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Comparative Effect of Groundnut (Arachis hypogea l.) Genotypes on Yield and N Fixation in Sudan and Northern Guinea Savannahs of Nigeria

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ABSTRACT

Recognition of high yielding and nitrogen (N) fixing groundnut genotypes and desegregating them in the cereal-based cropping systems common in savannah regions will enhance food security and reduce the need for high N fertilizers hence, minimize the high cost and associated environmental consequences. Field trials were conducted during the 2015 growing season at the Research Farms of Bayero University Kano (BUK) and Institute for Agricultural Research (IAR), Ahmadu Bello University, Samaru-Zaria to assess the yield potential and Biological N fixation in 15 groundnut genotypes **(**ICG 4729, ICGV-IS 07823, ICGV-IS 07893, ICGV-IS 07908, ICGV- SM 07539, ICGV- SM 07599, ICGV-IS 09926, ICGV-IS 09932, ICGV-IS 09992, ICGV-IS 09994, SAMNUT-21, SAMNUT-22, SAMNUT-25, KAMPALA and KWANKWAS). The groundnut genotypes and reference Maize crop (SAMMAZ 29) were planted in a randomized complete block design in three replications. N difference method was used to estimate the amount of N fixed. The parameters determined were the number of nodules, nodule dry weight, shoot and root dry weights, pod, and haulm yield as well as N fixation. The nodule dry weight, BNF, haulm, and pod yield were statistically significant ($P<0.01$) concerning genotype and location. Similarly, their interaction effect was also highly significant. ICGV-IS 09926 recorded the highest nodule dry weight of 2.07mg /plant across the locations while ICGV-IS 09932 had the highest BNF value of 140.27Kg/ha. Additionally, KAMPALA had the highest haulm yield, while ICGV-IS 07893 had the highest pod yield across the locations with a significant interaction effect. The result shows that ICGV-IS 07893 and ICGV-IS 09932, as well as ICGV-IS 09994 and SAMNUT – 22, were the best genotypes concerning BNF, haulm and pod yield in the Northern Guinea and Sudan Savannahs of Nigeria respectively with the potential for a corresponding beneficial effect.

1.0. Introduction

Nigeria used to be the highest groundnut producing and exporting country in Africa, accounting for 70% of the total Nigeria export earnings between 1956 and 1967 with an average yield of 3.2 Mt/ha (Ajeigbe *et al.*, 2015), but yields declined to almost half of the existing level of 1.7 Mt/ha due to increasing cost of production arising from inputs especially, nitrogenous fertilizers (Ajeigbe *et al.*, 2015; Yusuf *et al.*; 2013; Larinde, 1999). Food and Agricultural Organization Statistics (FAOSTAT, 2012) found that pod yields of groundnut in Africa are much lower (964kg/ha) than the average world yields (3500kg/ha). In Nigeria, the average productivity is 1720kg/ha far higher compared to other African countries but less than 3508kg/ha and 2595kg/ha recorded by North and South America, respectively. Researchers attribute this low yield to soil nutrient deficiencies (especially Nitrogen, calcium, and phosphorus), biotic, abiotic, and socio-economic factors (Caliskan *et al.*, 2008; Pande *et al.*, 2003; Upadhyaya *et*

al.; 2006).

Additionally, Nitrogen fixation, according to Nambiar *et al*. (1981), varies among groundnut genotypes. The Virginia types according to Nambiar *et al*., (1981), and Yakubu *et al*., (2010) cited in Umar, (2016) formed more nodules and fixed more nitrogen than Valencia and Spanish types with considerable variation in compatibility among the rhizobia strains that nodulate groundnut (Yakubu *et al*., 2010). Although researchers (Yusuf *et al*.; 2008 and Hardison *et al*.; 1991) have shown that, specific genotypes of legumes could make a net positive contribution to soil N at very low N starter (20-30 kg/ha N) while others required external N addition for increased BNF and yield. Several new genotypes of groundnut have been developed and are almost at the stage of being released. It is essential, therefore, to assess their BNF potentials in the soil. Similarly, there is a lack of information on the symbiotic N fixation of the genotypes under the prevailing N fertilizer regime. This research seeks to address this gap.

2.0. Materials and Methods

2.1. Site Description

The experiment was carried out on the research fields of International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) located in Bayero University Kano (latitude 11°58.550'N and longitude 008. 25.957'E) and Institute for Agricultural Research (I.A.R), Samaru, (Kaduna State on latitude 11°11'008'N and longitude 7°36'52.1'E) in the Sudan and Northern Guinea Savanna regions of Nigeria respectively. The Sudan and Northern Guinea Savannah regions of Nigeria are marked by a Mono-modal and Uni-modal rainfall patterns respectively with an average annual rainfall of 884mm in Kano state (Sudan Savannah) according to Murtala *et al.*, (2015); Tanko and Momale, (2013) cited in Shehu *et al*., (2015) and 1011±161mm in Samaru-Zaria (Northern Guinea Savannah) according to Oluwasemire and Alabi, (2004) concentrated almost entirely in the five months (May/June to September/October) of the cropping season.

2.2. Field Layout

The experimental areas of 542m^2 each were marked out from the fields and ridged into plot sizes, each measuring 3m by 4m; 1m was demarcated between plots and replications, respectively. Two seeds each of the groundnut genotypes were sown per hole by hand at a spacing of 10 cm by 75cm intra and inter-row spacing, respectively.

2.3. Treatments and Experimental Design

The treatments comprised of ten advanced lines, three improved and two local genotypes namely; ICG 4729, ICGV-IS 07823, ICGV-IS 07893, ICGV-IS 07908, ICGV-SM 07539, ICGV- SM 07599, ICGV-IS 09926, ICGV-IS 09932, ICGV-IS 09992, ICGV-IS 09994, ICGV-IS 09926, SAMNUT-21, SAMNUT-22, SAMNUT-25, KAMPALA and KWANKWASO. The experiment was laid out in a Randomized Complete Block Design (RCBD) with 15 treatments from early to late maturity period and 3 replications. NPK (100kg/ha) and SSP (200kg/ha) fertilizers were applied during sowing, and weeding was done with a hoe. A maize crop (SAMMAZ 29) obtained from the IITA Kano office was used as a reference crop for estimating biological nitrogen fixation (BNF) using the N difference method.

2.4. Soil Analysis

Initial soil sampling was done at plough depth (0 -20cm) for Physico-chemical analysis of the inherent nutrient status. A total of 15 soil samples collected using an auger were bulked to form a composite sample from which a subsample was taken for the analysis in each of the two locations. The samples were shade-dried, lumps crushed using pestle and mortar, and organic residues were removed. The soil samples were then sieved using a 2 mm mesh sieve, sub-samples were collected and routinely analyzed according to standard laboratory procedures.

2.5. Plant Analysis

Plant samples were collected in both locations at 50% flowering for nodule assessment and used to estimate BNF by determining the concentration of N in the plant tissue. Destructive sampling was carried out on four plants, two taken from each of the border rows. The plant samples were separated into shoot and roots, washed with clean water to remove adhering soils, placed in envelopes, and oven-dried at 65°C for 72 hours to constant weight. The oven-dried samples (shoots and roots residues) of the genotypes and the reference crop were then ground with a Willey mill and subjected to chemical analysis to determine the concentrations of N on a dry weight basis (Marr and Cresser, 1983 cited in Yakubu et al., 2010).

Estimation of Biological Nitrogen Fixation

BNF was estimated using the N-difference method described by Danso, (1995) and

Mary *et al.,* (1995) as cited in Yakubu *et al*., (2010), Muhammad *et al*., (2010) as stated below;

BNF = Nitrogen Yield (legumes) – Nitrogen Yield (Reference Crop)

Where;

Nitrogen Yield (Uptake) in plants = Dry matter weight X %N conc. in plants

Percent N derived from the atmosphere according to Yakubu et al., (2010) and Agah (2016) was estimated as the ratio of total N-fixed to the total plant N uptake computed as;

$$\textbf{\%Ndfa} = \frac{\textbf{BNF}}{\textbf{Nitrogen Yield (Legumes)}} \times 100$$

Statistical Analysis

The data collected were subjected to statistical analysis using Genstat discovery edition (2011). The analysis of variance method was done to ascertain yield differences among the genotypes. The genotypic N-fixation differences were compared and means separated using student Newman's keuls at 5 % and 1% probability level (Gomez and Gomez, 1984) to report the most promising genotypes among the groundnut genotypes.

3.0. Results and Discussion

3.1. Soil fertility

The results (Table 1) of the particle size distributions of the soils at the trial sites indicated that the soil in BUK research farm had relatively higher percentage sand composition with lower silt content but slightly higher clay content with a textural class; Sandy Clay Loam while the soil in IAR research farm had a lower percentage sand composition compared to BUK site and higher silt content than clay with a textural class; Loam. This result is in agreement with the work done by Shehu *et al.* (2015); Jones and Wild (1975) cited in Mulima *et al.* (2015) who reported sufficient variation in textural classes of most savanna soils from Sandy loam to Sandy Clay Loam and with low water holding capacity.

The alkaline and neutral soil pH (Table 1), as indicated by the result in BUK and IAR farms respectively, could be attributed to high levels of soluble soil calcium (Mustapha and Nnalee, 2007; Voncir *et al*., 2008). Samndi and Jibrin (2012) reported a slight decrease with soil depth and attributed it to the decrease in organic matter (low organic carbon), basic cation uptake, and leaching.

Table 1: Soil characteristics of the trial sites

Soil properties	BUK	IAR
Sand (gkg^{-1})	644.8	444.8
Silt (gkg^{-1})	103.6	343.6
Clay (gkg^{-1})	251.6	211.6
Textural class	Sandy clay loam	Loam
pH (H_2O) 1:2:5	7.400	6.700
pH (Kcl) 1:2:5	6.200	5.700
Ec (dSm^{-1})	0.043	0.022
Organic Carbon (gkg^{-1})	2.790	4.990
Total Nitrogen (gkg^{-1})	0.700	1.400
Available P (gkg^{-1})	8.940	9.430
Exchangeable Na^{+} ($cmolkg^{-1}$)	0.200	0.190
Exchangeable Ca^{2+} ($cmolkg^{-1}$)	1.500	2.750
Exchangeable Mg^{2+} ($cmolkg^{-1}$)	0.333	0.167
Exchangeable K^{+} ($cmolkg^{-1}$)	0.170	0.160
Exchangeable Acidity ($cmolkg^{-1}$)	0.170	0.330
ECEC ($cmolkg^{-1}$)	2.373	3.597
Extractable micronutrient (mg/kg)		
Mn	8.25	9.75
Fe	4.16	6.76

Key: N- Nitrogen, P- Phosphorus, K- Potassium, Na – Sodium, ECEC = Effective Cation Exchange Capacity Mn – Manganese, Fe – Iron.

The extractable micronutrients (Fe and Mn) were high in the soils at the IAR farm. Similarly, Mn was observed to be high, while Fe, on the other hand, was low in BUK farm. The low content of Fe in BUK farm could have been responsible for the reduction in specific rates of nitrogenase activity, which according to O'Hara *et al*., 1988 cited in Weria et *al*., 2013), has been observed to limit nodule function in peanut nodules.

3.2. Nodule number and weight

All the groundnut genotypes nodulated with indigenous rhizobia across the locations, but the number of nodules was statistically similar ($p>0.05$); however, variations existed among the genotypes. The number of nodules $plant^{-1}$ observed in this study fall within the range of 4.17 - 88.67 for groundnut genotypes in the Sudan Savannah region of Nigeria as reported by Yakubu et al., (2010) and 51 – 140 for groundnut genotypes investigated in Northern Guinea Savannah of Nigeria by Agah, (2016). According to Yusuf et al., (2008) and Subba, (2007), the number of nodules formed by promiscuous legume genotypes depends on the prevailing environmental conditions and the population of indigenous rhizobia during the process of nodulation. Low nodule count, particularly in BUK experimental site, could largely be attributed to low soil moisture, high soil temperatures, and pH (>6.2) even in the presence of a high number of indigenous rhizobia as reported by Yusuf *et al.,* (2008) and Zahran (1999). Also, the lack of significance ($p>0.05$) and low nodulation count (less than 100) across the locations could be attributed to low soil fertility and high percentage of ineffective rhizobia as well as lack of competitiveness and compatibility of the indigenous rhizobia population with the cultivated legumes as it has been reported by various authors to inhibit nodule initiation and formation (Badawi *et al*., 2011; Nkot *et al*., 2011).

On the other hand, the results on nodule dry weight **(**Table 2, Fig 1**)** differed significantly ($p<0.05$) among the genotypes and across the locations, however, the interaction effect was not significant ($p>0.05$). ICGV-IS 09926 recorded the highest nodule mass among all the genotypes. This result corroborates the work of Okogun *et al*., (2005) and Agah (2016) who both reported a significant difference concerning nodule biomass among some legume varieties in Sudan and Northern Guinea Savanna but contrast to the findings of Yusuf et al., (2008) who reported a non-

significance difference among legume varieties investigated in the Northern Guinea Savanna.

3.3. Effect of Genotype and Location on Haulm Yield

The result (Table 2) showed a highly significant difference ($p<0.01$) among the genotypes and their interaction with KAMPALA, consistently recording higher haulm yield (HY) among the genotypes. The high haulm yield recorded in ICGV-SM 07539, and ICGV-IS 09992 could be due to their Valencia and Virginia branching habits. The differences observed in haulm yield among the groundnut genotypes in this study are occasioned by the fact that varietal differences in haulm yield per hectare have earlier been reported in two groundnut genotypes in India (Patel *et al.*, 2005).

3.4. Nitrogen fixation and %Ndfa by groundnut genotypes

The amount of N fixed by groundnut genotypes ranged from 5.30kg/ha to 94.73kg/ha in BUK location (Sudan Savanna) with a mean nitrogen fixation value of 44.10kg/ha while in IAR location (Northern Guinea Savanna), the genotypes fixed between 5.23kg/ha to 140.27kg/ha with a mean BNF value of 58.30kg/ha (Fig. 2). The mean BNF value of 58.30kg/ha from IAR location reported in this research was more significant than the values of 20.71kg/ha N and 11.24 kg/ha reported by Agah (2016) and 40.9 kg/ha reported by Okito *et al*. (2004) but less than 96 kg/ha N reported by Burris, (1994). However, the amount of N fixed in this research falls within the range of 17-200Kg/ha N for groundnut as reported by peoples *et al*., (2008) and peoples and Craswell (1992), but disagrees with Dakora (1997) who reported 134kgN/ha as the highest BNF value estimated to be fixed by legume crops contrary to the value of 140.27kg/ha recorded in this study.

The highly significant difference observed in this research is in corroboration with the results of Patterson and La Rue (1983) as well as Hardarson *et al*. (1984) who previously reported a significant variation in N_2 fixation between various groups of soybean genotypes, but attributed the variation to the host plant characteristic which is controlled principally by the nitrogenase enzyme. Also, the wide variations observed in the amount of N fixed by different groundnut genotypes depends on N fixing capability of the genotypes, the native fertility of the soil (Sanginga *et al*., 1997), the indigenous rhizobia spp. and the method of crop management (Okogun *et al*., 2005).

Table 2: Nodulation, BNF and Yield characteristics

Genotype	**NN Plant^{-1}**	**NDW (mgplnt^{-1})**	**BNF (Kg/ha)**	**Ndfa (%)**	**HY (Kg/ha)**
ICG 4729	62.70	0.605b	21.51ef	46.02de	1304cd
ICGV-IS 07823	104.68	1.208ab	21.67ef	51.66b-e	1367cd
ICGV-IS 07893	80.97	1.028ab	81.21ab	78.74ab	1705bcd
ICGV-IS 07908	79.42	1.160ab	35.60c-f	63.79a-e	1242d
ICGV-IS 09926	86.75	2.068a	74.92abc	78.59ab	1828bcd
ICGV-IS 09932	79.58	1.040ab	86.57a	78.66ab	1356cd
ICGV-IS 09992	69.96	1.098ab	52.42a-f	66.25a-e	1733bcd
ICGV-IS 09994	98.83	0.968ab	32.49c-f	42.84e	2638ab
ICGV-SM 07539	92.67	1.133ab	56.33a-f	72.30a-d	2105abcd
ICGV-SM 07599	54.42	1.063ab	16.77f	38.79e	1677bcd
KAMPALA	129.90	1.812ab	62.54a-e	76.21abc	2982a
KWANKWASO	52.33	0.795ab	38.96b-f	48.34cde	2276abc
SAMNUT-21	81.74	1.057ab	28.74def	48.86cde	1467cd
SAMNUT-22	96.17	1.642ab	90.92a	81.73a	1546cd
SAMNUT-25	78.08	0.945ab	67.35a-d	75.45abc	1866bcd
p-Value	0.082	0.039	<.001	<.001	<.001
SE±	15.34	0.2740	5.87		
Location					
BUK	63.99b	1.448a	44.1	70.6	2663
IAR	102.43a	0.902b	58.3	55.9	949
p-Value	0.014	0.050	0.065	0.024	0.003
SE±	3.29	0.0896	4.65		
Interaction					
Genotype * Location					
p-Value	0.205	0.142	<.001	<.001	<.001
SE±	21.21	0.3849	21.06		

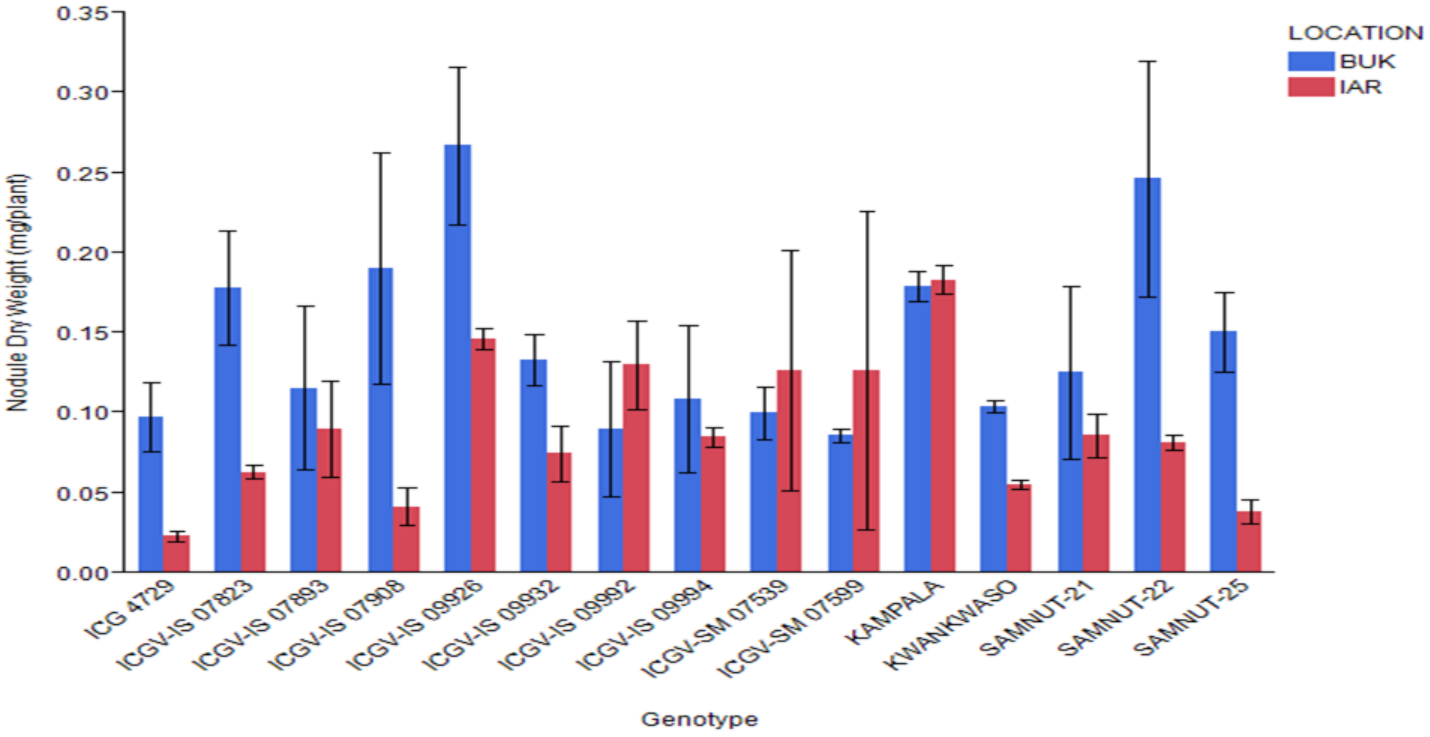


Fig. 1: Effect of Genotype and Location on Nodule Dry Weight (mg plant^{-1})

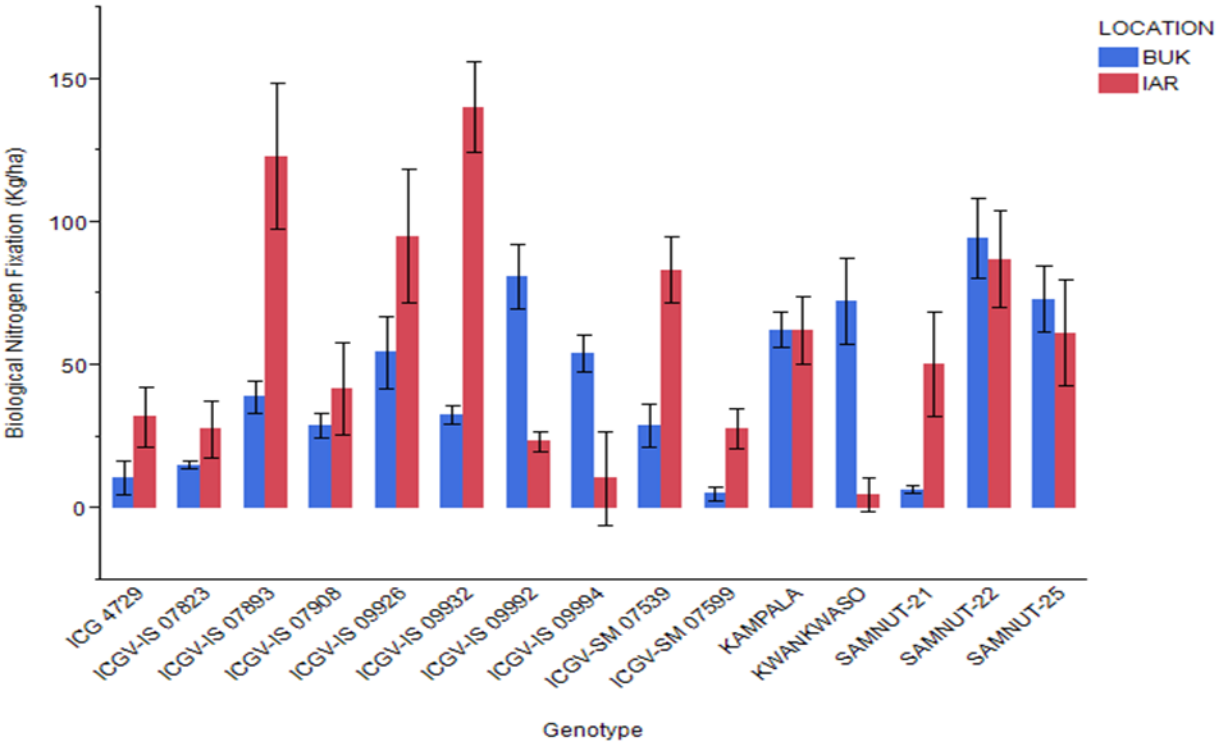


Fig. 2: Effect of Genotype and Location on Biological Nitrogen Fixation

The grain legumes showed wide variation across the locations in their proportion of plant N derived from the atmosphere. The results (Table 2) showed that the genotypes in BUK location had significantly higher %Ndfa than those from the IAR location. The mean values of the proportion of Ndfa in BUK and IAR locations were higher than 52.4% recorded by Okito *et al*. (2004) but fell within the range of 28-81% for groundnut as reported by Ganry (1992) and Badiane and Gueye (1992) in the Savanna regions of West Africa. The significant contribution of grain legumes to soil fertility lies in their ability to fix atmospheric nitrogen. Hence SAMNUT-22, ICGV –IS 09932, ICGV –IS 07893, ICGV –IS 09992, ICGV –IS 09926, SAMNUT-25 and ICGV –SM 07539 that derived high proportion of their N from fixation will be highly desirable and suitable especially in tropical soils; thus corroborating

the work of Yusuf *et al*., (2008).

Effect of Genotype and Location as influenced by BNF and pod yield of Groundnut

The result (Table 3) indicated that ICGV-IS 09932, ICGV-IS 07893, SAMNUT-22, ICGV-IS 09926, and SAMNUT-25, which fixed high amount of N also produced high pod yield across the locations, thus implying that the above genotypes are high fixers and high yielders, unlike KAMPALA and KWANKWASO. On the other hand, ICGV-IS 07823, which recorded the highest pod yield across the locations, fixed relatively moderate amounts of N, which was higher than the local genotypes in the IAR plot only. ICGV-IS 09932, ICGV-IS 07823, and ICGV-IS 09992 were the best genotypes with high N fixation and pod yield compared to the local varieties. Therefore, ICGV-IS 07893, ICGV-IS 09992, ICGV-IS 09994, ICGV-IS 09932, ICGV-IS 09926, SAMNUT-25 and SAMNUT-22 were consistent in high N fixation and pod yield across the locations, thus regarded as the best groundnut genotypes.

Table 2: Nodulation, BNF and Yield characteristics

GENOTYPE	**BUK**		**IAR**	
	BNF (kg/ha)	Pod Yield (kg/ha)	BNF (kg/ha)	Pod Yield (kg/ha)
ICG 4729	10.81fg	1010efg	32.21c-g	1976a-f
ICGV-IS 07823	15.36efg	1437c-g	27.98c-g	1318d-g
ICGV-IS 07893	39.16c-g	1882a-g	123.25ab	2888a
ICGV-IS 07908	29.03c-g	1613a-f	42.17c-g	1737a-g
ICGV-IS 09926	54.63b-g	1455c-g	95.22abc	2290a-e
ICGV-IS 09932	32.86c-g	2392a-d	140.27a	1563b-g
ICGV-IS 09992	81.19a-f	1769a-g	23.64d-g	2887a
ICGV-IS 09994	54.32b-g	2779ab	10.66g	1725a-g
ICGV-SM 07539	29.17c-g	1377c-g	83.49a-e	624g
ICGV-SM 07599	5.30g	1151d-g	28.23c-g	805fg
KAMPALA	62.61b-g	1159d-g	62.48bc-g	1612bc-g
KWANKWASO	72.70a-g	1492c-g	5.23g	2666abc
SAMNUT-21	6.80g	848fg	50.68c-g	1231d-g
SAMNUT-22	94.73abc	1869a-g	87.12a-d	1233d-g
SAMNUT-25	73.25a-g	1767a-g	61.46bc-g	1516b-g

4.0. Conclusion

The groundnut genotypes used in this study could be grouped into three categories based on the amount of biological nitrogen fixation and pod yield. ICGV-IS 07893, ICGV-IS 09992, ICGV-IS 09994, ICGV-IS 09926, SAMNUT-22, and SAMNUT-25 were high fixing and high yielding; ICGV-IS 09932 and KAMPALA were categorized as high fixing but low yielding while ICGV-SM 07599 and SAMNUT-21 were categorized as low fixing and low yielding.

On a site-specific basis, research findings in the BUK plot showed that SAMNUT-22, SAMNUT-25, and ICGV-IS 09992 were high fixing and yielding genotypes, whereas ICGV-IS 07893 and ICGV-IS 09932 were low fixing but high yielding. On the other hand, the findings in the IAR plot showed that ICGV-IS 07893 and ICGV-IS 09926 were high fixing and yielding, ICGV-SM 07539, and SAMNUT-22 were high fixing but low yielding.

The study also showed that the application of NPK and SSP fertilizers as a starter dose was adequate to enhance the ability of the newly developed genotypes in yield and fixing atmospheric N.

5.0. Recommendation

Experimental results demonstrated that SAMNUT-22 and ICGV-IS 09932 could be integrated into the cereal-based cropping systems in the Sudan and Northern Guinea Savannah regions of Nigeria, respectively, to improve the soil N status for improved crop yield.

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