at Jalingo and Yola trial locations. Interaction between intra-row spacing and nitrogen rate was highly significant ($p \leq 0.01$) on number of leaves per plant at 6 WAS in Jalingo trial location. Across the intra-row spacings, the response of nitrogen levels was in the same trend, but within each intra-row spacing, nitrogen response gave different trends. When 20 $kgNha^{-1}$ was applied at an intra-row spacing of 30 cm, the best interaction was recorded with the mean value of 52.07 number of leaves per plant. Meanwhile, the least interaction was registered when 30 $kgNha^{-1}$ was applied to Bambara groundnut at an intra-row spacing of 25 cm recording a mean value of 36.40 number of leaves per plant. In Yola trial location too, interaction between intra-row spacing and nitrogen rates had significant ($p \leq 0.05$) effect on number of leaves per plant.

The response of different levels of nitrogen with the increasing intra-row spacing was similar, but within each intra-row spacing, it gave different trends. Nitrogen rate 25 $kgNha^{-1}$ and intra-row spacing 25 cm recorded the highest mean value of 36.13 number of leaves/plant while 30 $kgNha^{-1}$ and

Table 2. Interaction between intra-row spacing and nitrogen rates on number of leaves per plant at 3 weeks after sowing for Jalingo location in 2015 cropping season.

Nitrogen rates (kgha-1)	Spacing (cm)				LSD
	20	25	30	35	
20	6.40	6.40	6.13	5.87	0.757
25	5.60	6.13	5.73	6.13	
30	6.60	5.53	6.00	6.67	
LSD	0.686				
(p≤0.05)	0.03				

Table 3. Interaction between intra-row spacing and nitrogen rates on number of leaves at 6 weeks after sowing in Jalingo and Yola locations in 2015 cropping season.

Nitrogen rates (kgha-1)	Spacing (cm)									
	Jalingo				LSD	Yola				LSD
	20	25	30	35		20	25	30	35	
20	50.33	48.27	52.07	49.87	4.924	33.20	27.87	30.07	28.93	5.295
25	49.73	45.27	44.33	49.80		28.93	36.13	31.07	33.07	
30	45.80	36.40	45.00	45.05		30.07	25.20	31.47	28.73	
LSD	9.194					16.110				
(p≤0.05)	0.01					0.02				

intra-row spacing of 25 cm gave the lowest mean value of 25.20 number of leaves per plant at 6 WAS. The trend is not unrelated with the amount of Nitrogen applied at the different rates and the effect of source to sink relationships which can translate to higher yield of the crop as against luxuriant growth.

Effects of Intra-row spacing and nitrogen rate on number of branches per plant of Bambara groundnut at 3, 6 and 9 Weeks after sowing

Table 4 shows the effect of Intra-row spacing and nitrogen rate on number of branches of Bambara groundnut in Jalingo and Yola trial locations in 2015 cropping season. In Jalingo location, there was no significant (p≤0.05) effect of nitrogen rate and intra-row spacing on number of branches at 3 and 9 WAS. Intra-row spacing showed significant (p≤0.05) difference on number of branches per plant at 6 WAS with the highest mean value of 16.80 at 25 cm and the lowest mean value (14.93) at 20 cm. In Yola trial location, both nitrogen rate and intra-row spacing showed no significant (p≤0.05) difference on number of branches at 3, 6 and 9 WAS. It signifies that, Nitrogen levels has little effect on number of branches during the early stage of growth of Bambara groundnut as the crop is struggling to adapt, survive and compete in the environment first before development.

Effects of intra-row spacing and nitrogen rate on plant height of Bambara groundnut at 3, 6 and 9 WAS

The effect of intra-row spacing and nitrogen rate on plant height at 3, 6 and 9 WAS is presented on Table 4. At Jalingo trial location, there was no significant (p≤0.05) difference between nitrogen rate and intra-row spacing on plant height at 3, 6 and 9 WAS. Statistically, similar results were observed in Yola trial location. Number of pods per plant and number of seeds per plant did not respond significantly to the application of nitrogen at Jalingo and Yola. This could be attributed to low amount of rainfall during pod formation and seed filling. Vurayai et al. (2011) stated that Bambara groundnut is more sensitive to water stress during reproductive growth stage as compared to vegetative growth stage. This result agreed with Latif et al. (2014) who also recorded no significant difference of Nitrogen application on number of pods of groundnut.

Effects of intra-row spacing and nitrogen rate on number of nodules per plant of Bambara groundnut at 15 and 30 days after sowing

The effect of intra-row spacing and nitrogen rate on total number of nodules per plant at 15 and 30 DAS in Jalingo and Yola is presented in Table 5. There was no significant (p≤0.05) effect of Nitrogen rate and intra-row spacing on number of nodules/plant at 15 and 30 DAS at both locations. This is not unrelated with the timing in developmental stages of the nodules, i.e. the plant clock pace. The plant can develop root nodules when the time is matured even though stress can also hasten the development of the nodules. This suggests that the symbiotically fixed nitrogen might have been adequate in meeting the crop's requirement for growth. Thus, the

Table 4. Effects of Intra-row Spacing and Nitrogen Rates on Number of Branches per Plant and Plant height of Bambara groundnut in Jalingo and Yola in 2015 Cropping Season:

Treatment	Number of Branches/Plant						Plant height (cm)					
	3 WAS		6 WAS		9 WAS		3 WAS		6 WAS		9 WAS	
	Jalingo	Yola	Jalingo	Yola	Jalingo	Yola	Jalingo	Yola	Jalingo	Yola	Jalingo	Yola
Nitrogen Rates (kgha-1)												
20	3.77	3.70	15.87	11.62	22.90	13.88	22.87	19.37	23.71	20.01	24.10	20.59
25	3.68	5.30	16.38	12.28	21.00	15.99	22.29	19.82	23.62	20.64	23.65	22.04
30	3.78	2.23	15.62	12.08	20.57	14.03	22.50	19.77	23.43	20.97	23.50	21.98
LSD	0.51	3.17	3.18	4.89	2.72	4.498	0.86	1.65	3.41	1.71	1.88	2.90
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Spacing's (cm)												
20	3.69	2.40	14.93	11.02	20.69	13.33	22.79	19.63	23.64	20.67	23.74	22.58
25	3.73	4.60	15.51	12.80	21.33	14.38	22.33	19.17	23.10	20.48	23.53	22.70
30	3.76	4.27	16.58	11.96	22.09	14.97	22.36	19.52	23.90	20.63	23.95	22.38
35	3.81	2.38	16.80	12.20	21.84	15.87	22.69	18.94	23.70	20.38	23.78	22.71
LSD	0.36	4.68	1.51	1.41	2.54	2.423	0.94	1.28	1.33	1.15	1.17	1.07
Significance	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
Interaction (N x S)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

WAS = weeks after sowing; * = Significant (P≤0.05); NS = Not significant.

nitrogen applied might have been used for unproductive consumption (Maunde et al., 2002).

Effects of intra-row spacing and nitrogen rate on number of non-effective nodules at 15 and 30 DAS

The effect of intra-row spacing and nitrogen rate on the number of non-effective nodules is presented on Table 5. Results showed no significant (p≤0.05) effect of nitrogen rates and intra-row spacing on the number of non-effective nodules per plant at 15 DAS in Jalingo and Yola locations. At 30 DAS, there was no significant (p≤0.05) effect of nitrogen and intra-row spacing on number of non-effective nodules in Jalingo. In Yola, there was significant (p≤0.05) influence of intra-row spacing on number of non-effective nodules at 30 DAS with 25 cm producing the highest mean value (3.14) of number of non-effective nodules while 35 cm gave the lowest mean value (1.36) number of non-effective nodules per plant. The trend is similar to that of effective nodules at 15 and 30 DAS in the two locations. This finding agrees with that of Henriques et al. (2012). Jalal, (2008) also observed no significant effect of spacing on number of nodules per plant on bambara groundnut in his research conducted at Shambat, Khartoun. A possible reason is the fact that seeds were not inoculated with *Bradyrhizobium* at planting (Jalal, 2008; Dakora and Moufhe, 1995). The result may be due to unconducive environment which leads to low population of the specific Rhizobia to nodulate bambara groundnut and inadequate number of correct strain of the species to effectively fix nitrogen (Chemining'wa et al., 2013; Kinkema et al., 2006). Interaction between nitrogen rates and intra-row spacing had significant difference on number of nodules and non-effective nodules at 30 DAS in Yola.

Effects of Intra-row spacing and nitrogen rate on number of effective nodules per plant at 15 and 30 DAS

The effect of intra-row spacing and nitrogen rate on number of effective nodules is presented on Table 5. Application of nitrogen and the use of intra-row spacing had no significant (p≤0.05) difference on number of effective nodules at 15 DAS at Jalingo and Yola locations. The result of the study showed that growth parameters were affected by application of nitrogen and intra-row spacing at the two trial locations. Also, nitrogen fertilizer and intra-row spacing had no significant effect on plant emergence in Jalingo and Yola trial locations. This may be due to the application of nitrogen a week after emergence which could not have influence on it. This suggests that when conditions for germination are favourable, seeds would germinate and emerge even if the nutrient status of the soil is poor. This agrees with the report of Madukwe et al. (2010) that nitrogen fertilizer had no significant effect on germinability of Bambara groundnut seeds.

Interaction between intra- row spacing and nitrogen rate on total number of nodules per plant at 30 days after sowing

The interaction between intra-row spacing and nitrogen rate on number of nodules per plant at 30 DAS at Yola trial location in 2015 cropping season is shown in Table 5. Intra-row spacing had significant effect on number of leaves per plant at 6 WAS in Jalingo location with 35 cm (48.24) having the highest number of leaves per plant. Similarly, spacing had significant effect on number of branches per plant at 6 WAS in Jalingo location at 35 cm (16.80). This agrees with Akpalu et al. (2012) and Akpalu (2010) who reported that the higher leaf number produced by the higher spacing could be attributed to reduced interplant competition. Such plants had more growth resources; nutrients, water and abundant sunlight, leading to much branching and production of more leaves. Non-significant effect of Spacing on number of leaves per plant and branches per plant in Yola location agrees with Jalal (2008) who attributed such to poor growth of the plant. Interaction between nitrogen rates and intra-row spacing had significant influence on number of leaves and branches per plant in Jalingo and Yola locations.

Weight of 100 seeds also was not significantly influenced by intra-row spacing. The result of the research corroborated with Edje and Mavimbela (2014), Jalal (2008) and Akpalu et al. (2012) who also recorded no significant difference on 100 seeds weight of Bambara groundnut.

The result on grain yield per kgha^{-1} followed the same trend. There was no significant influence of intra-row spacing on grain yield but the differences in mean values of yield decreased as the intra-row spacing increased in Jalingo location. This is in agreement with the findings of Akpalu (2010) and Kouassi and Zorobi (2011). These researchers reported that increasing plant population density resulted in high pod and grain yield. Yola analysis showed inconsistent mean differences in yield per kgha^{-1}. The result corresponds with Ibudialo et al. (2013) whose research on soybeans in Enugu yielded no significant difference on grain yield and Jalal (2008) who attributed his result to low moisture in the soil. Also, Alhassan et al. (2012) had no significant difference of spacing on the yield of Bambara groundnut. They stated that, water stress reduces the growth of Bambara groundnut, number of pods which leads to immature seeds with low weight. Edje and Mavimbela (2014) reported no significant effect on grain yield per kgha^{-1} in which they stated that most of the pods were green for which they attributed to insufficient soil to earthen up the pods. In this research, there were many green pods among Jalingo harvest. Most of the pods harvested from Yola experiment were observed to be either empty or contained smaller sizes of seeds. This agrees with Madukwe et al. (2011) who reported that plants under moisture stress during pod filling produce lower weights of individual seeds.

Effect of intra-row spacing and nitrogen rate on number of pods per plant and seed per plant of Bambara groundnut

The effect of intra-row spacing and nitrogen rate on number of pods per plant is presented in Table 6. Nitrogen rate as well as intra-row spacing had no significant ($p \leq 0.05$) difference on number of pods per plant in both Jalingo and Yola locations. Results on number of seeds per plant in both Jalingo and Yola trial location revealed no significant ($p \leq 0.05$) difference of nitrogen rate and intra-row spacing on the character. Even though in Yola experimental site, the result showed no significant difference but there was inconsistent number of pods and seeds per plant spacing. Here, there were some empty pods and most of the pods that contained seeds had smaller sizes of seeds. This result agrees with Mkandawire and Sibuga (2002) who conducted their research at Morogoro in Tanzania on Bambara groundnut. They attributed the lower pod yield to low total precipitation and subsequent reduced moisture availability in the season.

Effects of intra-row spacing and nitrogen rate on weight of 100 seeds and grain yield ha^{-1} of Bambara groundnut

The effects of intra-row spacing and nitrogen rate on 100 seed weight of Bambara groundnut in Jalingo and Yola in 2015 cropping season is presented in Table 7. There was no significant ($p \leq 0.05$) difference between nitrogen rates and intra-row spacings on weight of 100 seeds in both Jalingo and Yola trial locations. The result of the research corroborated with Edje and Mavimbela (2014), Jalal (2008) and Akpalu et al. (2012) who also recorded no significant difference on 100seeds weight of bambara groundnut. The result on grain yield per kgha^{-1} followed the same trend. There was no significant influence of intra-row spacing on grain yield but the differences in mean values of yield decreased as the intra-row spacing increased in Jalingo

Table 6. Mean effects of intra-row spacing and nitrogen rates on days to 50% flowering, days to 95% maturity, number of pods per plant and number of seeds per plant of bambara groundnut in Jalingo and Yola locations in 2015 cropping season.

Treatment	Days to 50% flowering		Days to 95% maturity		Number of pods per plant		Number of seeds per plant	
	Jalingo	Yola	Jalingo	Yola	Jalingo	Yola	Jalingo	Yola
Nitrogen rates (kgNha-1)								
20	42.50	42.17	110.25	105.75	27.13	11.37	27.38	11.78
25	42.00	43.00	109.67	106.00	22.45	12.85	22.65	13.10
30	42.50	42.67	106.08	107.00	17.10	13.33	17.25	13.58
LSD	1.30	1.94	7.87	4.34	10.16	2.57	9.97	2.82
Significance	NS	NS	NS	NS	NS	NS	NS	NS
Spacings (cm)								
20	42.78	43.00	108.33	105.00	23.24	12.40	23.49	12.64
25	43.00	42.11	108.78	106.89	23.09	12.02	23.47	12.16
30	41.89	42.78	109.44	106.56	22.27	12.80	22.44	13.33
35	41.47	42.56	108.11	106.56	20.31	12.84	20.51	13.16
LSD	0.95	1.07	0.69	1.38	3.27	2.49	3.24	2.72
Significance	*	NS	NS	NS	NS	NS	NS	NS
Interaction	NS	NS	NS	NS	NS	NS	NS	NS

NS= Not significant; * = Significant ($p \leq 0.05$).

location. This is in agreement with the findings of Akpalu (2010) and Kouassi and Zorobi (2011).

Table 7 shows the effects of intra-row spacing and nitrogen rates on grain yield in kilogram per hectare of Bambara groundnut in Jalingo and Yola locations in 2015 cropping season. There was no significant ($p \leq 0.05$) effect of nitrogen rate and intra-row spacing on grain yield in both Jalingo and Yola locations. Intra-row spacing had significant effect on number of leaves per plant at 6 WAS in Jalingo location with 35 cm (48.24) having the highest number of leaves per plant. Similarly, spacing had significant effect on number of branches per plant at 6 WAS in Jalingo location at 35 cm (16.80). This agrees with Akpalu et al. (2012) and Toungos (2007). Akpalu (2010) also reported that the higher leaf number produced by the higher spacing could be attributed to reduced interplant competition. Such plants had more growth resources; nutrients, water and abundant sunlight, leading to much branching and production of more leaves. Non-significant effect of spacing on number of leaves per plant and branches per plant in Yola location agrees with Jalal (2008) who attributed such to poor growth of the plant. Interaction between nitrogen rates and intra-row spacing had significant influence on number of leaves and branches per plant in Jalingo and Yola locations.

Plant height was not significantly influenced by spacing in both locations, but in Jalingo, plant height was generally higher at the low intra-row spacing than at higher intra-row spacing. This finding corroborated Ibudialo et al. (2013) and Jalal (2008) who observed no significant difference on plant height in their research conducted in Enugu (Nigeria) and Shambat, Khartoun State (Sudan) on soybeans and Bambara groundnut, respectively. Jalal further stated that this may be attributed to generally poor plant growth which might have removed competition between plants. The result also agrees with that of Edje and Mavimbela (2014) who also observed no significant effect of spacing on plant height.

Days to 50% flowering were significantly influenced by spacing in Jalingo location. This disagrees with Ibudiola et al. (2013) and Jalal (2008). There was no significant effect of spacing on days to 95% maturity. This result may be due to environmental influence on the crop.

Effects of intra-row spacing and nitrogen rates on yield and yield parameters of Bambara groundnut

Number of pods per plant and number of seeds per plant did not respond significantly to the application

Table 7. Effects of intra-row spacing and nitrogen rate on weight of 100 seeds (g), grain yield ha^{-1} (kg) of Bambara groundnut in Jalingo and Yola in 2015 cropping season.

Treatment	Weight of 100 Seeds (g)		Grain Yield ha^{-1} (kg)	
	Jalingo	Yola	Jalingo	Yola
Nitrogen Rates ($kgha^{-1}$)				
20	83.19	80.69	1033	418
25	82.54	75.79	868	368
30	86.01	79.69	607	357
LSD	9.64	4.60	485	54.8
Significance	NS	NS	NS	NS
Spacing(cm)				
20	83.57	79.48	959	391
25	84.20	74.70	826	367
30	83.71	80.24	798	407
35	84.18	80.48	761	359
LSD	4.93	6.58	192	86
($P \leq 0.05$)	NS	NS	NS	NS
Interaction X (Nitrogen Spacing)	NS	NS	NS	NS

NS=Not significant.

of nitrogen at Jalingo and Yola. This could be attributed to low amount of rainfall during pod formation and seed filling. Vurayai et al. (2011) stated that Bambara groundnut is more sensitive to water stress during reproductive growth stage as compared to vegetative growth stage. This result agrees with Latif et al. (2014) who also recorded no significant difference of nitrogen application on number of pods of groundnut. Their reason for the result was that, there was drought which resulted in poor pod formation and low response to fertilizer application. Utietiang et al. (2013) and Mehmet (2008) also asserted that application of nitrogen below 50 $kgha^{-1}$ had no significant effect on pods and seeds per plant of soybeans.

100-seed weight was not significantly influenced by nitrogen rates in the two locations. This agrees with the findings of Oyatokun and Oluwasemire (2014) who reported that 100 seed weight of soybean was not significantly affected by nitrogen rates. They revealed that nitrogen application favoured vegetative growth and by extension, seems to hinder seed yield. The results on grain yield per $kgha^{-1}$ followed the same trend as no significant difference was recorded by the treatments. This result agrees with those of Tanimu et al. (1991) and Chiezey et al. (2005) whose research conducted in Samaru, Zaria on Bambara groundnut showed no significant difference of nitrogen starter dose on the grain yield. Although the nitrogen rate did not influence the yield of Bambara groundnut at both locations which soils were very low in nitrogen content, application of higher dose of nitrogen may actually influence crop yield (Tanimu et al., 1991). For example, Wamba et al. (2012) observed that higher nitrogen treatment of 100 $kgNha^{-1}$ gave significant increase of growth and yield parameters as well as yield per $kgha^{-1}$. Lacks of Bambara groundnut response to nitrogen starter doses may also be attributed to the fact that yield were generally poor during the year of the experiment as complained of its scarcity by Bambara groundnut producers in Jalingo and marketers in Girei and Jimeta market.

There was no significant influence of spacing on yield and yield parameters in both trial locations. In Jalingo location, the number of pods per plant and seeds per plant decreased as the spacing increased. In this location, some plants develop leaves up to harvesting period. This result agrees with Akpalu (2010) and Toungos (2007) who attributed the non-significant influence of spacing on number of pods/plant of Bambara groundnut to leaf development during the pod filling period which could result to low yield since the dry matter that would have been portioned into pods filling was used in leaf production. In Yola experimental site, the result showed no significant difference but inconsistent number of pods and seeds per plant spacing. Here, there were some empty pods and most of the pods that contained seeds had smaller sizes of seeds. This result agrees with Mkandawire and Sibuga (2002) who conducted their research at Morogoro in Tanzania on Bambara groundnut. They attributed the lower pod yield to low total precipitation and subsequent reduced moisture availability in the season.

A number of investigators explained the factors which reduce the yield of Bambara groundnuts. El Wakeel and Osman (1992) in Jalal (2008) stated that low yields are due to late planting, erratic rainfall and low soil fertility, and that the crop is usually planted after the first effective rains (about 15 mm or more). Collinson et al. (2000) reported that the highest pod yields were achieved at the earliest sowing date.

Conclusion and recommendations

The effect of intra-row spacing and nitrogen rate on growth and yield of Bambara groundnut (*Vigna subterranea* (L.) *Verdc.*) in North Eastern Nigeria showed significant influence on number of leaves per plant and number of branches per plant and effective nodules per plant with wider spacing of 35 cm resulted in higher number of leaves and branches per plant. The spacing of 25 cm intra-row produced more non-effective nodules per plant and increase days to 50% flowering. There was significant interaction between nitrogen rate and intra-row spacing on number of leaves per plant, number of nodules per plant and number of non-effective nodules per plant.

Based on the result of the study, the following conclusions are drawn. The least nitrogen rate of 20 $kgNha^{-1}$ should be used for the growth of Bambara groundnut in the study area to minimize cost of fertilizer and an intra-row spacing of 35 cm is recommended for the growth of Bambara groundnut in the study areas.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

REFFERENCES

Adebayo, A. A., & Tukur, A.L. (1999). *Mean Annual Rainfall. Adamawa State in Maps.* 1st Edition. Paraclete Publishers Nigeria Ltd, Yola-Nigeria. Pp. 23-26.

Akpalu, M. M. (2010). Growth, yield and nutritional quality of five Bambara groundnut *(Vigna subterrenea* (L.) *Verdc.):* Landraces to different plant population densities. Thesis (Master of Science), Kwame Nkrumah University of Science and technology, Kumasi, Ghana.

Akpalu, M. M., Atubilla, I. A., & Oppong-Sekyere, D. (2013). Assessing the level of cultivation and utilization of bambara groundnut (Vigna subterranea (L.) Verdc.) in the Sumbrungu community of Bolgatanga, Upper East Region, Ghana. *International Journal of Plant, Animal and Environmental Sciences*, 3(3), 68-75.

Akpalu, M. M., Sarkodie-Addo, J., & Akpalu, S. E. (2012). Effect of Spacing on Growth and Yield of Five Bambara Groundnut (*Vigna subterranea* (L) Verdc.) Landraces. *Journal of Science and Technology (Ghana)*, 32(2), 9-19.

Alhassan, G. A., Kalu, B. A. & Egbe, O. M. O. (2012). Influence of planting densities on the performance of intercropped Bambara groundnut with cowpea in Makurdi, Benue State, Nigeria. *International Journal of Development and Sustainability,*1(3), 860-879.

Anonymous (2011). Production Guidelines for Bambara groundnut. Agriculture Forestry and Fishery. Republic of South Africa. Retrieved 8th November, 2014.

Asiwe, J. A. N., & Kutu, R. F. (2007). Effects of plant spacing on yield, weeds, insect infestation and leaf blight of bambara groundnut (*Vigna subterranea*) (L.) Verde. In *8th African Crop Science Society Conference, El-Minia, Egypt, 27-31 October 2007* (pp. 1947-1950). African Crop Science Society.

Bamshaiye, O. M., Adegbola, J. A., & Bamishaiye, E. I. (2011). Bambara groundnut: An under-utilized nut in Africa. *Advances in Agricultural Biotechnology*, 1(1), 60-72.

Chiezey, U. F., Haruna, I. M., & Odion, E. C. (2005). Productivity of sorghum/soybean mixture and influence of N, P and plant arrangement in the Northern Guinea Savanna Zone of Nigeria. *Crop Research*, *29*(1), 1-14.

Edje, O. T., & Mavimbela, E. K. (2014). Response of Bambara groundnuts *(Vigna subterranean* (L.) *verdc.)* to Inter-row Spacing in Swaziland. *African Journal of Applied Agricultural Science and Technologies,* 1(2) 91-104.

Egbe, M. O., Alhassan, G. A., & Ijoyah, M. (2013). Nodulation, nitrogen yield and fixation by bambara groundnut (Vigna subterranea (L.) Verdc.) landraces intercropped with cowpea and maize in Southern Guinea Savanna of Nigeria. *Agricultural Science*, *1*(4), 15-28.

El wakeel, A. S. and Osman, A. (1992). Bambara groundnut (*Vigna subterranean* L.) production in Kordofan region. *El Obeid Agricultural Research Station, El Obeid, Sudan*. Pp. 22-27.

Elijah, D. M. (2011). Effects of NPK Rates on Growth and yield of some local cultivars of Bambara groundnut *(Vigna subterranea* (L.) *verdc.).* Unpublished M. Tech thesis, Department of Crop Production and Horticulture, MAUTECH Yola.

Hepper, F. W (1970). Bambara groundnut (*Vigna subterranean* (L.) Verdc.). *Field Crop Abstract*, 23(1), 1-6.

Heuze, V., & Tran, G. (2013). Bambara groundnut (*Vigna subterranea*) Seeds. Feedipedia. A programme by INRA, CIRAD, AFZ and FAO. Retrieved from https://www.feedipedia.org/node/530.

Hillocks, R. J, Bennet, C., & Mponda, O. M. (2012). Bambara Nut: A Review of Utilization, Market Potential and Crop Improvement. *African Crop Science Journal*, 20(1), 1-16.

Ibudialo, A.N., Ezema,R. A., and Ugwu, I. E (2013). Effect of different plant spacing on the growth and yield of soybeans (*Glycine max*) in Enugu South Eastern Nigeria. 1st National Annual Conference on the Role of Crop Science in the Agricultural Transformation Agenda (2013) at University of Nigeria, Nsukka Nigeria. 15-19 September, 2013.

Jalal, H. A. A (2008). Effect of Sowing Date and Plant Spacing on Growth and Yield of Bambara Groundnut (*Vigna subterranean* (L.) *Verdc).* Unpublished M.Sc Thesis, Agronomy Department, University of Bakht Al Ruda.

Kouassi, N. J., & Zorobi, I. A. (2011). Evaluation of agronomic performance of two landraces of Bambara groundnut (Vigna subterranea) in woodland savannahs of Cote dIvoire. *African Journal of Agricultural Research*, 6(21), 4852-4856.

Latif, R., Islam, M., Khalid, R., Subhani, A., Khan, M., & Iqbal, M. S. (2014). Significance of groundnut inoculation and NP fertilizer application on yield, nitrogen uptake, fixation and soil N balance sheet under rainfed conditions. *Journal of Biology and Medical Sciences*, *2*, 7-14.

Linnemann, A. R. (1988). Cultivation of Bambara groundnut (*Vigna subterranean* (L.) Verdc.) in Nigeria. *Tropical Crops Communication*, 15, 13.

Madukwe, D. K., Nwaigbo, I. C., & Anele, V. M. (2010). Response of Bambara groundnut *(Vigna subterranean* (L.) to organic and inorganic fertilizer application. *International Science Research Journal* 2, 78-81.

Madukwe, D. K., Omuh, M. O., & Christo, I. E. C. (2011).

Agronomic and physiological performance of Bambara groundnut (*Vigna subterranean* (L.) *Verdc*) in Southern Nigeria. *World Journal of Agricultural Sciences,* 7(2), 166-171.

Mkandawire, F. L., & Sibuga, K. P. (2002). Yield response of Bambara groundnut to plants population and seedbed type. *African Crop Science Journal,* 10(1), 39-49.

Oyatokun, O. S., & Oluwasemire, K. O. (2014). Evaluating starter N application to soybean with CROPGRO-soybean model in the Southern Guinea Savanna agro-Ecology of Nigeria. *Journal of Agricultural Science*, *6*(8), 83-100.

TADP (2012). Annual report: Taraba Agricultural Development Programme Jalingo, Nigeria.

Tanimu, B. (1997). Effect of sowing dates and inter-row spacing on the yield characteristics of two Bambara groundnut varieties. Unpublished PhD thesis. Ahmadu Bello University, Zaria, Nigeria.

Tanimu, B., Ogunlela, V. B., Olufajo, O. O., & Iwuafor, E. N. O (1991). Effect of fertilizer elements on the yield and yield characters of Bambara groundnut (*Vigna subterranean* (L.) Verdc.). *Proceedings of the Second International Workshop of International Bambara Network (BAMNET) 23-25th September. Accra, Ghana.* Pp. 66-73.

Toungos, M. D. (2007). *Effects of sowing dates and levels of phosphorus fertilizer on the performance of Bambara groundnut*. Annual Report of Farm Management Data, Zimbabwe. Pp. 14-21

Undie, L. U., Uwah, D. F., Umoetuk, S. B. A., Attoe, E. E., & Effa, E. B. (2013). Response of late season maize/soybean intercropping to nitrogen in the humid environment of South Southern Nigeria. *Journal of Biology, Agriculture and Healthcare*, 3(10), 84-91.

Utietiang, L. Undie, Donatus F. Wwah, Sylvia B.A Umoetuk, Emmanuel E. Attoe,Emmanuel B. Effa (2013) Response of Late Season Maize/Soybean Inter cropping to Nitrogen in the Humid Environment of Southern Nigeria. *Journal of Biology, Agriculture and Healthcare* 3(10); 84-91

Vurayai, R., Emongor, V., & Moseki, B. (2011). Physiological responses of bambara groundnut (Vigna subterranea L. Verdc) to short periods of water stress during different developmental stages. *Asian Journal of Agricultural Sciences*, 3(1), 37-43.

Vusamuzi, M. (1992). *Promotion of Bambara groundnut*. Annual Report of Farm Management Data, Zimdabwe.p. 102.

Wamba, O. F., Taffouo, V. D., Youmbi, E., Ngwene, B., & Amougou, A. (2012). Effects of organic and inorganic nutrient sources on the growth, total chlorophyll and yield of three bambara groundnut landraces in the coastal region of Cameroon. *Journal of Agronomy*, 11(2), 31-42.