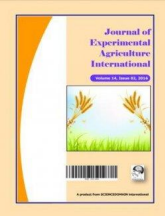

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Nitrogen Contribution by Groundnut (*Arachis hypogaea* L) Genotypes in the Northern Guinea Savanna of Nigeria

Agah Boniface Unimke[1*], Magaji Yusuf Tagwai[2], and Jeremiah Idongesit Mbre[1]

[1]National Agricultural Extension and Research Liaison Service, A.B.U, Zaria, Kaduna State, Nigeria.
[2]Kaduna State University, Kaduna, Nigeria.

Authors' contributions

This work was carried out in collaboration among all authors. Author ABU designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors MYT and JIM managed the analyses of the study. Author MYT managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Most grain legumes irrespective of their ability to fix substantial amount of nitrogen to the soil, could impact negatively on the soil nitrogen balance, particularly if the fix nitrogen is exported from the field with harvested biomass (Shoot, root, grain/kernel). Thus, for agronomic purposes, it is important to quantify the potential amount of nitrogen from this source that will become available to the soil for subsequent crop uptake and/or ecosystem balance. The field trial was undertaken at the teaching and research field of the Institute for Agricultural Research (IAR) Samaru Zaria in the wet planting season of 2011 and 2012. The treatments consist of ten groundnut genotypes (SAMNUT 24, SAMNUT 22, ARRORSICGX-SM 00017/5/P15/P2, SAMNUT 10, ICIAR 7B, ARRORSICGX 000201/5/P4P10, SAMNUT 21, 6AT, SAMNUT 23 and SAMNUT 14), and two rates (0 and 30 kg N ha-1) of nitrogen (urea) fertilizer arrange in a split plot design. Nitrogen balance was estimated as the difference in nitrogen fix by the plant and nitrogen content of kernels/haulms. Results of the analysis of variance indicate that there was significant variation among the selected groundnut

**Corresponding author: E-mail: bonyagah@gmail.com;*

genotypes in their net contribution of nitrogen in both 2011 and 2012 at instances where both the groundnut kernel and haulms were exported from the field. Nitrogen contributions by the genotypes were not consistence in both years. In 2011, while SAMNUT 14 left the highest value of 9.79 kg N ha-1, ICIAR 7B returned the highest value in 2012. ICGX-SM 00017/5/P15/P2 (-16.55 kg N ha-1) and SAMNUT 22 (-56.07 kg N ha-1) contributed the least amount of nitrogen in 2011 and 2012 respectively when the kernel were removed from the field. On the other hand, 6AT was relatively stable in both years, and contributed close to 1 kg N ha-1. Even though negative nitrogen balances were reported at instances where the kernels were exported from the field, a more severe N depleting effect was observed when both haulms and kernels were removed from the field. Although, negative N balance was predominant at both rates (0 and 30 kg N ha-1) of N application, but the average nitrogen contribution was significantly higher (-1.10 kg N ha-1) with the application of starter nitrogen than the control (-13.23 kg N ha-1). In view of these findings, groundnut genotypes 6 AT, SAMNUT 14 and ICIAR 7B could be elite genotypes if building a resilience sustainable ecosystem is a priority due to their high biological nitrogen fixing abilities and nitrogen contributing potential.

Keywords: Groundnut genotypes; starter nitrogen; nitrogen contribution; northern guinea savannah.

1. INTRODUCTION

Humans are currently confronted by many global challenges. These include achieving food security for a rapidly expanding population, lowering the risk of climate change by reducing the net release of greenhouse gases into the atmosphere due to human activities, and meeting the increasing demand for energy in the face of dwindling reserves of fossil energy and uncertainties about future reliability of supply. Legumes deliver several important services to societies. They provide important sources of oil, fiber, and protein-rich food and feed while supplying nitrogen (N) to agro-ecosystems via their unique ability to fix atmospheric N_2 in symbiosis with the soil bacteria rhizobia, increasing soil carbon content, and stimulating the productivity of the crops that follow [1].

The yields of cereals grown after grain legumes are almost always increased often by as much as 0 – 80% compared to cereals grown after cereals. Vanotti et al. [2] & Agboola and Fayemi [3] observed significant increase in maize grain yield when grown to rotation with soybean and cowpea. Maize following groundnut significantly out yielded maize following cotton and sorghum in Samaru, Nigeria [4]. Suwanarit et al. [5], observed an increase of 0.49 t ha^{-1} of maize following soybean relative to a cereal cropping system. An increase of 0.91 and 0.85 t ha^{-1} in the yield of maize following cowpea and groundnut was found respectively, in relative to the cereal-cereal cropping sequence were also observed by Dakora et al. [6]. In multi-year trials of legume rotation with cereals, [7] opined that maize grain yield was higher than maize after maize fertilized with 200 kg urea ha^{-1}.

The efficiency of biological nitrogen fixation (BNF) by legumes will depend on their ability to contribute significant amount of nitrogen to the soil. It is an established fact that groundnut *(Arachis hypogaea L)* contribute substantial amount of nitrogen to the ecosystem and also offer opportunity to increase the supply of N through symbiotic association with effective rhizobia [8,9]. However, the amount of nitrogen fix by groundnut varied depending on the genotypes which could influenced their net contributions to subsequent non-legumes crops [9].

Biological nitrogen contribution by legumes to any given ecosystem is a function of the total nitrogen content of the soil and the amount of nitrogen fix in different plant part (i.e. root/shoot biomass). Hence, the ability of subsequent non legumes crops to explore the biologically fix nitrogen in the soil and plant part will depend on the soil and biomass management strategies adopted. In Nigeria, residues from groundnut cultivation are subjected to varying usage which in most instances is at variance with improvement of soil fertility status. No serious attention have been devoted by way of research to quantify the amount of biologically fix nitrogen that is potentially lost when groundnut biomass (Shoot, roots and kernel) is exported from the field at the end of the planting season. Therefore, this finding is aimed at evaluating nitrogen contribution by groundnut genotypes in the northern guinea savanna of Nigeria.

2. MATERIALS AND METHODS

2.1 Site Description

The experiment was conducted on one of the experimental fields of the Institute for Agricultural Research (I.A.R) Samaru located at an altitude of 686 m above sea level, latitude 11°11'008´N and longitude7°36'52.1"E in the Northern Guinea Savanna of Nigeria (NGS). The NGS is characterized by a mono-modal rainfall pattern. Total annual rainfall was 1207 mm and 1333 mm for 2011 and 2012 respectively and an average minimum temperatures of 18°C and 19°C and maximum temperatures of 35°C and 34°C in 2011 and 2012 respectively. Soils in the experimental area are classified as Typic Haplustalf according to the USDA soil taxonomy [10] and Acrisols according to [11]. The soil is low in inherent fertility: organic matter, cation exchange capacity and dominated by low activity clays [12].

2.2 Field Layout, Treatment and Experimental Design

The experimental area was marked out from the field, ploughed, disc-harrowed and ridged at an inter-row spacing distance of 0.75 m. The various treatments consisting of ten genotypes of groundnut; SAMNUT 24, SAMNUT 22, ARRORS ICGX-SM 00017/5/P_{15}/P_2, SAMNUT 10, ICIAR 7 B, 6 AT, ARRORS ICGX 000201/5/P_4P_{10}, SAMNUT 21, SAMNUT 23, SAMNUT 14, and two rates of nitrogen fertilizer (0 kg ha^{-1} and 30 kg ha^{-1}) were arranged in a split plot design. (One non nodulated groundnut genotypes ICGL 5 was also included to determined symbiotic nitrogen fixation by N- difference method). Nitrogen rates was selected to represent the main plots while the sub plots consisted of ten groundnut genotypes replicated three times giving a total treatment combination of 60 Basal application of 20 kg/ha K as Muriate of Potash (60% K_20), 20 kg/ha P as Single Superphosphate (18% P_2O_5). One third of 30 kg/ha N of Urea (46% N) was equally applied two weeks after planting (2 WAP); while the remaining part (two third) was applied eight weeks after planting (8 WAP). The fertilizers were applied by banding about 5 cm away from the seed. One seed each of groundnut genotype was sown by hand at a spacing of 20 cm by 75 cm inter and intra row spacing respectively. Each plot size measure 3 m by 3 m, and 1 m and 2 m where demarcated between sub plots and replications, respectively. The total plot area was 34 by 65 m^2.

2.3 Soil Analysis

Initial soil sampling was done at a depth of 0 -15 cm for physico-chemical analysis of the inherent nutrient status. An auger was used to collect a total of 20 soil samples bulked to form composite sample from which sub sample was taken for the analysis. The collected soil samples were air-dried, sieved using 2-mm mesh sieve and bagged with polythene bags in readiness for the following physico-chemical laboratory analysis; Particle size distribution was determined by the hydrometer method, as described by [13], using distilled water and calgon (sodium hexametaphosphate) as dispersing agents while soil textural class was obtained from the USDA soil textural triangle; Soil pH was determined electrometrically in a soil to solution ratio of 1:2.5 [14]. Total nitrogen was estimated by micro-Kjeldahl digestion method [15]; Organic carbon was measured by the method described by Olsen and Sommers, [16]. Available phosphorus was estimated by the Bray 1 method [16]. Exchangeable Ca^{2+}, Mg^{2+}, K and Na^{+} were extracted with 1N ammonium acetate buffered at pH 7.0 [17]. Exchangeable Ca^{2+} and Mg^{2+} were determined by EDTA complexometric titration while exchangeable K^{+} and Na^{+} were estimated by flame photometry [18]. Exchangeable acidity was determined by titration method [19]. The effective cation exchange capacity (ECEC) was estimated by summation method of all the exchangeable acidity and exchangeable bases. The extractable micro nutrients such as zinc (Zn), iron (Fe), manganese (Mn), and copper (Cu) were extracted with 0.1N NH_4Cl and read with Atomic Absorption Spectrophotometer (AAS).

2.4 Plant Analysis

Plant samples were collected at eight weeks after planting in both cropping seasons (2011 and 2012) for the determination of plant N-accumulation. Destructive sampling was carried out on four plants, two taken from each of the outer rows. The plant samples were separated into shoot and roots, washed with distilled water to removed adhering soils, placed in paper envelops and oven dried at 65°C for 72 hrs when constant weight was attained. After oven drying, shoots and roots were ground and allowed to pass through a 0.5 mm mesh before analysis for total N concentration using the micro Kjedahl method [15].

2.5 Calculations/Estimations

The net contribution of N_2-fixation to the N balance of the soil was calculated by the method described by [20] thus;

Net N balance = NF – NK/NT

Where

NF = Amount of nitrogen fixed
NT = Total N in kernel+haulm
NK = Total N in Kernel
Nitrogen fixation was estimated using the N-difference methods thus:

(i.e N content of nodulated - non-nodulated groundnut genotypes); [21].

2.6 Statistical Analysis

Individual analysis of variance was performed for each character in each year using the General Linear Model (GLM) procedure of SAS; [22]. The effects of the various treatments and their interactions were compared using standard error of difference (SE), and LSD was used for means separation.

3. RESULTS AND DISCUSSION

3.1 Experimental Soil Characteristics in 2011 and 2012

Some physical and chemical properties of the site (soil) before commencement of the study were determined before the establishment of the trials in 2011 and 2012 and the results obtained are as shown in Table 1. The results showed that the texture of the soil in both years was sandy-loam. This may be due to sorting of soil materials (such as decomposed roots, leaves etc.) by biological activities, clay migration (Illuviation/elluviation) or erosion by run–off or a combination of these factors [23].

The soil reaction was slightly acidic (5.30 - 6.00) but did not pose any limitation to groundnut production. The organic carbon and total N were both low in the soil in both years. However, there was a slight increase in soil total nitrogen in 2012 than in 2011 which could probably be due to the residual nitrogen resulting from mineralisation of below ground residues of previous groundnut crop. Similarly, decrease in organic carbon (OC) in 2012 might be due to increase in soil N which will enhance soil organic matter decomposition by soil organisms. The available P content and the exchangeable bases fall within the medium class for Nigerian soils [24]. The experimental soil can be classified as moderately suitable for the cultivation of most arable crops according to the modified FAO suitability classification [25].

The exchangeable acidity and effective cation exchange capacity (ECEC) were all low in the soil. The extractable micronutrients (Zn, Fe, and Mn) were all high while the extractable Cu was medium in the soil [26]. Hence, the micronutrients were considered adequate and did not limit groundnut production [27]. Generally, the soils properties were typically characteristic of Alfisols of Northern Guinea Savanna of Nigeria as described by [26], and the level of the various nutrient elements fell within the ranges described for Nigeria soils [27].

3.2 Soil N Balance as Influenced by Groundnut Genotypes and N Fertilizer

The results obtained showed that there was a significant difference among groundnut genotypes in their net contributions to soil nitrogen balance when groundnut kernels were exported (removed) from the field in both 2011 and 2012 planting season (Table 2). The mean N balance values were significantly higher in 2011 (-7.12) than in 2012 (-20.03). However, N rate effect was not significant in both 2011 and 2012. The highest and lowest soil N balances were reported in SAMNUT 14 (9.79) and ARRORS ICGX-SM 00017/5/P15/P2 (-16.55) in 2011 while in 2012, ICIAR 7B (1.78) and SAMNUT 22 (-56.07) returned the highest and lowest nitrogen balance respectively. Generally, negative N balance was predominance at both rates of nitrogen application; with the 30 kg/ha N rates returning significantly higher value (-1.10) than the control (-13.23) in 2011 (Table 3). Result of the two years averages shows that SAMNUT 14 impacted positively on the soil nitrogen balance. Although ICIAR 7B which in 2011 was among genotypes leaving close to zero nitrogen balance could be seen imparting positively on the soil nitrogen balance in 2012. This indicates that continuous cultivation of such genotype could have a marked significant improvement on the soil residual nitrogen. Genotype and nitrogen interaction was only significant in 2011(Fig. 1).

Table 1. Physical and chemical properties of the soil of the experimental site in 2011 and 2012

Soil Properties	Level in soil		
	2011	2012	Average
Sand (%)	67.10	64.00	65.55
Silt (%)	19.80	20.00	19.90
Clay (%)	13.10	16.00	14.55
Textural class	Sandy-loam	Sandy-loam	Sandy-loam
pH 1:2.5 water	5.30	6.00	5.65
pH 1:2.5 $CaCl_2$	5.10	5.15	5.13
Organic Carbon (g kg^{-1})	5.37	2.28	3.83
Total Nitrogen (%)	0.15	0.19	0.17
Available P (mg kg^{-1})	11.00	8.32	9.66
Exchangeable Ca^{2+}(Cmol/kg)	2.32	3.15	2.74
Exchangeable Mg^{2+} (Cmol/kg)	0.40	1.01	0.71
Exchangeable K^{+}(Cmol/kg)	0.20	0.16	0.18
Exchangeable acidity(Cmol/kg)	0.18	0.12	0.15
ECEC (Cmol/kg)	3.10	4.44	3.78
Extractable micronutrient (mg/kg)			
Zn	2.28	1.86	2.07
Cu	1.00	1.00	1.00
Mn	16.00	13.00	14.50
Fe	9.00	10.00	9.50

ECEC = Effective Cation Exchange Capacity

Table 2. Soil N balance as influenced by groundnut genotypes and N fertilizer in 2011, 2012 and combined (Grain removed)

Genotype (G)	Soil N-balance (kg/ha)		
	2011	2012	Combined
SAMNUT 24	-1.23	-20.44	-10.83
SAMNUT 22	-12.03	-56.07	-34.05
ARRORS ICGX-SM 00017/5/P_{15}/P_2	-16.55	-48.98	-32.77
SAMNU 10	-16.40	-21.88	-19.14
ICIAR 7B	-9.34	1.78	-3.78
6AT	4.32	-19.34	-7.51
ARRORS ICGX 000201/5/P_4P_{10}	-15.98	-33.55	-24.77
SAMNUT 21	-4.26	-8.95	-6.61
SAMNUT 23	1.50	-1.82	-0.16
SAMNUT 14	9.79	-1.11	4.34
Means	-7.12	-20.03	-7.85
SE±	6.07**	7.64**	4.87**
Nitrogen N (kg/ha)			
0	-13.13	-19.80	-16.47
30	-1.10	-20.25	-10.68
Means	-7.12	-20.03	-13.58
SE	2.71*	3.26^{NS}	2.16^{NS}
Interactions			
G*N	*	NS	NS

*NS=Not significant at 5% level of probability, *Significant at 5% level of Probability, **Significant at 1% level of probability.*

Similarly, considering the other instance where both the groundnut haulms and kernels were removed from the field, a more negative nitrogen balance was observed as shown in Table 3. Results of the combined analysis of variance showed that, soil nitrogen balance at this stage ranges from -53.08 kg/ha to -10.95 kg/ha. The highest value was reported in SAMNUT 14 with a mean value of -10.95 kg/ha which was significantly different from all other genotypes;

closely followed by groundnut genotype 6 AT (-11.78 kg/ha) while the least value was reported in ARRORS ICGX-SM 00017/P15/P2. This implies that SAMNUT 14 and 6 AT was reported to have moderate depleting effects on soil nitrogen status. Interaction between genotypes and nitrogen rates was significant in both 2011 and 2012 (Figs. 2 and 3). However, in both 2011 and 2012, supplementary addition of 30 kg N ha-1 resulted to a significant increase in soil nitrogen balance over the control (0 kg/ha N).

Most grain legumes irrespective of their ability to fix reasonable amount of nitrogen to the soil, impact negatively on the soil nitrogen balance [28]. This could be due to the fact that the benefit of nitrogen fixation is not often realizable to the current crop but depend on whether their residue is incorporated back into the soil. For instance, [28] recorded a mean range of -18.9 and 9.4 kg/ha N for cowpea and soybeans respectively, and [29] recorded a mean range of -10.6 to 11.1 kg/ha N for 8 cowpea genotype. The positive N balance observed in SAMNUT 14 (9.79 kg/ha), 6 AT (4.32 kg/ha) and SAMNUT 23 (1.50 kg/ha) in 2011 as well as ICIAR 7B (1.78) in 2012 when only the kernel was exported from the field respectively could be attributed to the amount of biologically fixed N as reported by [9]. However, for such a positive N balance to occur, it is expected that the amount of fixed N by the legumes to the soil must be greater than the amount of soil N in the harvested kernel [30].

From the result of the interaction between genotypes and nitrogen rates, significant difference were observed among the genotypes whereby some genotypes left a positive N balance at 30 kg/ha N rates; whereas majority were with negative nitrogen balance. However, it's interesting to know that some genotypes notably SAMNUT 14, SAMNUT 22 and SAMNUT 24 left close to zero nitrogen balance at 0 kg/ha N rates but these genotypes however responded to nitrogen fertilizer application by impacting positively on the soil nitrogen balance. Although this trend was not so pronounced for SAMNUT 21, which even though response to nitrogen application but could not attain a positive nitrogen balance. This was probably due to the fact that the maximum nitrogen rate was yet to be attained by this genotype.

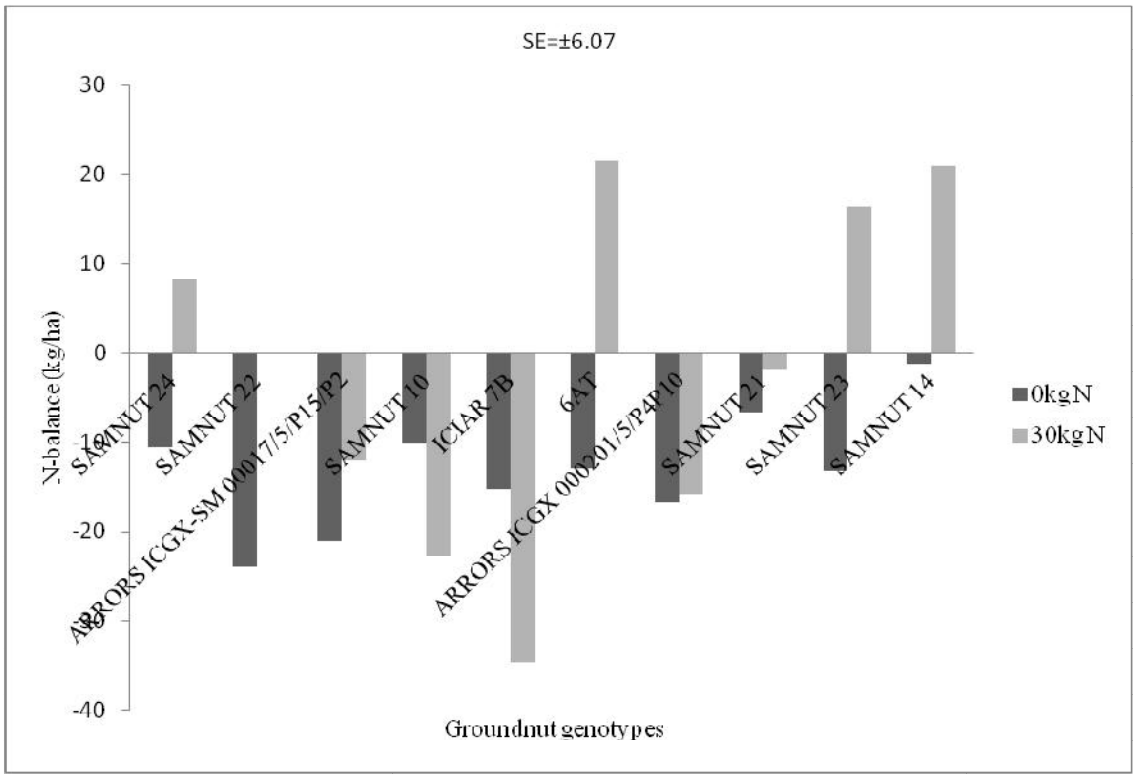

Fig. 1. Interaction between genotypes and N-rates on nitrogen balance of groundnut in 2011 (only kernel removed)

Table 3. Effect of nitrogen rates and genotypes on soil nitrogen balance (Haulm + kernel)

Genotypes	Nitrogen balance (kg/ha)		
	2011	2012	Combined
SAMNUT 24	-15.11	-32.58	-23.84
SAMNUT 22	-48.3	-54.43	-51.37
ARRORS ICGX-SM 00017/P_{15}/P_2	-42.95	-63.21	-53.08
SAMNUT 10	-62.11	-35.14	-48.62
ICIAR 7B	-36.03	-20.84	-28.44
6AT	-12.42	-11.14	-11.78
ARRORS ICGX 000201/5/P_4P_{10}	-49.57	-26.24	-37.91
SAMNUT 21	-52.56	-41.24	-46.90
SAMNUT 23	-21.25	-17.96	-19.61
SAMNUT 14	-13.01	-8.89	-10.95
SE±	7.24**	4.86**	4.36**
Mean	-34.45	-29.66	-32.06
Nitrogen rates (kg/ha)			
0	-41.05	-32.71	-36.88
30	-27.85	-26.60	-27.23
Mean	-34.45	-29.66	-32.06
SE±	3.09**	2.07**	1.89**
Interactions			
G*N	**	*	NS

*NS=Not significant at 5% level of probability, *Significant at 5% level of Probability, **Significant at 1% level of probability.*

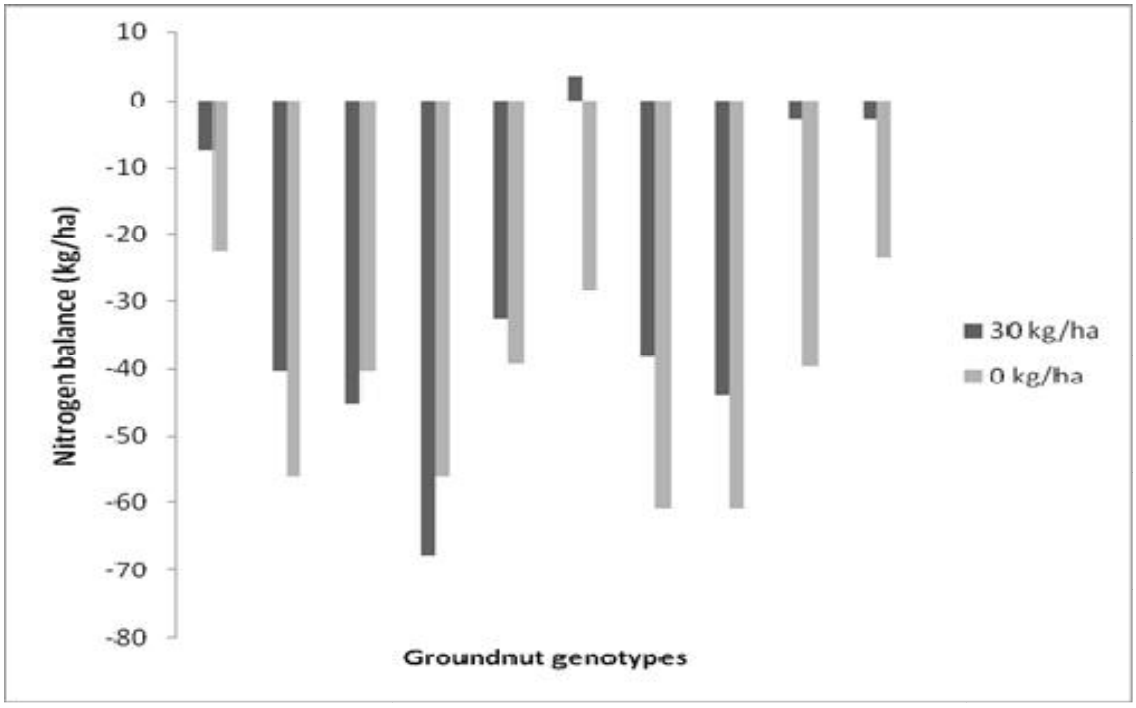

Fig. 2. Interaction effect of nitrogen rates on soil nitrogen when both the haulms and kernel are removed in 2011

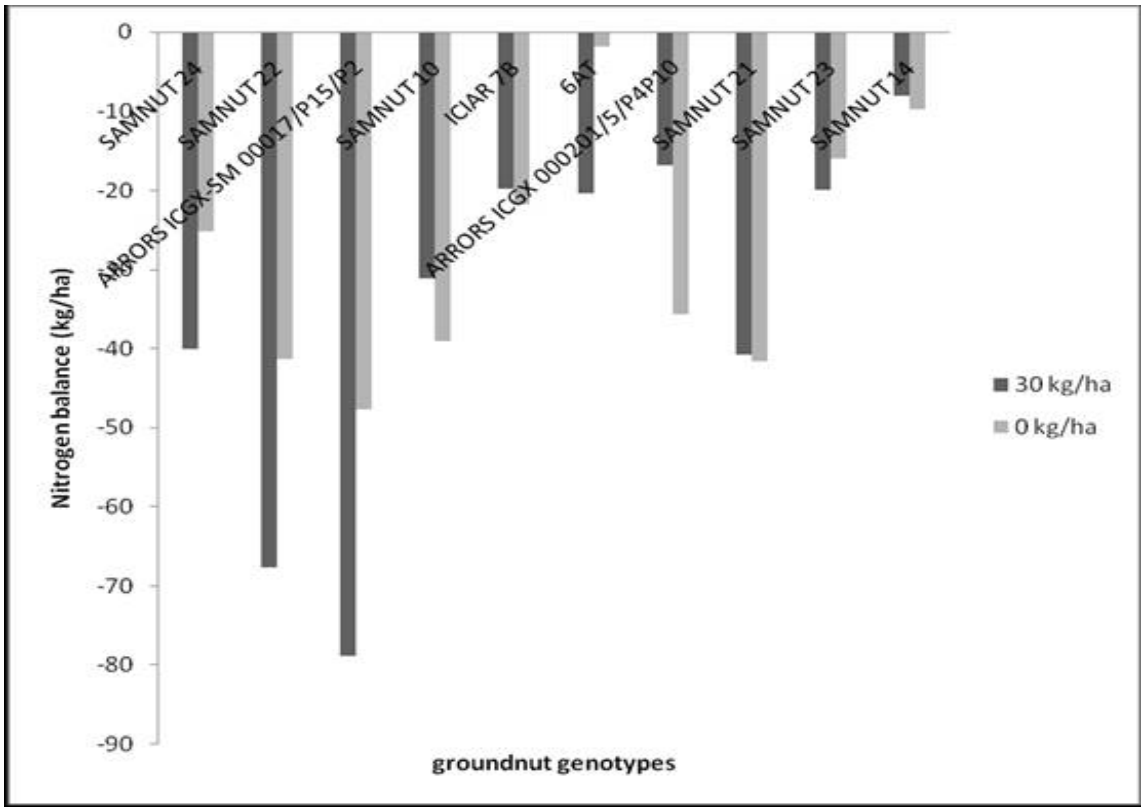

Fig. 3. Interaction effect of nitrogen rates on soil nitrogen when both the haulms and kernel are removed in 2012

The occurrence of legume benefit does not necessarily translate into a positive soil nitrogen balance of legume crops. Hence, higher soil mineral nitrogen content after legumes can be due to the nitrogen saving effect of legumes [31]. Factors such as the removal of the above ground crop residues and clear weeding could promote the predominance of negative soil nitrogen balance which could likely explain the overall negative nitrogen balance observed in our current study. In addition, soil nitrogen balance depends on the nitrogen harvest index (NHI) of the total plant (including roots) and soil nitrogen status. For instance, research findings by [32] showed that short duration pigeon pea with a NHI of 54% had a negative nitrogen balance of -32 kg/ha N even when crop residues remained in the system in contrast to late maturity type with NHI of 21% given a positive nitrogen balance of 41 kg/ha N. Further justifying our result where negative soil nitrogen balance was observed in both years, higher soil N availability has been found to reduce the nitrogen balance of cowpea from a positive nitrogen balance of +52 kg/ha to 0 kg/ha N due to reduced nitrogen fixation [33].

Thus, for agronomic purposes, it is important to know when and how much nitrogen from this source become available to the following crops and also from sustainability point of view, it is also important to know how soil fertility changed in the long term if legumes provide the sole means of nitrogen input into system [31].

4. CONCLUSION

Genotypic variation exists among cultivated lines of groundnut in their net contribution to soil N balance. The effect of nitrogen and genotypes on soil N balance revealed a significant difference at both instances (kernel and/or haulm) under consideration. At one instance where only the kernel was removed from the field, relatively mild damage was observed on the soil N balance sheet, indicating the predominance of near – positive or positive N-balance with SAMNUT 14, ARRORS ICGX 000201/5/P_4P_{10}, 6 AT and SAMNUT 22 outperforming other genotypes. Nitrogen rates effects was significant with 30 kg/ha N leaving an average of 36 kg/ha N representing 55% increase above the control,

thus, indicating a significant improvement of the soil N balance. Whereas, at the other extreme (haulm and kernel), negative N balance predominate. ICIAR 6AT was the best genotype; even though SAMNUT 22 and ARRORS ICGX 000201/5/P_4P_{10} were still able to impact positively on the soil N balance but at a lower rate relative to ICIAR 6 AT. Also, N-rates effect was equally significant with the 30 kg/ha N improving the groundnut ability to positively influenced the soil N balance. SAMNUT 21, even at 0 kg N still left a positive N-balance at both extreme. Thus, SAMNUT 22, SAMNUT 14 and SAMNUT 24 are elite genotypes if building sustainable ecosystem resilience is a priority, considering the fact that the genotypes left close to zero nitrogen balance indicating their capacity to minimally deplete soil nitrogen balance sheet.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Jensen ES, Peoples MB, Boddey RM. Legumes for mitigation of climate change and the provision of feedstock for biofuels and biorefineries. A review. Agron. Sustain. Dev. 2012;32:329.
   DOI: 10.1007/s13593-011-0056-7
2. Vanotti MB, Brundy LG. Soybeans Effects on soil nitrogen availability in crop rotations. Agrronomy Journal. 1993;87(4): 676–680.
3. Agboola AA, Fayemi AA. Preliminary trials onthe intercropping of maize with different tropical legumes in Western Nigeria. J. Agric. Sci. Camb. 1971;77:219-225.
4. Jones AS, Wild A. Soils of the West Africa Savanna. Tech. Comm. CAB Harpenden. 1975;55.
5. Suwanarit A, Suwannarat C, Chotechaungmanirat S. Quantities of fixed N and effects of grain legumes on following maize, and N and P status of soil as indicated by isotopes. Plant and Soil. 1986; 93:249-258.
6. Dakora FD, Keya SO. Contribution of legumes nitrogen fixation to sustainable agriculture in sub Saharan Africa. Soil Biology and Biochemistry. 1997;1997(29): 809-817.
7. Rodriquez-Kabana R, Ivey H. Crop rotation systems for the management of meloidogyne arenaria in peanut. Nematropica. 1986;16:53–63.
8. Yusuf AA, Abaidoo RC, Iwuafor ENO, Olufajo OO. Genotypic effects of cowpea and soybeans on nodulation, N_2 fixation, and n-balance in the northern guinea savanna of Nigeria. Journal of Agronomy. 2008;7:258-264.
9. Agah BU, Idehen EO, Jeremiah IM, Magaji TY. Nodulation and symbiotic nitrogen fixation by groundnut (*Arachis hypogaea* L) genotypes as influence by inorganic nitrogen fertilizer in the northern guinea savanna of Nigeria. International Journal of Plant and Soil Science, IJPSS. 2016;13(5): 1-15.
   Available:http://www.sciencedomain.org/issue/2112.
10. Ogunwole JO, Babalola OA, Oyinlola EY, Raji BA. A pedological characterization of soils in the samaru area of Nigeria. Samaru Journal of Agricultural Research. 2001;17: 71-77.
11. FAO-UNESCO. Soil Map of the World. Revised Legend. Tech. FAO/Rome and ISRIC/Wageningen, The Netherlands. 1994;20:42-47.
12. Odunze AC. Effects of forage incorporation on selected soil chemical properties in the northern guinea savanna of Nigeria. Journal of Sustainable Agriculture. 2003; 22:1-12.
13. Gee GW, Or D. Particle size analysis. In: Methods of Soil Analysis, Dane JH, Topp GC, (Eds.) Part 4. physical methods. Soil Science Society of American. Book series 5, ASA and SSSA, Madison, Wisconsin. 2002;255-293.
14. Hendershot WH, Laland H, Duquette M. Soil reaction and exchangeable acidity. In: Soil sampling and methods of analysis. Carter MR (Ed.). Canadian Society of Soil Science, Lewis publishers London. 1993; 141-145.
15. Bremmer JM, Mulvaney CS. Total nitrogen. In: Methods of Soil Analysis. Page AL, Miller RH, Keeping DR. (Eds) of Soil. Part 2. American Society of Agronomy Madison Wisconsin. 1982;595–624.
16. Olsen SR, Sommers LE. Phosphorus. In: Page AL, Miller RH, Keeney DR, (Eds). Methods of soil Analysis. Part 2. American Society of Agronomy, Madison Wisconsin. 1982;403-430.
17. Chapman HD. Total Exchangeable Bases. In: Black CA. (Ed); Methods of soil analysis, characterization of Soils in the Samaru area of Nigeria. Samaru Journal of Agricultural Research. 1965;54:10-17.

18. Jackson ML. Soil chemical analysis. Prentice hall, New York. 1962;42.
19. McLean EV. Aluminum, In: Page AL, Miller RH, Keeney DR. (Eds.). Methods of Soil Analysis, Part 2, Madison, WI. 1982;978-998.
20. Peoples MB, Crasswell ET. Biological nitrogen fixation: Investments, expectations and actual contributions to agriculture. Journal of Plant and Soil, 1992;141:13-23.
21. Mary SV, Carlos MS, Segundo U, Rober MB. Quantification of the contribution of N2 fixation to tropical forage legumes and transfer to association grass. Soil Biology and Biochemistry. 1995;27:1193-1200.
22. SAS. Institute Inc. SAS/STAT. Users guide. version 6.4ed. Statistical Analysis Institute: Cary. N. C; 2000.
23. Ojanuga AG. Clay mineralogy of soils in the Nigerian tropical savanna regions. Soil Science Society of America Journal. 1979; 43:1237-1242.
24. Federal ministry of agriculture and natural resources (FMANR). Literature Review on Soil Fertility Investigations in Nigeria (In Five Volumes). Federal Ministry of Agriculture and Natural Resources, Lagos, Nigeria; 1990.
25. Young A. Tropical soils and soil survey. Cambridge University press, London, UK. 1976;468.
26. Odunze AC. Soil properties and management strategies for some sub humid Savanna zone alfisols in Kaduna State, Nigeria. Samaru Journal of Agricultural Research. 2006;22:3-14.
27. Food agriciltural organisation (FAO). Soil Fertility Management in Support of Food security in Sub-Saharan Africa; 2001. Available:ftp://ftp.fao.org/agl/agll/docs/foodsec.pdf
28. Yusuf AA, Jemo M, Ncho C, Abaidoo RC. Effect of rhizobium inoculation and phosphorus sources on the productivity of groundnut in Samaru. Northern Guinea Savannah. 2011;191-198.
29. Sanginga N, Okogun J, Vanlauwe B, Dashiell K. The contribution of nitrogen by promiscuous soybeans to maize based cropping in the moist savannah of Nigeria. Plant and Soil. 2002;251:1-9.
30. Giller KE. Nitrogen Fixation in Tropical Cropping Systems. (2nd Edn.), CAB International, Wallingford, UK. 2001;78-97.
31. Rego TJ. Seeling B. Long term effects of legume-based cropping systems on soil nitrogen status and mineralization in vertisols. International crops research institute for the semi- arid tropics (ICRISAT), Andhira Pradesh, India. 1996; 1370.
32. Kumar Rao JV, Dart PJ. Nodulation, nitrogen fixation and nitrogen uptake in pigeon pea (*Cajanus cajan* L) of different maturity groups. Plant and Soil. 1987;99: 255-266.
33. Eagleshawn ARJ, Ayanaba A, Ranga Rao V, Eskew DL. Mineral nitrogen effect on cowpea and soybean crops in a Nigerian soil .11. Amounts of N-fixed and accrual to the soil. Journal of plant and soil. 1992; 68:183-192.

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