AF-807
[1-5]

RESEARCH ARTICLE Indian Journal of Agricultural Research

Yield Response of Bambara Groundnut [*Vigna subterranea* (L.) Verdc.] to Fertilizer Application and Plant Spacing

Emmanuel Essel[1], Kwadwo Gyasi Santo[2], Joseph Nketiah Berchie[3], Abdul Aziz Khalid[2], Muntala Abdulai[2], Kwabena Atakora[2], Daniel Afreh Ntiamoah[2], Patrick Mawuenyegan Norshie[2], Samuel Novor[2]

10.18805/IJARe.AF-807

ABSTRACT

Background: An experiment was conducted at Nkoranza in the Bono-East Region and Ejura Sekyedumase in the Ashanti Region of Ghana from July to December, 2021 to evaluate the effects of P based fertilizer and plant spacing on leaf area, leaf area index and seed yield and yield components of Bambara groundnut.

Methods: The experiment was a 3×3 factorial, arranged in a Randomized Complete Block Design with three replicates. The first factor was plant spacing with three levels, including 50 cm × 20 cm, 40 cm × 20 cm and 40 cm × 25 cm, while the second factor was application of P based complex fertilizer (NPK 11:22:20) with three levels, including 0 kg/ha, 30 kg P/ha and 60 kg P/ha.

Result: Results of the study revealed that leaf area, leaf area index, yield components and seed yield of Bambara groundnut were significantly affected by plant spacing. Wider spacing of 50cm row was better than 40cm. Fertilizer application had mixed responses, with no significant impact when the plant density was 10 m^{-2}, whereas under a plant density of 12.5 m^{-2} there was a response to 60 kg P based fertilizer application, which needs further study.

Key words: Bambara groundnut, P based complex fertilizer, Plant density, Plant spacing, Pod yield.

INTRODUCTION

Bambara groundnut [*Vigna subterranea* (L.) Verdc.] is an indigenous legume crop known to be originated from North Africa. It is one of the imperative and neglected legume crops that contribute positively to improving global food and nutrient safety (Khan *et al.,* 2021). In Ghana, Bambara is mostly cultivated in the northern and coastal areas, with a yield not exceeding 300 kg/ha (Asante *et al*., 2021).

Because of its ability to survive drought through improved soil water uptake, lower water usage, and cellular hydration maintenance through osmotic adjustment, it is also called a drought-avoiding crop (Blum, 2005). Additionally, the crop has the capacity to preserve leaf turgor pressure by combining osmotic adjustment, decreased leaf area, and efficient stomatal regulation (Berchie *et al*., 2012).

Nucleic acids, proteins, lipids, carbohydrates, and adenylate are a few compounds that include P and are necessary for plant cells to operate (Zhang *et al*., 2014). Lack of phosphorus (P) in the soil has a negative effect on the growth of legumes because it is necessary for nodule energy conversion and improved N-fixation (Yadav *et al*., 2017).

Plant spacing is an important agronomic practice because it affects light interception, and it is the plant's green parts' primary source of energy (Ibeawuchi *et al*., 2008). Because the crop canopy closes sooner with narrower row spacing than with broader row spacing, it reduces weed development (Knezevic *et al*., 2003). Shaukat *et al*. (2012) reported that numbers of pods and seeds per pod increased at a wider row spacing.

Dankyi *et al.* (2005) made reference to poor soil nutrition in crop production as among the causes of declining yields in crops. The quality and productivity of many farmlands in Ghana have been lost through a combination of human-induced natural processes, which affect the capacity of the soil to function optimally. Continuous cultivation of lands has contributed to soil fertility depletion. Soil nutrient deficiency is a major constraint to yield maximization in the tropics, especially small holder farms (Obidiebuba *et al*., 2012). The aim of the study was, therefore, to evaluate the effects of P based fertilizer and plant spacing on leaf area, leaf area index, seed yield and yield components of Bambara groundnut.

[1]Cocoa Health and Extension Division, P.O. Box 1974, Kumasi, Ghana. [2]Department of Horticulture and Crop Production, School of Agriculture and Technology, Dormaa Ahenkro Campus, University of Energy and Natural Resources, P.O. Box 214, Sunyani, Ghana. [3]Council for Scientific and Industrial Research-Crop Research Institute, P.O Box 3785, Kumasi-Ghana.

Corresponding Author: Kwadwo Gyasi Santo, Department of Horticulture and Crop Production, School of Agriculture and Technology, Dormaa Ahenkro Campus, University of Energy and Natural Resources, P.O. Box 214, Sunyani, Ghana.
Email: kwadwo.santo@uenr.edu.gh

How to cite this article: Essel, E., Santo, K.G., Berchie, J.N., Khalid, A.A., Abdulai, M., Atakora, K., Ntiamoah, D.A., Norshie, P.M. and Novor, S. (2024). Yield Response of Bambara Groundnut [*Vigna subterranea* (L.) Verdc.] to Phosphorus Nutrition and Plant Spacing. Indian Journal of Agricultural Research. doi: 10.18805/IJARe.AF-807.

Submitted: 21-07-2023 **Accepted:** 03-04-2024 **Online:** 26-05-2024

MATERIALS AND METHODS

The experiment was conducted as an on-farm trial at Nkoranza in the Nkoranza North District in the Bono-East Region and Ejura in the Ejura Sekyedumase Municipality in Ashanti region of Ghana from July to December, 2021. The experimental areas experience bimodal rainfall patterns and have a forest-savanna transition zone and sandy loam soils (Ghana Statistical Service, 2012).

The experimental design was a 3×3 factorial with treatments being laid out in a randomized complete block design with three (3) replications. The treatments were made up of three P based complex fertilizer (NPK 11:22:20) application rates, namely 0kg P/ha, 30 kg P/ha and 60 kg P/ha and three spacing; 50 cm × 20 cm, 40 cm × 20 cm and 40 cm × 25 cm (accommodating 10, 12.5 and 10 plants per square metre, respectively). The experimental field was cleared, lined and pegged and demarcated into experimental units or plots. The experimental fields were slashed and tilled manually by hoeing. Hoeing was done twice, first, to earthen-up the soil and secondly, to break the soil clods. Each plot measured 12 m × 12 m with an alley of 1m and 2m between plots and replication, respectively. The plots were labelled prior to planting.

Seeds of an early maturing landrace of Bambara groundnut named *Black eye* obtained from Crop Research Institute-CSIR, Fumesua, were planted in three levels of spacing; 50 cm × 20 cm, 40 cm × 20 cm and 40 cm × 25 cm. Planting was done at two seeds per hill and thinned to one plant per hill on ridges. Phosphorus-based complex fertilizer (NPK 11:22:20) was applied at two weeks after planting at 0 kg/ha, 30 kg/ha and 60 kg/ha. Each plot had equal chance of receiving any of the application rates. The hand-held hoe was used to control weeds at two and four weeks after planting.

Ten soil samples were picked with an auger along the two diagonals of the study field, five from each diagonal and composited. The composite soil sample was characterized using the ordinary procedures described by Motsara and Roy (2008) (Table 1). The climatic data are presented in Table 2. Lengths and breadths of sampled leaves (3rd and 4th leaflets on the 5th compound leaf from the base of the plant) were measured and multiplied to obtain leaf area at 2 weeks interval, from the 2nd to 8th weeks after emergence. Means were computed and recorded. After obtaining leaf area, the figure obtained was divided by the ground area covered by the crop to compute the leaf area index (LAI). This was done manually due to unavailability of LAI tools.

The pods in each plot were harvested, dried and weighed. Weights obtained from each treatment/experimental unit were converted to kg/ha to obtain pod weight. One hundred pods were counted from every plot and the weight was taken. The harvested pods were dried and manually threshed. The seeds were separated from the thrash, dried and weighed. Weights obtained from each treatment/experimental unit were converted to kg/ha. Weighing of pods and seeds was done using an electronic balance. Data collected were subjected to ANOVA using the GenStat Statistical Package, current edition (Payne *et al*., 2009). Means were separated using the LSD at 5% level of significance.

RESULTS AND DISCUSSION

Vegetative growth

Leaf area was significantly (P<0.05) affected by treatments with plants under wider row spacing of 50 cm × 20 cm treated with 60 kgP/ha recording the largest leaf area. Closer row spacing of 40 cm × 20 cm with 12.5 plants per unit area and treated with no fertilizer P (0 kgP/ha) recorded the least leaf area value (Table 3 and Table 5). The 60 kgP/ha with 40cmx20cm treatment combination differed significantly (P<0.05) from the other treatment combinations, except 60 kgP/ha under 40 cm × 25 cm and 0 kgP/ha with 50 cm × 20 cm treatment combinations. The 0 kgP/ha × 40 cm × 20 cm and 30 kgP/ha x 40 cm × 20 cm treatment combinations had the lowest leaf area index of 0.01. All other treatment combinations were similar in leaf area index.

Table 1: Physico-chemical properties of soil at the Ejura and Nkoranza experimental sites.

Parameter	Ejura		Nkoranza	
	Initial level	Post level	Initial level	Post level
pH 1:2.5	5.77	6.03	6.16	6.08
% OC	1.60	1.60	0.96	1.00
% TN	0.3	0.14	0.08	0.09
% OM	2.5	2.75	1.66	1.72
Ca me/100 g	2.7	2.77	1.70	1.92
Mg me/100 g	0.6	0.96	1.28	0.85
K me/100 g	0.29	0.36	0.17	0.10
Na me/100 g	0.01	0.01	0.01	0.01
CEC me/100 g	4.48	4.24	3.26	2.98
P ppm	7.19	6.65	9.51	6.42
Texture	Sandy loam		Sandy loam	

Source: Soil Research Institute (2021).

Table 2: Temperature, relative humidity and rainfall figures at the Nkoranza and Ejura experimental sites in 2021.

Month	Maximum °C		Minimum °C		Relative humidity %		Monthly total rainfall (mm)	
	EJ	NK	EJ	NK	EJ	NK	EJ	NK
January	37.8	37	20.9	21	34.5	55	3	12
February	38.9	37	22.2	22	46.6	65	18	38
March	38.3	36	24.8	23	60.2	73	58.7	96
April	37.1	35	24.6	23	68.6	77	77.6	109
May	34.9	34	24.6	22	77.7	82	108.6	107
June	31.9	31	22.6	22	84.9	88	74.1	136
July	29.7	29	21.8	21	87.3	88	83.5	118
August	29.6	29	21.4	21	86.6	87	74.6	84
September	29.8	29	22.2	21	90.0	90	138.5	155
October	34.8	31	22.6	22	72.0	88	4.8	143
November	31.9	33	22.5	22	85.5	81	139.8	47
December	36.0	35	21.7	21	45.3	63	66.6	42
Total							847.8	1087
Mean	34.2	33	22.7	21.8	69.9	78.1	70.7	90.6

Table 3: Effects of phosphorus × plant spacing interactions on leaf area and leaf area index of Bambara groundnut at Nkoranza in 2021 minor rainy season.

Treatment	Leaf area (cm^2)			Leaf area index
	1 WAP	2 WAP	3 WAP	3 WAP
0 Kg × 20×50	13.8cd	14.93bc	16.47bc	0.023b
0 kg × 20×40	8.73e	9.5d	9.93e	0.01c
0 kg × 25×40	11.13cde	12.07cd	12.53cde	0.01c
30 kg × 20×50	13.67cd	14.93bc	15.47bcd	0.01c
30 kg × 20×40	10.27de	11.4cd	11.87de	0.01c
30 kg × 25×40	14.2bc	15.4bc	15.73bcd	0.01c
60 kg × 20×50	18.57a	19.7a	21.27a	0.03a
60 kg × 20×40	17.43ab	18.17ab	18.2ab	0.02b
60 kg × 25×40	13.1cd	14.1bc	16.43bc	0.02bc
Grand means	13.43	14.47	15.32	0.02
LSD (0.05)	3.41	3.72	4.03	0.01
CV (%)	14.7	14.9	15.2	23.1

Values followed by the same letter(s) in columns are not significantly different from each other (DMRT).
WAP: Weeks after planting.

Table 4: Effects of phosphorus × plant spacing interactions on harvest index, number of pods per plant, pod weight and seed yield of Bambara groundnut at Nkoranza in 2021 minor rainy season.

Treatment	Harvest index	Number of pods per plant	Hundred pod wt. (g)	Seed yield (kg/ha)
0 kg × 20×50	0.40a	35.3bc	116.5bc	3566b
0 kg × 20×40	0.40a	22.7a	104.2d	1884a
0 kg × 25×40	0.40a	29.7ab	110.2cd	3055ab
30 kg × 20×50	0.43ab	31.0abc	108.7cd	2632ab
30 kg × 20×40	0.43ab	28.7ab	111.8bcd	2901ab
30 kg × 25×40	0.40a	31.0abc	105.7d	3051ab
60 kg × 20×50	0.50ab	40.7c	125.7a	3734b
60 kg × 20×40	0.53b	38.3bc	118.7ab	3592b
60 kg × 25×40	0.47ab	34.3bc	116.7bc	2965ab
P-value	0.002	<.001		<.001
LSD (0.05)	0.07	11.2	7.39	947.77
CV (%)	8.7	6.22	3.8	18.2

Values followed by the same letter(s) in columns are not significantly different from each other (DMRT).

The increase in plant growth in the form of leaf area and leaf area index following application of 60 kgP/ha could have smothered the growth of weeds in the field. This could have conserved soil moisture, reduced pest problems and nutrient mining through erosion and leaching, thus, making nutrients available to Bambara plants for proper growth and development.

Yield and yield components

Weight of hundred pods was significantly (P<0.05) affected by plant spacing and fertilizer application (Tables 4 and 6). Wider row spacing with 60kgP/ha gave the highest 100-pod weight (125.67 g) and differed significantly from the other treatments, except the 60kgP/ha under 40 cm × 20 cm, which was similar to 60 kgP/ha with 40 cm × 25 cm, 30 kgP/ha × 20 cm × 40 cm and 0 kgP/ha × 20 cm × 50 cm treatment combinations. The least weight of hundred pods (104.17 g) was noticed in 0 kg/ha × 40 cm × 20 cm.

Pods per plant varied (22.7 to 35.3) due to plant spacing in Bambara groundnut. Wider row spacing of 50 cm × 20 cm produced more pods than 40 × 20 cm row spacing. Increasing the plant density per unit area from 10 numbers (50 × 20 cm or 40 × 25 cm) to 12.5 (40 × 20 cm) decreased the number of pods per plant. Though 50 × 20 cm and 40 × 25 cm spacing accommodated equal number of plants (*viz.*, 10) per square metre, they differed in number of pods per plant. Row spacing of 50cm x 20cm seems better (35.7 pods/plant) under 50 × 20 cm spacing than increasing the inter-plant spacing from 20 to 25cm, but decreasing the row spacing from 50 to 40 to accommodate the same level of plants (10 plants per square metre) produced only 31.7 pods/plant (Table 4 and Table 6).

Application of fertilizers had limited impact on the Bambara groundnut during the season tested, but the impact was well pronounced only under closer spacing, that is under 40x20 cm (12.5 plants/m^{-2}). The pods per plant had increments from no fertilizer to 60 kg P based complex fertilizer per hectare. Wider spacing of 50 cm × 40 cm without any fertilizer application produced pods equal to 60kg P applied

Table 5: Effects of phosphorus × plant spacing interactions on leaf area and leaf area index of Bambara groundnut at Ejura in 2021 minor rainy season.

Treatment	Leaf area (cm^2)		Leaf area index	
	1 WAP	2 WAP	3 WAP	3 WAP
0 Kg × 20×50	15.6bc	18.27ab	21.2abc	0.03c
0 kg × 20×40	8.77d	12.6c	14.57d	0.01e
0 kg × 25×403	13.63bc	17.23abc	18.83bc	0.02de
0 kg × 20×503	11.83cd	16.23bc	19.83bc	0.02def
0 kg × 20×40	12.07cd	15.23bc	17.6cd	0.02d
30 kg × 25×40	11.3cd	16.83abc	19.47bc	0.02cd
60 kg × 20×50	20.43a	21.8a	24.47a	0.04a
60 kg × 20×40	17.17ab	20.37ab	22ab	0.03b
60 kg × 25×40	12.8bcd	16.53bc	18.97bc	0.02cd
Grand means	13.73	17.23	19.66	0.02
LSD (0.05)	4.20	4.71	3.80	16
CV (%)	17.7	15.8	11.2	16.8

Table 6: Effects of phosphorus × plant spacing interactions on harvest index, number of pods per plant, pod weight and seed yield of Bambara groundnut at Ejura in 2021 minor rainy season.

Treatment	Harvest index	Number of pods per plant	Hundred pod weight (g)	Seed yield (kg/ha)
0 Kg × 20×50	0.37a	35.0bcd	116bc	3539b
0 kg × 20×40	0.40a	23.33a	101.3e	1881a
0 kg × 25×40	0.43a	29.7abc	106.2de	2945ab
30 kg × 20×50	0.40a	28.0ab	109.8cd	2684ab
30 kg × 20×40	0.40a	27.3ab	105.2de	2922ab
30 kg × 25×40	0.33a	28.0ab	104de	3209b
60 kg × 20×50	0.50a	41.3d	123.8a	3750b
60 kg × 20×40	0.47a	38.7cd	117.5b	3619b
60 kg × 25×40	0.40a	34.3bcd	110.2cd	3236b
P-value	0.32	<.001		<.001
LSD (0.05)	NS	10.9	5.96	686.05
CV (%)	18.7	5.91	3.1	13.0

Values followed by the same letter(s) in columns are not significantly different from each other (DMRT); NS: Non-significant difference.

to other two spacings *viz.*, 40 × 20 and 40 × 25, which needs further investigation to draw any valid conclusion.

The dry seed yield of Bambara groundnut for different plant spacings and rate of fertilizer application was very similar to that of number of pods observed. The Bambara groundnut seed yield was found significantly affected by wider row spacing of 50 cm × 20 cm more than 40 cm × 20 cm and 40 cm × 25 cm. It was also observed that merely altering the inter-plant spacing from 20 to 25 cm under 40 cm row spacing, which resulted in reduction of number of plants from 12.5 to 10 per unit area, was seen with significant seed yield improvement by more than 50 per cent without any other manipulation like fertilizer application compared to 40 × 20 cm without any fertilizer application (Table 4 and Table 6).

Increasing the plant density from 10 to 12.5 per unit area decreased the Bambara seed yield from 3566kg/ha under 50 cm × 20 cm to 1884 kg/ha for 40 cm × 20 cm; the decrease measured as 47 per cent. The reduced seed yield under 40 × 20 cm spacing was compensated by fertilizer application. To compensate the seed yield reduction under 40 × 20 cm spacing compared to 50 × 20 cm spacing under no fertilizer regime, a fertilizer level of 60 kg P based fertilizer per hectare was needed. In other words, there is no advantage for fertilizer application when the plant spacing was wider (10 plants/unit area). Seed yield reduction under wider spacing when 30 kg P based fertilizer was applied could not be justified, which needs further investigation to draw any valid conclusion.

CONCLUSION

Results of the study revealed that leaf area, leaf area index, yield components and seed yield of Bambara groundnut were significantly affected by plant spacing and P based fertilizer. Wider spacing of 50 cm × 20 cm row was better than 40 cm × 20 cm and 40 × 25 cm. Fertilizer application had mixed responses, with no significant impact when the plant density was 10 m^{-2}, whereas under a plant density of 12.5 m^{-2}, there was a response to 60kg P based fertilizer application, which needs further study.

Conflict of interest

All authors declare that they have no conflict of interest.

REFERENCES

Asante, O.B., Adabah, R., Agyemang, K., Ayeh, S.J., Aidoo, R. and Afona, D. (2021). Preference for improved varietal attributes of bambara groundnut among smallholder farmers in Ghana. African Journal of Agriculture and Resource Economics. 16(2): 155-168.

Berchie, J.N., Opoku, M., Adu-Dapaah, H., Agyemang, A., Sarkodie Addo, J., Asare E., Addo, J. and Akuffo, H. (2012). Evaluation of five Bambara groundnut [*Vigna subterranea* (L.) Verdc.] landraces to heat and drought stress at Tono Navrongo, Upper East Region of Ghana. African Journal of Agricultural Research. 7: 250-256.

Blum, A. (2005). Drought resistance, water-use efficiency and yield potential-are they compatible, dissonant, or mutually exclusive? Australian Journal of Agricultural Research. 56: 1159-1168.

Dankyi, A.A., Andah, K., Moris, M.M. and Fosu, Y. (2005). Farmer characteristics, ecological zones and adoption decisions: A tobit model application for maize technology in Ghana. Agricultural and Food Science Journal of Ghana. 4: 341-351.

Ghana Statistical Service (2012). 2010 Population and Housing Census: Summary Report of Final Results Accra: Ghana Statistical Service.

Ibeawuchi, I.I., Matthews-Njoku, E., Ofor, M.O., Anyanwu, C.P. and Onyia, V.N. (2008). Plant spacing, dry matter accumulation and yield of local and improved maize cultivars. The Journal of American Science. 4(1): 11-19.

Khan, M.M.H., Rafii, M. Y., Ramlee, S.I., Jusoh, M. and Al-Mamun, M. (2021). Bambara groundnut [*Vigna subterranea* (L.) Verdc]: A crop for the new millennium, its genetic diversity and improvements to mitigate future food and nutritional challenges. Sustainability. 13, 5530. https://doi.org/10.3390/ su13105530.

Knezevic, S.Z., Evans, S.P. and Mainz, M. (2003). Row spacing influences the critical timing for weed removal in soybean (*Glycine max* L.). Weed Technology. 17(4): 666-673. http://dx.doi.org/10.1614/WT02-49.

Motsara, M.R. and Roy, R.N. (2008). Guide to laboratory establishment for plant nutrient analysis. Food and Agriculture Organization of the United Nations FAO Fertilizer and Plant Nutrition Bulletin No 19. ISBN 978-92-5-105981-4. 204pp.

Obidiebuba, E.A., Achebe, U.A., Akparobi, S.O. and Kator, P.E. (2012). Effect of different levels of NPK 15:15:15 on growth and yield of maize in rainforest agro-ecological zone. International Journal of Agriculture Science. 2(12): 1103-1106.

Payne, R., Murray, D., Harding, S., Baird, D. and Souter, D. (2009). GenStat for windows (12th edition) Introduction. Hemel Hempstead: VSN International.

Shaukat, S.A., Ahmad, Z., Choudhary, Y.A. and Shaukat, S.K. (2012). Effect of different sowing dates and row spacing on the growth, seed yield quality of off-season pea [*Pisum sativum* (L.) cv. Climax] under temperature conditions of Eawalakot Azad Jammu and Kashmir. Sci. J. Agric. 1: 117-125.

Yadav, G.S., Babu S., Meena, R.S., Debnath, C., Saha, P., Debbaram, C. and Datta, M. (2017). Effects of godawariphosgold and single supper phosphate on groundnut (*Arachis hypogaea* L.) productivity, phosphorus uptake, phosphorus use efficiency and economics. Indian J. Agric. Sci. 87(9): 1165-1169.

Zhang, Z., Liao, H. and Lucas, W.J. (2014). Molecular mechanisms underlying phosphate sensing, signaling and adaptation in plants. J. Integr. Plant Biol. 56: 192-22.