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INFLUENCE OF NEUTRON IRRADIATION AND PHOSPHORUS ON THE PERFORMANCE OF GROUNDNUT [*Arachis hypogaea* (L.)] GENOTYPES GROWN ON A P-DEFICIENT ALFISOLS AT SAMARU, NIGERIA

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ABSTRACT
There is a dearth of information on the effective irradiation dose for inducing variability in groundnut genotypes. A screen house experiment was conducted at the Department of Soil Science, Ahmadu Bello University, Zaria (ABU). It was to investigate the effect of induced genetic variability (by neutron irradiation) and four phosphorus rates (0, 20, 40 and 60 kg P_2O_5 ha^{-1}) on the performance of some groundnut [(Arachis hypogaea (L.)] genotypes grown on a P-deficient Alfisols at Samaru, Zaria. A fraction of each of the two genotypes (SAMNUT 24 and SAMNUT 26) was irradiated, in a 5-Curie Americium-Beryllium (Am-Be) isotope neutron source, having a thermal neutron flux of 2.7387×10^4 n cm^{-2} sec^{-1} for six days, at the Centre for Energy Research and Training, ABU. The irradiated (G_{1A} and G_{2A}) and non-radiated (G_{1B} and G_{2B}) seeds; and the P rates were laid out in a randomised complete block design (RCBD), in a screen house, and replicated thrice. Data collected during the study included; plant height, numbers of branches, flowers, nodules, leaves and chlorophyll content (CC). Both G_{1A} and G_{2A} significantly ($P<0.0001$) produced the highest CC, highest numbers of branches, leaves, flowers, nodules and effective nodules; and the tallest plants. Treatment with 60 kg P_2O_5 ha^{-1} significantly ($P<0.0001$) increased the number of leaves, flowers, branches and plant height. The irradiated genotypes were generally observed to significantly perform better than their non-radiated counterparts under the application of both 60 kg P_2O_5 ha^{-1} and 20 kg P_2O_5 ha^{-1}. Thus, application of 20 kg P_2O_5 ha^{-1} is recommended for optimum plant height, flowers and CC in groundnut production; while 60 kg P_2O_5 ha^{-1} is recommended for optimum numbers of branches and leaves, especially when the irradiated SAMNUT 24 and SAMNUT 26 are to be used for production of both seeds and biomass.
Keywords: Alfisols, Chlorophyll content, Neutron irradiation, SAMNUT

INTRODUCTION

Groundnut (*Arachis hypogaea* L.), a self-pollinating crop, belongs to the family *Fabaceae*, sub-family *Papilionidae*, tribe *Aeschomeneae*, sub-tribe *Stylosanthinae*, genus *Arachis* and species *hypogaea* (Isleib *et al*., 1994). It is an annual herb with an indeterminate growth habit and ranks 13th among the world food crops, 4th most important source of edible oil and 3rd most important source of vegetable protein FAOSTAT (2011). Nigeria is the largest producer in Africa, producing 30 % of the Continent's total production, followed by Senegal and Sudan, each with about 8 %; and Ghana and Chad, with about 5 % each (Gwata *et al*., 2003). Groundnut seeds are mainly comprised of protein, fat and carbohydrate. This makes it sensitive to radiation induced stress. High gamma rays (0.7 - 2.3 KiloGray) have suppressive effects on germination and growth parameters of groundnut (Aparna *et al*., 2012); however, low doses have been reported to be beneficial (Tshilenge-Lukanda *et al*., 2013). Gamma rays produce radicals that can damage or differentially affect plant morphology, anatomy, biochemistry and physiology. Lower exposures to gamma rays were sometimes stimulatory and several studies have reported improvement in agronomic characteristics in radiated groundnuts (Tshilenge-Lukanda *et al*., 2013). Radiation induced mutation played a significant role in the improvement of groundnut genotypes with a large number of pods and high yield have been developed in many countries (Ramani and Jadon, 1991; Micke, 1997).

Phosphorus (P) is one of the most essential elements for plant growth and therefore its deficiency is a factor that limits crop production in tropical and sub-tropical soils (Fairhust *et al*., 1999).

It is considered the second most limiting element for crops, after nitrogen (N) (Arcand and Schneider, 2006). It is an essential plant macronutrient which is required to build important molecules such as nucleic acids and phospholipids. Phosphorus also plays a central role during energy transfer in processes mediated by nicotinamide adenine dinucleotide phosphate (NADPH), adenosine triphosphate (ATP) and in regulation of enzymatic and metabolic reactions (Craufurd *et al.*, 2000; Theodorou and Plaxton, 1993).

Knowledge on the effective irradiation dose on varieties developed by Institute for Agricultural Research (IAR) is currently unavailable. Obtaining high-yielding, stress-tolerant groundnut cultivars using conventional breeding methods is difficult due to limited genetic diversity in groundnuts (Sui *et al.*, 2013). This study sought to determine the effect of radiation on growth parameters in groundnuts.

MATERIALS AND METHODS

Experimental Site

The study was carried out on an Alfisols sampled from the experimental research farm of IAR, Samaru - Zaria (lat. 11^0 10' N, long. 7^0 36' E). The soil of the area was described as leached tropical ferruginous, classified as Typic Haplustalf in soil taxonomy, Acrisol in the FAO system and Alfisols in the USDA system (Uyovbisere *et al.,* 2000). The characteristic vegetation in the area is the northern Guinea savannah, having a sparse regrowth of low grass and shrubby vegetation (Kawo *et al.*, 2006).

Soil sampling, preparation and analysis

Composite samples from surface (0 - 15 cm) and sub-surface (15 - 30 cm) of the soil were randomly collected from 5 points on the experimental site. These were thoroughly mixed, air-dried, crushed and passed through a 2-mm sieve. The less than 2-mm fraction was used for the various physical and chemical analyses conducted. This fraction was, however, further sieved through a 0.5-mm mesh and was used for the determination of organic carbon (OC) and total N. Another sample was also collected, from 0 - 15 cm depth, prepared and passed through a 6 mm mesh and was used for the pot experiment.

Three (3)-litre plastic pots, each 13.5 cm in length and 17.6 cm in diameter were used for the experiment. Three (3) kg of the 6 mm-sieved soil was weighed into each pot. Each pot was perforated by making 3 holes beneath, paper was placed before the soil was put into the pots and the pot covers were placed underneath each pot in order to collect drained water, containing dissolved nutrients, which was returned into the pots appropriately.

Treatments and experimental design

The treatments consisted of two groundnut genotypes (SAMNUT 24_A and $_B$ and; SAMNUT 26_A and $_B$) and four rates (0, 20, 40 and 60 kg P_20_5 ha^{-1}) of phosphorus. The genotypes (SAMNUT 24 and SAMNUT 26) were, however, divided into two portions of which one part was irradiated ($_A$) and the other left as was (as non-radiated, $_B$). They were, therefore, respectively designated as irradiated and non-radiated SAMNUT 24 (G_{1A} and G_{1B}) and irradiated and non-radiated SAMNUT 26 (G_{2A} and G_{2B}). All treatment combinations were randomly allocated in a randomised complete block design (RCBD) and replicated three times, in a (heterogeneous) screen house of Soil Microbiology Unit of the Department of Soil Science, Ahmadu Bello University (ABU), Zaria.

Seeds were exposed to thermal neutrons from an Americium-Beryllium (Am-Be) source for six days at the Centre for Energy Research and Training, Ahmadu Bello University, Zaria. The Am-Be neutron source had a thermal neutron flux of 1.3×10^4 n cm^{-2} Sec^{-1}. The irradiation assembly consisted of a paraffin cylinder having six symmetrical irradiation positions with the Am-Be neutron source at the centre. The source was cylindrical with a dimension of 30 mm x 48 mm in diameter. The seeds were placed into a string tied-plastic bottle. This was used for placing the seeds into and from the radiation source hole (Onoja *et al.,* 1995; Marcu *et al.*, 2013).

Data collection

The data were collected in the three growth phases (pre-harvest, harvest and post-harvest), were obtained on weekly basis for eight weeks. The data collected (before harvest) included; plant height (cm); measured using a 30 cm rule from the ground level to the apical leaf. Others were numbers of branches, leaves and flowers, as well as chlorophyll content (CC). The number observed was counted for each parameter while the CC was measured using a digital (SPAD-502Plus) chlorophyll meter (Konica Minolta Inc., 2017).

At harvest, the root, as detached from the shoot, was carefully washed with tap water immediately after harvest, and length was measured with a 30 cm rule. Their fresh weights were also recorded. Root nodules were earlier carefully removed with a pair of forceps and their number recorded. Thirty (30) root nodules, sampled from each plant, were used in the determination of effective nodules. Each of these nodules was sliced into two halves, using a razor blade, and active ones termed effective, were determined by their pinkish or reddish pigmentation and the number recorded.

Those observed to be white, green, or greenish brown in colour were not active, and therefore, termed ineffective (Gwata *et al.*, 2003). After harvest, the fresh nodules, roots and shoots were separately enveloped and oven-dried at 105 ^{0}C for 48 hours before a Mettler weighing balance was used to measure their dry weights.

Statistical analysis

All the data collected were subjected to analysis of variance (ANOVA) using generalised linear model (GLM) of the statistical analysis system (SAS) computer statistical package (SAS, 2014). Means with significant difference at 5 % level of probability were separated using the Duncan's multiple range test (DMRT).

RESULTS AND DISCUSSION

Physical and chemical characteristics of the experimental soil

The physical and chemical properties of the soil, at 2 depths (0 - 15 cm and 15 - 30 cm), were determined. The result of particle size analysis showed a proportion of 54, 25, and 21 % for sand, silt and clay respectively at the depth of 0 - 15 cm. At the depth of 15 – 30 cm, 62, 17 and 21 % were respectively observed for sand, silt and clay. The textural class was observed to be a sandy clay loam (Table 1). This type of texture is regarded suitable for groundnut production (Raemaekers, 2001). The bulk density (Table 1) also indicated that the soil was good for agriculture, as soils with bulk densities greater than 1.65 g cm^{-3} are not agriculturally good (Vickers, 1979).

The soil reaction (pH) was slightly acidic both in water (5.9 and 6.1 at 0 - 15 cm and 15 - 30 cm, respectively) and $CaCl_2$ (4.8 and 4.5 at 0 - 15 cm and 15 - 30 cm, respectively), hence the soil was suitable for most crops, including groundnuts. Unless there is a calcium deficiency, soils with this type of acidity require no liming (Chude *et al.*, 2004). The organic carbon content was, however, low in both depths of 0 - 15 cm (0.35 %) and 15 - 30 cm (0.42 %). This type of condition encourages rapid leaching of cations and consequent low CEC values (Enwezor *et al.*, 1990). The total N and available P were also on the lower side (Table 1). The N and P deficiencies; and that of organic carbon/organic matter contents indicated poor nutrient reserve of the soil.

Effects of genotype and P rate on plant height, numbers of branches, leaves and flowers in the groundnut genotypes

There was a significant ($P<0.05$) difference between the genotypes in terms of plant height and numbers of branches, leaves and flowers (Table 2). Irradiation significantly ($P\leq0.05$) affected most of the growth parameters observed in the genotypes (Table 2). There was also a significant ($P<0.0001$) effect of the interaction of genotype and P rate in terms of plant height (Tables 2 and 3); and numbers of branches (Tables 2 and 4) and leaves (Tables 2 and 5), but not ($P>0.05$) the number of flowers (Table 2). Tallest plants were observed in the irradiated SAMNUT 26 (G_{2A}) at all the P rates. This genotype was, however, statistically similar with the non-radiated SAMNUT 26 (G_{2B}) at 0 kg P_2O_5 ha^{-1} rate (Table 3). This indicated neither a need for irradiation nor P application to achieve a good plant height in SAMNUT 26. Irradiation and an economical application of P at 20 kg P_2O_5 ha^{-1} is, however, needed in SAMNUT 24 in order to produce plants with a good height (Table 3). The non-radiated G_{1B} produced the least plant height (Tables 2 and 3). Highest mean plant height was observed by Rao (1988) and Khan *et al.* (1989) due to gamma radiation-induced variability. Salve and Gunjal (2011) reported statistically similar plant height records under an application of 50 and 75 kg P_2O_5 ha^{-1} in groundnuts, compared to the application of 25 kg P_2O_5, ha^{-1}.

Highest number of branches was recorded in the irradiated genotypes and P application of 20, 40 and 60 kg P_2O_5 ha^{-1}, which were at par, except in case of G_{1A} at 40 kg P_2O_5 ha^{-1} (Table 4). This suggested for a need of irradiation and a P application of 20 kg P_2O_5 ha^{-1} for a good number of branches in the two (SAMNUT 24 and SAMNUT 26) genotypes. Shiyam (2010), in a study, reported a non-significant difference between P rates on plant height and numbers of flowers and branches. However, Gobarah *et al.* (2006) reported an increase in vegetative growth due to increase in P rate of application. Application of P fertiliser also increased number of branches at growth stage in a study by Alam *et al.* (2009). Adequate P rates were observed to promote root growth, stimulate branching and hasten maturity (USDA, 2014). The two irradiated (G_{1A} and G_{2A}) genotypes each produced statistically similar and more leaves, also at 20 kg P_2O_5 ha^{-1} rate of application. These were, however, at par with G_{1A}, G_{2A} and $_{B}$, at 60 kg P_2O_5 ha^{-1} and G_{2A} at 40 kg P_2O_5 ha^{-1} (Table 4), thus further reaffirming the 20 kg P_2O_5 ha^{-1} as a more economical rate of application also for number of leaves in the groundnuts.

Effects of genotype and P rate on chlorophyll content, nodule number and effective nodulation of the groundnut genotypes

There was no significant ($P>0.05$) difference in the effect of genotype on chlorophyll content (CC), nodule number and effective nodulation. However, the P rates of application differ significantly ($P<0.0001$) in terms of all the parameters (Table 6).

All the P rates were statistically at par with respect to CC of the genotypes, except 0 kg P_2O_5 ha^{-1}, which had the lowest CC record. The two nodule parameters were statistically at their best at 40 and 60 kg P_2O_5 ha^{-1} rates of application, compared to the also statistically similar but lowest 0 and 20 kg P_2O_5 ha^{-1} (Table 6). Good CC, nodule number and effective nodulation can, therefore, be more economically achieved through the application of 20 and 40 kg P_2O_5 ha^{-1}, respectively (Table 6).

The effect of interaction on CC and effective nodulation of the genotypes was not significant (P>0.05), it was, however, significant (P<0.0001) for the nodule number observed (Table 6 and Figure 1). Irradiated (G_{1A} and G_{2A}) genotypes recorded the highest number of nodules at 60 and 40 kg P_2O_5 ha^{-1} respectively, whereas G_{1B} and G_{2B} were statistically similar at 60 kg P_2O_5 ha^{-1} and together followed those (Figure 1). Irradiated G_{2A}, at 40 kg P_2O_5 ha^{-1} rate of application, can be good for an enhanced nodule formation compared to the other genotypes and P rates. Hence, it had a better chance of possible high yield due to its good N_2-fixation potential, depending on the effectiveness of the nodules to be formed. Increase in shoot dry weight, nodule number, nodule mass, nodule size and nodulation index were observed due to availability of P in a study by Kuang *et al*. (2005). Mapfumo *et al*. (2005) reported that P availability has been widely observed to have a significant effect on nodulation, N accumulation and biomass production. The 60 and 40 kg P_2O_5 ha^{-1} had the highest nodules numbers and effective nodules, because P is required for the normal functioning of nitrogen fixing bacteria (the microsymbiont) and thus has a favourable effect on the nodule parameters (Mapfumo *et al*., 2005), which are a part of the fixation indices. Thus, the lower nodulation, which may eventually lead to lower N_2-fixation, in genotypes that received 0 and 20 kg P_2O_5 ha^{-1}, was due to the limited supply of available P, as its deficiency decreases nodulation and N_2 fixation (Tang *et al*., 2001).

Table 1: Characterisation of the experimental soil

Parameter	**Unit**	**Depth (cm)**	
		0 - 15	**15 - 30**
Particle size distribution			
Sand	%	54.00	62.00
Silt	%	25.00	17.00
Clay	%	21.00	21.00
Textural class	-	Sandy clay loam	Sandy clay loam
Bulk density	g cm^{-3}	1.34	1.34
pH (water)	-	5.90	6.10
pH ($CaCl_2$)	-	4.80	4.50
Organic C	g kg^{-1}	0.35	0.42
Organic matter*	g kg^{-1}	6.80	7.20
Total N	g kg^{-1}	0.65	0.45
Available P	mg kg^{-1}	3.30	4.20
Exchangeable Bases	Cmol(+) kg^{-1}		
K		0.50	0.19
Na		0.53	0.15
Ca		2.60	2.40
Mg		0.77	0.72
CEC	Cmol (+) kg^{-1}	7.50	10.20

*OC (g kg^{-1}) x 1.724 (Juo, 1979)

Table 2: Effect of genotype and P rate on plant height and numbers of branches, leaves and flowers

Treatments	Plant height (cm $plant^{-1}$)	Number of branches $plant^{-1}$	Number of leaves $plant^{-1}$	Number of flowers $plant^{-1}$
Genotype (G)				
SAMNUT 24-A (G_{1A})	15.1^{b}	10.7^{a}	46.2^{a}	8.2^{a}
SAMNUT 24-B (G_{1B})	13.4^{c}	8.1^{b}	35.3^{c}	5.5^{b}
SAMNUT 26-A (G_{2A})	16.5^{a}	10.5^{a}	46.2^{a}	5.2^{b}
SAMNUT 26-B (G_{2B})	13.7^{c}	9.9^{a}	41.3^{b}	4.1^{b}
SE$\pm$	0.35	0.40	1.57	0.51
P rate (P, kg P_2O_5 ha^{-1})				
0	14.2^{b}	7.9^{c}	34.9^{c}	5.3^{b}
20	14.6^{ab}	9.7^{b}	41.4^{b}	7.0^{a}
40	14.5^{ab}	10.0^{b}	42.6^{b}	3.4^{c}
60	15.4^{a}	11.5^{a}	49.9^{a}	7.4^{a}
SE$\pm$	0.32	0.40	1.57	0.51
Interactions				
G x P	**	**	**	NS

** = significant at 1 % level probability, NS = Not significant at 5 % level of probability, means with the same letter(s) within a column are not significantly different according to DMRT.

Table 3 Effect of genotype and P interaction on plant height of the genotypes

Genotype	Phosphorus rate (kg P_2O_5 ha^{-1})			
	0	20	40	60
SAMNUT 24-A	13.82^{b-f}	15.85^{a-d}	16.72^{ab}	13.93^{b-f}
SAMNUT 24-B	13.62^{c-f}	12.22^{ef}	13.95^{b-f}	13.77^{b-f}
SAMNUT 26-A	14.89^{a-e}	17.37^{a}	16.42^{a-c}	17.26^{a}
SAMNUT 26-B	14.65^{a-e}	12.81^{d-f}	10.94^{f}	16.50^{a-c}

SEM±= 0.700

Table 4 Effect of genotype and P interaction on number of branches of the genotypes

Genotype	Phosphorus rate (kg P_2O_5 ha^{-1})			
	0	**20**	**40**	**60**
SAMNUT 24-A	9.71^{b-e}	11.58^{ab}	9.83^{b-d}	11.71^{ab}
SAMNUT 24-B	6.25^{e}	9.42^{b-e}	7.92^{c-e}	8.79^{b-e}
SAMNUT 26-A	7.88^{c-e}	11.50^{ab}	10.75^{a-c}	11.75^{ab}
SAMNUT 26-B	7.96^{c-e}	6.38^{de}	11.46^{ab}	13.88^{a}

SEM± = 0.800

Table 5 Effect of genotype and P interaction on number of leaves of the genotypes

Genotype	Phosphorus rate (kg P_2O_5 ha^{-1})			
	0	**20**	**40**	**60**
SAMNUT 24-A	42.58^{b-d}	49.75^{ab}	43.25^{b-d}	48.58^{a-c}
SAMNUT 24-B	26.75^{ef}	39.83^{b-e}	34.50^{d-f}	39.96^{b-e}
SAMNUT 26-A	35.75^{c-f}	50.33^{ab}	46.96^{a-d}	51.63^{ab}
SAMNUT 26-B	34.42^{d-f}	25.71^{f}	45.50^{b-d}	59.42^{a}

SEM± = 3.140

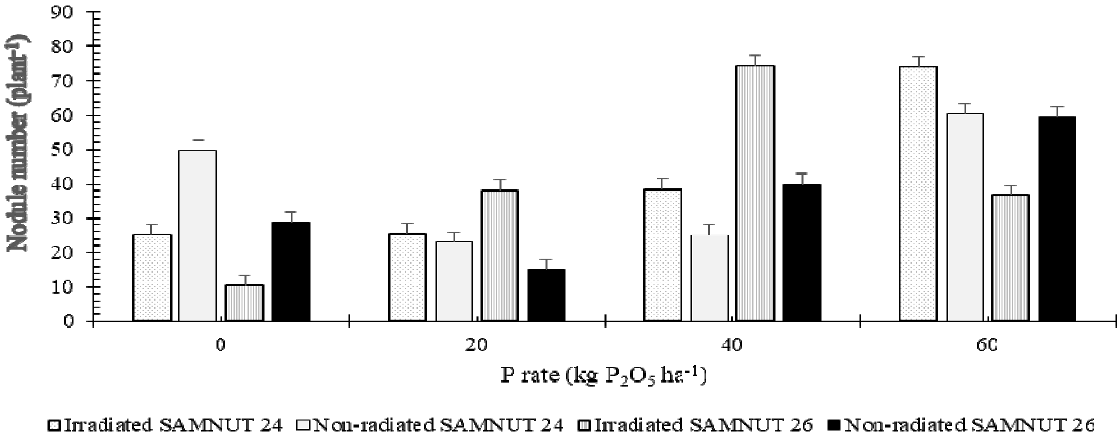

Figure 1 Effect of genotype and P rate interaction on nodule number of the groundnuts

Table 6: Effects of genotype and P rate on chlorophyll content, nodule number and effective nodulation of the groundnut genotypes

Treatments	Chlorophyll content (SCMR)	Nodule number plant-[1]	Effective nodules plant-[1]
Genotype (G)			
SAMNUT 24-A (G_{1A})	47.24	42.50	4.58
SAMNUT 24-B (G_{1B})	49.38	42.00	5.00
SAMNUT 26-A (G_{2A})	48.83	40.00	5.82
SAMNUT 26-B (G_{2B})	48.50	37.96	4.58
SE$\pm$	1.664	3.241	0.497
P rate (P)			
0	43.81^{b}	28.41^{b}	3.83^{b}
20	49.69^{a}	26.82^{b}	3.91^{b}
40	49.43^{a}	48.54^{a}	6.33^{a}
60	51.02^{a}	57.58^{a}	5.75^{a}
SE$\pm$	1.664	3.241	0.497
Interaction			
G x P	NS	**	NS

SCMR = SPAD Chlorophyll Meter Reading (Sonsgri *et al.*, 2009), NS = Not significant at 5 % level of probability, ** = significant at 1 % level probability, means with the same letter(s) within a column are not significantly different according to DMRT.

CONCLUSION

The study showed that the irradiation had significant impact on the genotypes. It was observed that gamma irradiation played an important role in increasing groundnut performance such as in plant height and numbers of branches, leaves and flowers, as well as chlorophyll content. Non-radiated SAMNUT 26, and without P application, was observed to be best for plant height. Irradiation and P application at 20 kg P_2O_5 ha^{-1} is recommended for an economically optimum chlorophyll content; and numbers of branches and leaves in the groundnut genotypes. The two nodule parameters were best at 40 kg P_2O_5 ha^{-1}. More research should be conducted on effects of different irradiation sources and exposure duration on various groundnut performances.

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