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Genotypic Effect of Groundnut on Nodulation, N Fixation and N Balance in The Two Savannahs of Nigeria

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ABSTRACT

Identification of high N-fixing groundnut genotypes and integrating them into the prevailing cereal-based cropping systems can reduce the need for nitrogen (N) fertilizers, thus minimizing their high cost and associated environmental consequences. This study was conducted to estimate the amount of symbiotically fixed N by groundnut genotypes and its contribution to soil N and yield of groundnut. Trials were carried out during the 2015 rainy season at Bayero University Kano (BUK) Agricultural Research Farm and the research farm of the Institute for Agricultural Research (IAR), Samaru-Zaria. The treatments comprised of 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 KWANKWASO) arranged in a randomized complete block design in three replicates. Data on nodulation, nitrogen fixation and N balance were collected. The results of the study showed that ICGV-IS 09932 significantly fixed the highest amount of N at IAR location while the lowest was obtained in KWANKWASO. On the other hand, SAMNUT-22 fixed the highest N among the genotypes while ICGV- SM 07539 fixed the lowest N in BUK location. Similarly, SAMNUT-22 which fixed moderate to high amount of N but low to moderate NHI was the best genotype that imparted positively to soil N balance among the genotypes when only the grains were removed across the locations. On the other hand, SAMNUT-21 which fixed low to high amount of N to the soil but accumulated low N in its grains was the best genotype that left fairly close to zero nitrogen balance, even though imparted negatively on soil N balance when both grains and haulms were removed.

1.0. Introduction

Essentially, Nitrogen (N) is one of the major determinants of yield in crop productivity. The Sudan and Northern Guinea Savanna soils of Nigeria are inherently low in Nitrogen fertility (Rayar, 2000; FMNAR, 1990) especially when cropped continuously without restoring the exported nutrients in harvested produce. About 100 million tons of N fertilizers according to Unkovich et al., (2008) and Graham, (2004) are fixed annually in a bid to meet the N requirement of the soils in these fragile ecosystems (tropics) through the Haber Bosch process. However, this output is far less than the contribution of N acquired by grain legumes such as groundnut (Arachis hypogaea L.) through Biological Nitrogen Fixation (BNF). Soil scientists and agronomists generally consider groundnut as a safe, cheap and renewable N source for crops not capable of fixing N in the prevailing cereal-based cropping systems and therefore useful in soil fertility enhancement and environmental sustainability (Vance, 2001).

Previous researches have shown that groundnut can fix up to 300kgN/ha symbiotically per year (Hungria et al. 2006) and still relies less on soil N reserve in agricultural sys-

tems (Liu et al., 2011). Despite this, its N fixing potential may be constrained at very low soil N until nodules begin to function, in addition to unavailability of effective strains of rhizobia in the soil, nutrient deficiencies, unfavourable temperatures, and inadequate soil moisture. Hence complementing the soil N status with a starter N dose of 20-30 or even 40kgN/ha recommended for Nigerian Savannahs is justifiable for increased BNF and yield. However, resource-poor farmers in the agro-ecological regions have not fully exploited the enormous benefits of N-fixation by groundnut due principally to their inability to comply with the above recommendations because of the exorbitant cost of mineral N fertilizers and the use of genotypes limited in their symbiotic N fixing potentials (Graham and Vance, 2003; Mariangela and Vargas, 2000). This may subsequently affect soil N balance and crop yields in a way that groundnut and cereal production may no longer be sustained (Agah et al., 2016).

Studies on symbiotic N fixation by grain legumes have been restricted to other legumes and few groundnut genotypes in the Northern Guinea Savannah of Nigeria thus creating a huge gap on N fixation and yield potentials of many of the improved varieties and newly developed groundnut genotypes in the Sudan and Northern Guinea Savannahs of Nigeria. Similarly, no information is available on the N balance of the popular groundnut genotypes in the Sudan and Northern Guinea Savannahs of Nigeria. The study is therefore designed to evaluate nodulation, N fixation and N balance of these groundnut genotypes in the Sudan and Northern Guinea Savannahs of Nigeria.

2.0. Materials and Methods

2.1. Site Description

The experiment was conducted on the experimental fields of International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) located in Bayero University Kano (latitude 11o58.550'N and longitude 008. 25.957'E) and Institute for Agricultural Research (I.A.R), Samaru, (Kaduna State on latitude 11o11'008'N and longitude 7o36'52.1'E) in the Sudan and Northern Guinea Savanna regions of Nigeria respectively. The Sudan and Northern Guinea Savannah regions of Nigeria are characterized 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 542m2 each were marked out from the field 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. Treatment 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 a depth of 0 -20cm for Physico-chemical analysis of the inherent nutrient status. An auger was used to collect a total of 15 soil samples bulked to form a composite sample from which a subsample was taken for the analysis in each of the two locations.

The collected soil samples were air-dried under shade. Soil lumps were crushed using pestle and mortar and organic residues were separated. The soil samples were then sieved using a 2 mm mesh sieve, sub-samples were collected and routinely analyzed according to standard laboratory procedures (IITA, 1989).

2.5. Plant Analysis

Plant samples were collected in both locations at 50% flowering for nodule assessment and used to determine 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 65oC 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). Total nitrogen and P were determined by the Macro-Kjeldahl and Vanado-molybdate yellow method described by Black (1965) and Olsen and Sommers (1982) respectively. Furthermore, ten representative nodules were randomly selected from each genotype, dissected using a sharp razor blade to determine their effectiveness. Nodules with pink colours were classified as effective whereas those with colours other than pink were considered ineffective. The sample size of ten nodules was taken to represent 10% of the overall nodule number.

2.6. Estimation of Biological Nitrogen Fixation and Soil Nitrogen Balance

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) both referenced in Moji et al., (2020) 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

The net contribution of Nitrogen fixation to the N balance of the soil was calculated by the method described by Peoples and Craswell, (1992) as cited in Moji et al., (2020); computed thus:

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

NHI is simply the amount of nitrogen in grain (seed) as a proportion of total above ground plant nitrogen. It is illustrated below (Muhammad *et al*., 2010; Agah, 2016 cited in Moji *et al*., (2020));

$$NHI = \frac{Ng}{Nt} \times 100$$

Where; **NHI**= Nitrogen harvest index; **Ng**= Nitrogen in Grain (kg N ha^{-1}),

Nt= Total Nitrogen in plant (kg N ha^{-1}).

2.7. 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 Discussions

Soil fertility: The result of the chemical and physical properties of the soil at the sites is presented in Table 1. Calcium and Magnesium levels were generally low in both locations. The levels of exchangeable sodium and potassium were moderate across the locations. Values of Electrical Conductivity (EC) of the saturation extract were generally low, indicating that the soils are generally non-saline. The soil reaction was alkaline and neutral in BUK and IAR research farms respectively. The variation in the pH values across the study sites could probably be attributed to the differences in the soil type, vegetation and agricultural practices. The texture of the soils was Clay Loam and Loam in BUK and IAR research farms respectively. The organic Carbon levels in the Sudan and NGS were very low and low based on the fertility classes for Northern Nigerian Savanna soils by Esu, (1991). The low levels of organic carbon could be attributed to continuous and intensive cropping without much addition/incorporation of organic matter in the form of manures and crop residues. Also, the high pH, particularly in the Sudan savannah, might have affected the accumulation and mineralization of organic matter (Rangasamy and Olsson, 1991). Total N levels in the Sudan and NGS were low and moderately low respectively. The low levels of N could be associated with the low soil organic matter levels of the soils in the experimental sites. The availability of N could also be reduced under high pH values when urea is the source of applied N because of the low activity of urease at high pH (Nitant and Bhumbla, 1974). Levels of available P were low in BUK and IAR trial sites. Therefore, response to phosphate fertilizers will be expected if heavy feeders are planted in these regions. 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 high levels of Mn and Fe are not surprising due to neutral pH reactions of the soils since Manganese and Fe deficiencies are unlikely to occur in acid to neutral soils. Generally, the properties of the soils at BUK and IAR farms were typical characteristics of Alfisols of Sudan and Northern Guinea Savannah as described for northern Nigerian soils (Chude et al, 2012; FAO, 2001).

The total annual rainfall recorded was far higher in IAR (1363mm) than in BUK (749 mm). On the other hand, average minimum temperatures of 23oC and 24oC and maximum temperatures of

37oC and 40oC respectively were observed in IAR and BUK locations.

3.1. Nodule number and weight at BUK and IAR research farms

The analysis of variance revealed that 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 falls within the range of 4.17 - 88.67 for groundnut genotypes in North-Eastern Nigeria (Sudan Savannah) 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 result on nodule dry weight (Table 2., Fig 3) differed significantly ($p<0.05$) among the genotypes and across the locations with BUK location recording a significantly higher mean nodule dry weight of 1.448mg over IAR location (0.902mg), however, the interaction effect was not significant ($p>0.05$). ICGV-IS 09926 recorded the highest nodule mass of 2.068mg /plant 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 the Sudan and Northern Guinea Savanna but a contrast to the findings of Yusuf et al., (2008) who reported a non-significance difference among legume varieties investigated in the Northern Guinea Savanna. Additionally, the higher nodule weight observed in ICGV-IS 09926, SAMNUT-22 and ICGV-SM 07539 could be attributed to the higher percentage of effective nodules and largely to the inherent morphological differences existing among groundnut genotypes according to Okito et al., (2004).

3.2. Nitrogen fixation by groundnut genotype in BUK and IAR sites

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 result of the analysis of variance showed a highly significant difference ($p<0.01$) among the main effect of the treatments with SAMNUT – 22 fixing the highest amount of nitrogen across the locations though statistically similar to ICGV-IS 09932.

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. 4). Okito et al. (2004) in his research reported a mean BNF value of 40.9 kg/ha for groundnut, a value which was less than the estimated value of 96 kg/ha N by Burris, (1994); both of which were greater than the mean values of 20.71kg/ha N and 11.24 kg/ha reported by Agah (2016) in 2011and 2012 experimental work respectively in the Northern Guinea Savanna. The mean BNF value of 58.30kg/ha from IAR location reported in this research was greater 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 the amount of N2 fixed by the groundnut genotypes 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 N2 fixation between various groups of soybean genotypes, but attributed the variation to the host plant characteristic which is controlled principally by the nitrogenase enzyme that is reserved only for prokaryotes that are responsible for BNF. 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). Aside from some physiological processes that influence BNF in groundnut genotypes, diverse environmental conditions act as limiting factors to the growth and activity of the nitrogen-fixing plants. Unlike in most soil-plant systems, the principle of limiting factor is equally at play in this regard. Therefore, a competitive and persistent rhizobia strain is not expected to express its full capacity for nitrogen fixation if limiting factors (e.g., salinity, unfavourable pH, nutrient deficiency, mineral toxicity, temperature extremes, insufficient or excessive soil moisture, inadequate photosynthesis, plant diseases, and grazing) impose limitations on the vigor of the host plant.

Previous researches have shown that volatilization losses double from 10 to 20% with soil pH increasing from 6.5 to 7.5. This implies that the starter dose of fertilizer applied could largely have been lost through volatilization considering the higher temperature and soil pH values as well as inadequate soil moisture experienced, thus constraining nutrient availability, nodule initiation, formation and subsequently nitrogen fixation as opposed to IAR location with favourable soil pH, optimal temperature and adequate moisture.

3.3. Proportion of percent N Derived from Atmosphere (% Ndfa) per genotype

The grain legumes showed wide variation across the locations in their proportion of plant N derived from the atmosphere. The result of the analysis as presented in Fig. 5, showed that the genotypes in BUK location had signifi-

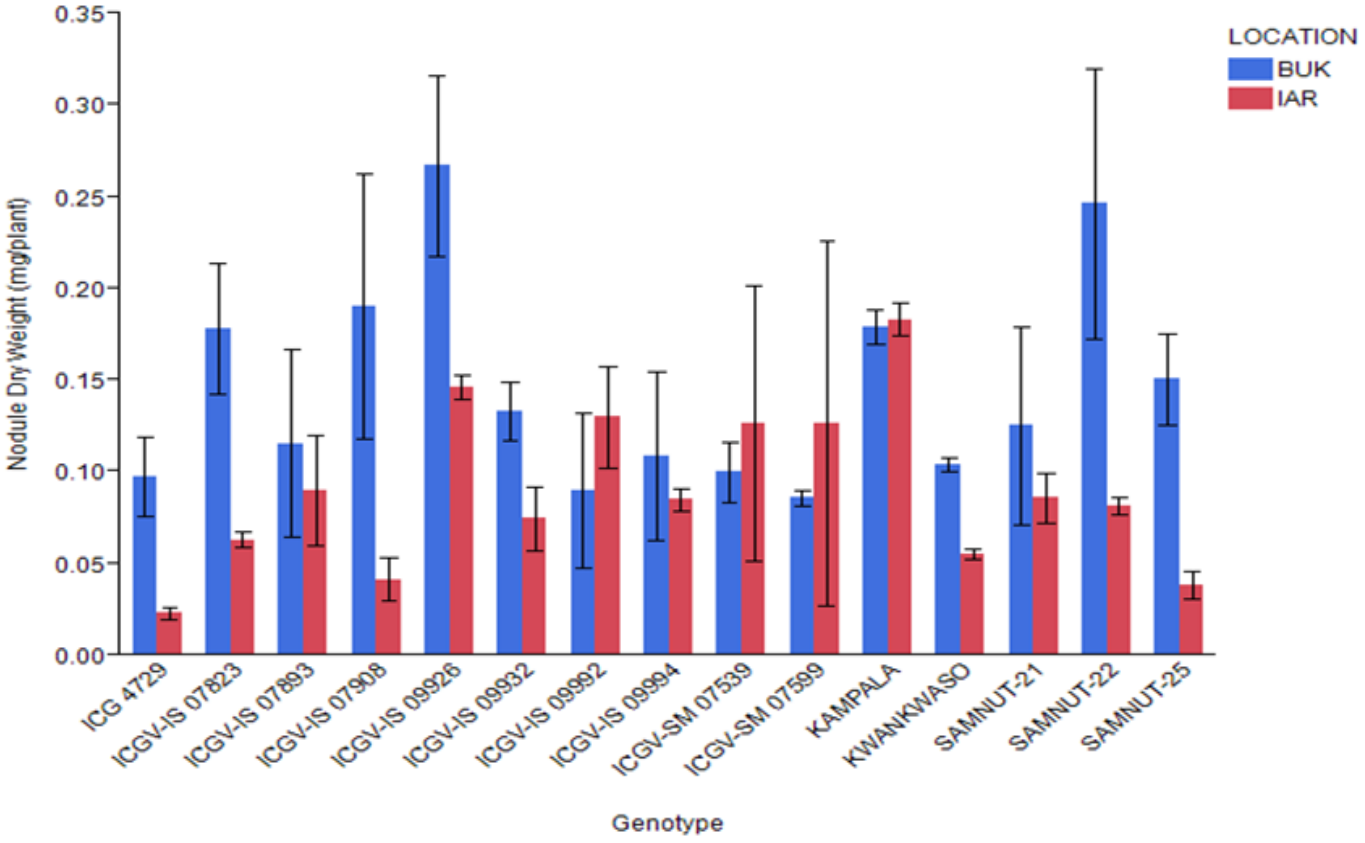


Fig. 1.3: Effect of Genotype and Location on Nodule Dry Weight (mg plant^{-1})

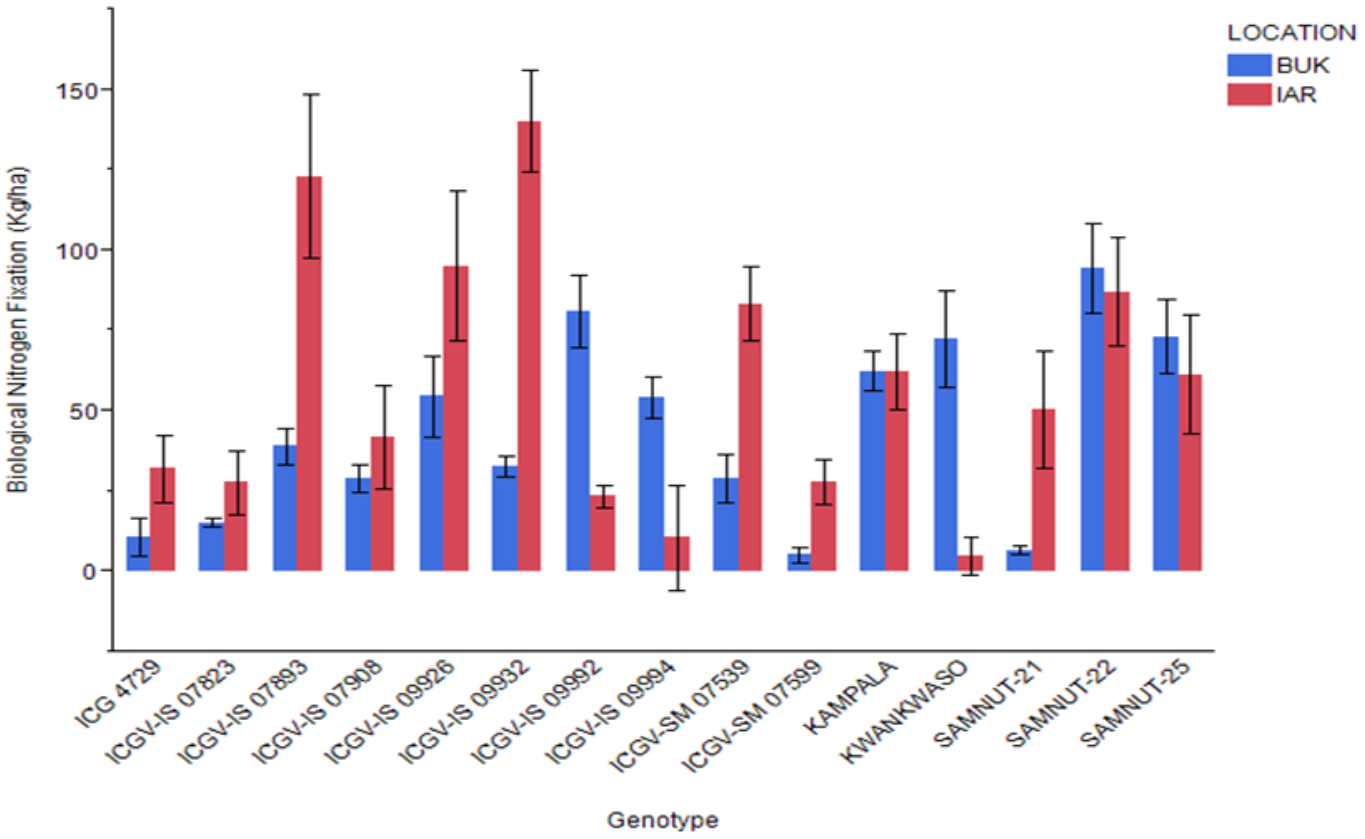


Fig. 1.4: Effect of Genotype and Location on Biological Nitrogen Fixation

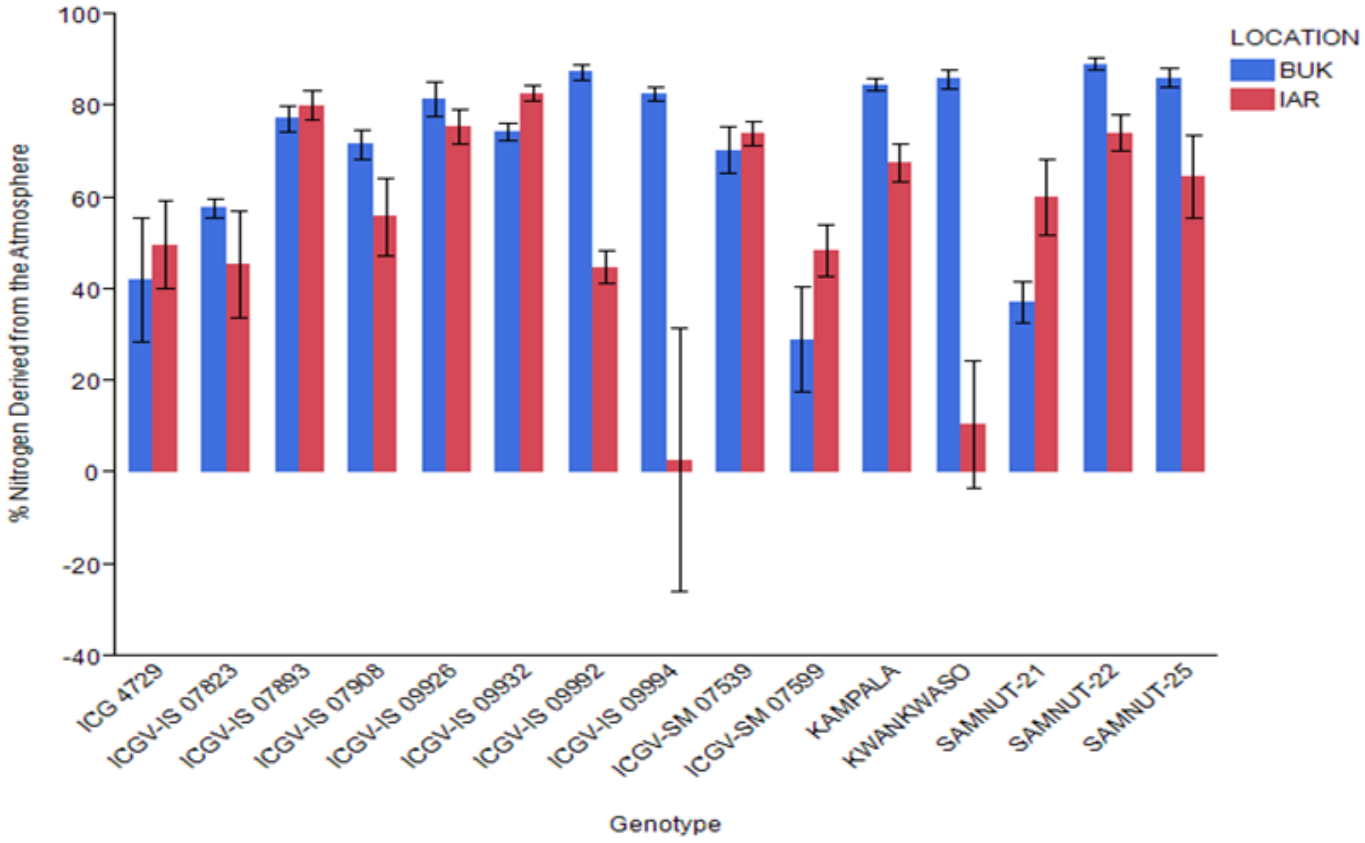


Fig. 5: Effect of Genotype and Location on percent N derived from the atmosphere

cantly higher %Ndfa than those from IAR location with an average %Ndfa of 70.6% and 55.9% in BUK and IAR experimental sites respectively. In the BUK location, SAMNUT-22 was the highest while ICGV –SM 07599 was the lowest. In IAR however, ICGV–IS 09932 recorded the highest %Ndfa while KWANKWASO and ICGV –IS 09994 recorded the lowest values respectively. The interaction was highly significant ($p<0.01$) with SAMNUT -22 recording consistently higher %Ndfa followed by ICGV –IS 07893, ICGV–IS 09932 and ICGV–IS 09926. The wide variation in %Ndfa is not peculiar to legume species only but also within legume genotypes as is evident in this study.

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 fall within the range of 28-81% for groundnut reported by Ganry (1992) and Badiane and Gueye (1992) in the moist Guinea Savanna of West Africa. The major contribution of grain legumes to soil fertility lies in their ability to fix atmospheric nitrogen, hence the genotype that derived a high proportion of their N from fixation will be highly desirable especially in soils with low N status (Yusuf, et al., 2008). The result in this study showed that most of the plant total N was derived from the atmosphere indicating that SAMNUT-22, ICGV –IS 09932, ICGV –IS 07893, ICGV –IS 09992, ICGV –IS 09926, SAMNUT-25 and ICGV –SM 07539 will be able to meet their N requirement for growth and development, hence highly suited for tropical soils; thus corroborating the work of Yusuf, et al., (2008).

3.4. Effect of Genotype and Location on Grain N Yield

The result obtained from BUK location (Fig.6) showed that the genotypes accumulated a range of 12.05kg/ha to 79.74kg/ha. ICGV –IS 09932 accumulated a significantly higher grain N than all other genotypes while ICGV –IS 09926 and ICGV –IS 09994 accumulated the lowest N in its grains. On the other hand, the genotypes in IAR location accumulated a range of 27.53kg/ha to 86.36kg/ha with ICGV –IS 09926 accumulating a significantly higher grain N among all the genotypes while ICGV –SM 07539 accumulated the lowest value in their grains. Consequently, ICGV –IS 09932 consistently accumulated significantly higher grain N yield across the locations while SAMNUT-21 accumulated the lowest N in its grains. This explains why most of the high N fixers with significantly high grain N are very poor in returning N to the soil (N balance). On the other hand, the genotypes that accumulated the lowest amount of N in their grains invariably turned out to be the most desirable genotypes with high potential for returning N to the soil.

Generally, the grain N yield in this study was lower than the range of 46-57kg/ha reported by Eaglesham et al., (1982), 51-61kg/ha reported by Sanginga et al., (2003) and Bala et al., (2003), however higher than the range of 30.8 to 32.80kg/ha reported by Yusuf et al., (2008) for cowpea. The differences could be attributed to differences in grain yields, as high yielding genotypes in most cases produce correspondingly high N content in their dry matter.

Therefore, ICGV –IS 09932, ICGV –IS 07908 and ICGV –IS 07893 were best genotypes by this study in translocating N to the grains than the local genotypes, KAMPALA and KWANKWASO.

3.5. Effect of Genotype and Location on Nitrogen Balance 1 (Only pods removed)

The importance of nitrogen harvest index (NHI) according to Yusuf et al., (2008) depends on how it affects nitrogen balance. The result obtained (Fig 8) showed that there was a highly significant difference ($p<0.01$) among the genotypes tested and their interaction in their contribution to soil nitrogen balance both in BUK and IAR locations. The mean N balance value was significantly higher in BUK location (14.1kg/ha) than in IAR (4.3kg/ha). The result from BUK location showed a range of -46.88 to 69.7 with SAMNUT-22 recording a significantly higher N.

3.6. Effect of Genotype and Location on Soil N balance 2 (Haulm and Pods removed)

Balance while ICGV-IS 09932 recorded the lowest when only pods were removed. On the other hand, a range of -40.90 to 59.22 was observed in the IAR location with ICGV-IS 09932 recording the highest N balance. Generally, higher values of N balance recorded by the above-listed genotypes when only pods were removed could be attributed to their high amount of BNF thus corroborating with the work of Giller (2001) who reported that, for a beneficial residual effect to occur, the amount of fixed nitrogen returned by the legume to the soil must be greater than the amount of N in the harvested grain.

The result (Fig. 9) showed that there is a highly significant difference ($p<0.01$) with a significantly higher mean negative balance of -40.1 kg/ha in BUK location over -81.2 kg/ha recorded in IAR location. The result of the genotypes with low NHIs was better concerning their contribution to nitrogen balance even though imparted negatively on soil nitrogen balance in IAR (Northern Guinea Savanna) and BUK (Sudan Savanna) Farms respectively.

4.0. Conclusion

In conclusion, the research findings on a site-specific basis showed that SAMNUT-22, SAMNUT-25 and ICGV-IS 09992 were high in N fixing and N balance, whereas ICGV-IS 07893 and ICG 4729 were low fixing but high in soil N balance in BUK plot. On the other hand, the findings in the IAR plot showed that ICGV-IS 09932, ICGV-IS 07893 and SAMNUT-22 were high in N fixing and N balance, ICGV-SM 07539 and were low in fixing but high in soil N balance. The study also showed that the application of NPK and SSP fertilizers as a starter dose was adequate to support groundnut production in the Nigerian savannas without depleting soil N. This rate also enhanced the ability of the newly developed genotypes in fixing atmospheric nitrogen.

The higher grain N and percentage NHI recorded in this study could be due to the ability of the groundnut genotypes to effectively translocate N to the grains than to the vegetative parts. It is on this account that the research findings recommend SAMNUT-22 for Sudan savannah and ICGV-IS 07893 for Northern Guinea Savanna regions of Nigeria concerning high N fixing and yielding as well as their contribution to soil N reserve.

5.0. Recommendation

Information obtained from this research work may be limited to the groundnut genotypes used in this study and the specific environmental condition in the locations in which the parameters were measured. Nevertheless, experimental results demonstrated that SAMNUT-22 and ICGV-IS 09932 should be integrated into the cereal-based cropping systems in the Sudan and Northern Guinea Savannah regions of Nigeria respectively.

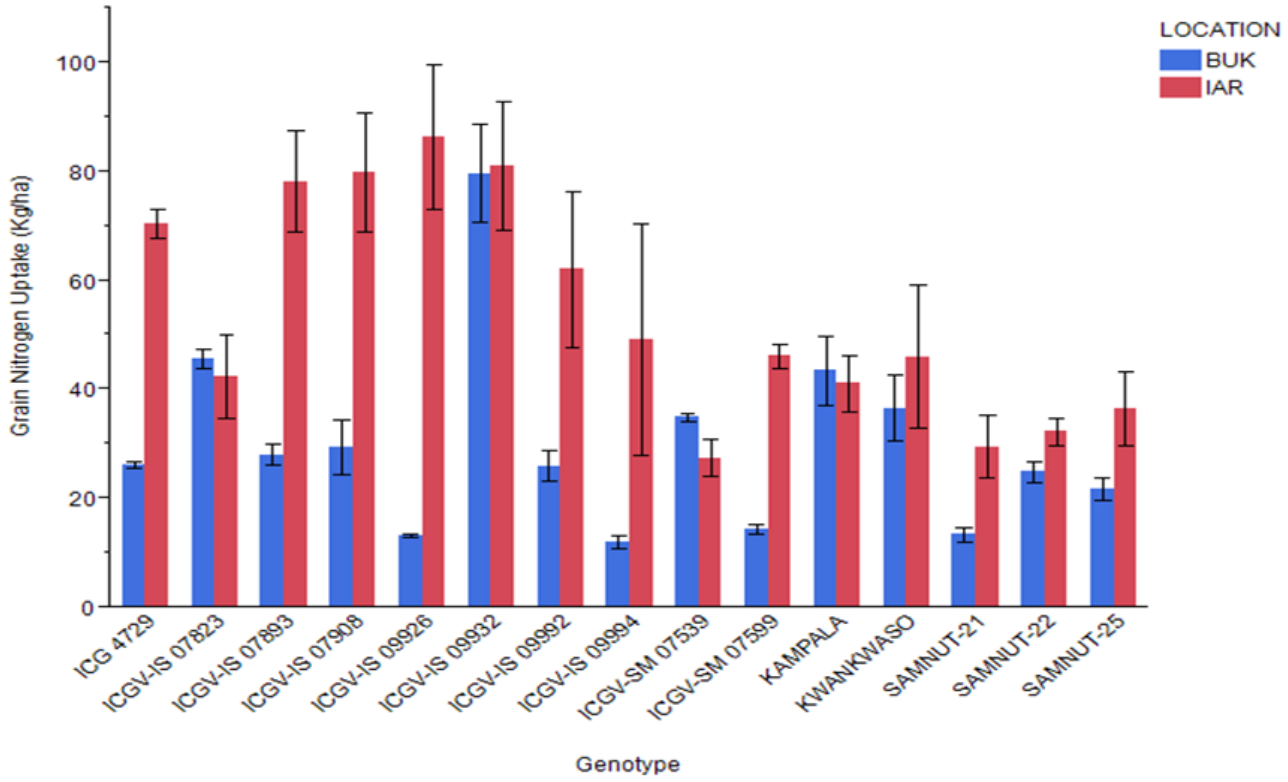


Fig. 6: Effect of Genotype and location on Grain N uptake (Kg/ha)

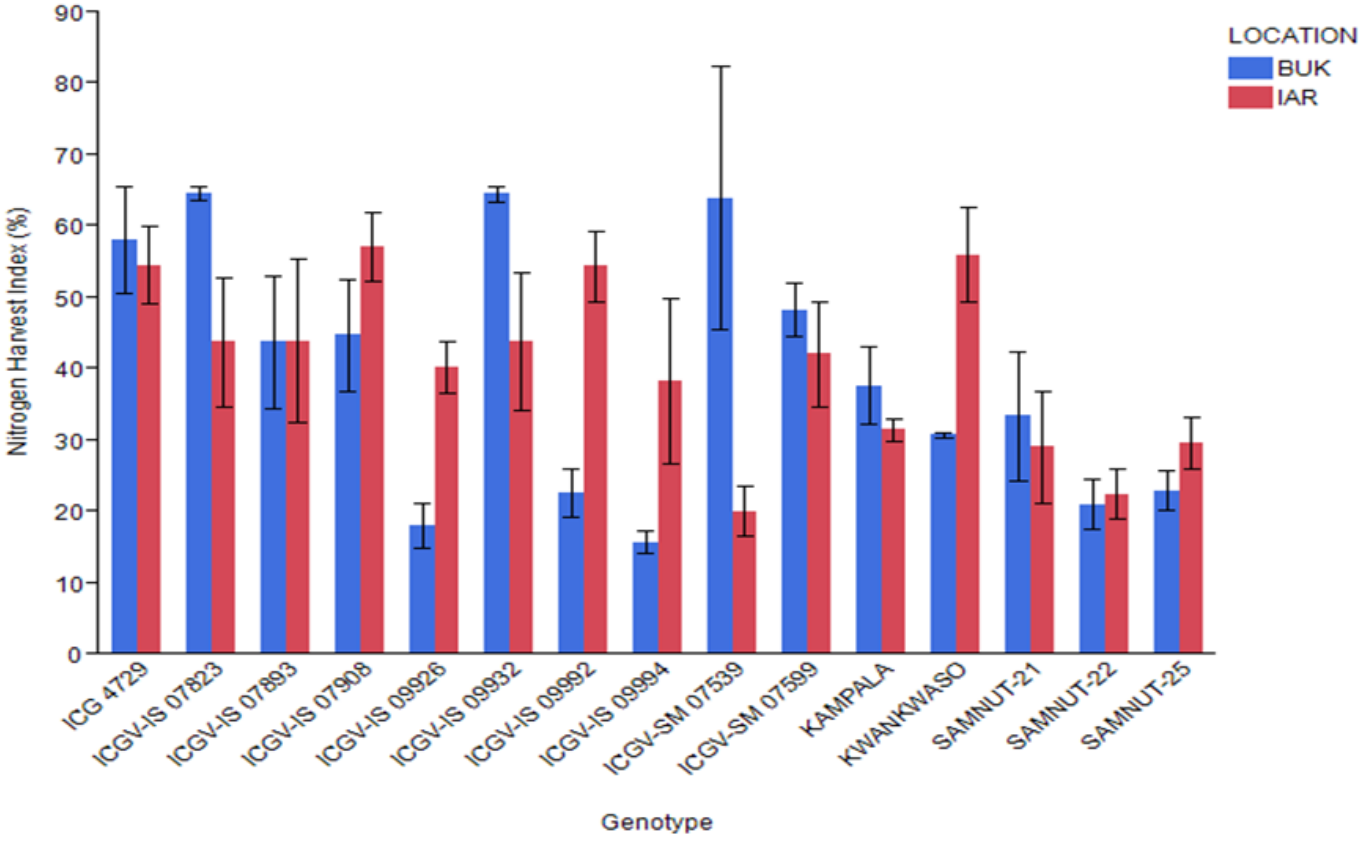


Fig. 7: Effect of Genotype and location on Nitrogen Harvest Index (%)

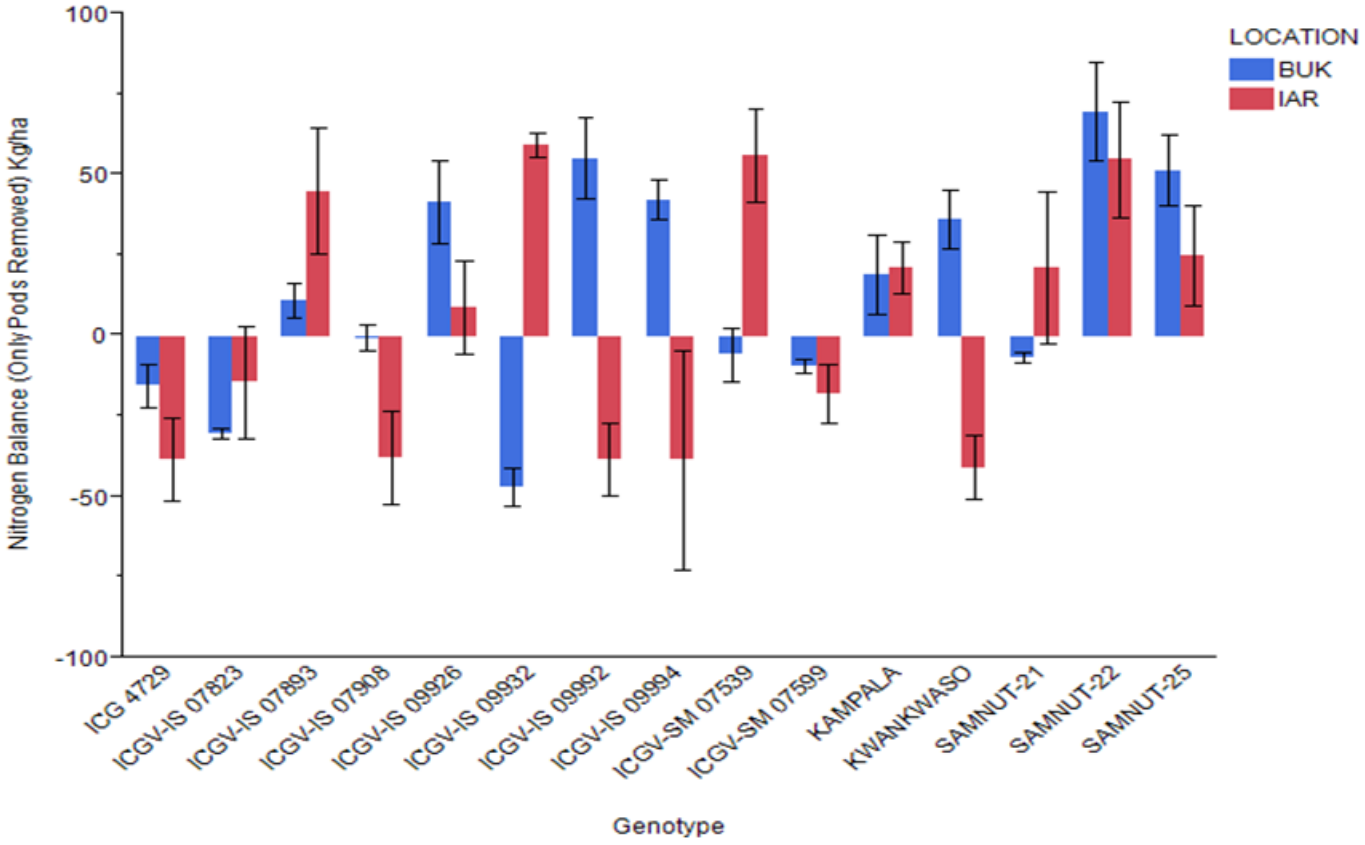


Fig. 8: Effect of Genotype and Location on Nitrogen balance 1 (Pods removed)

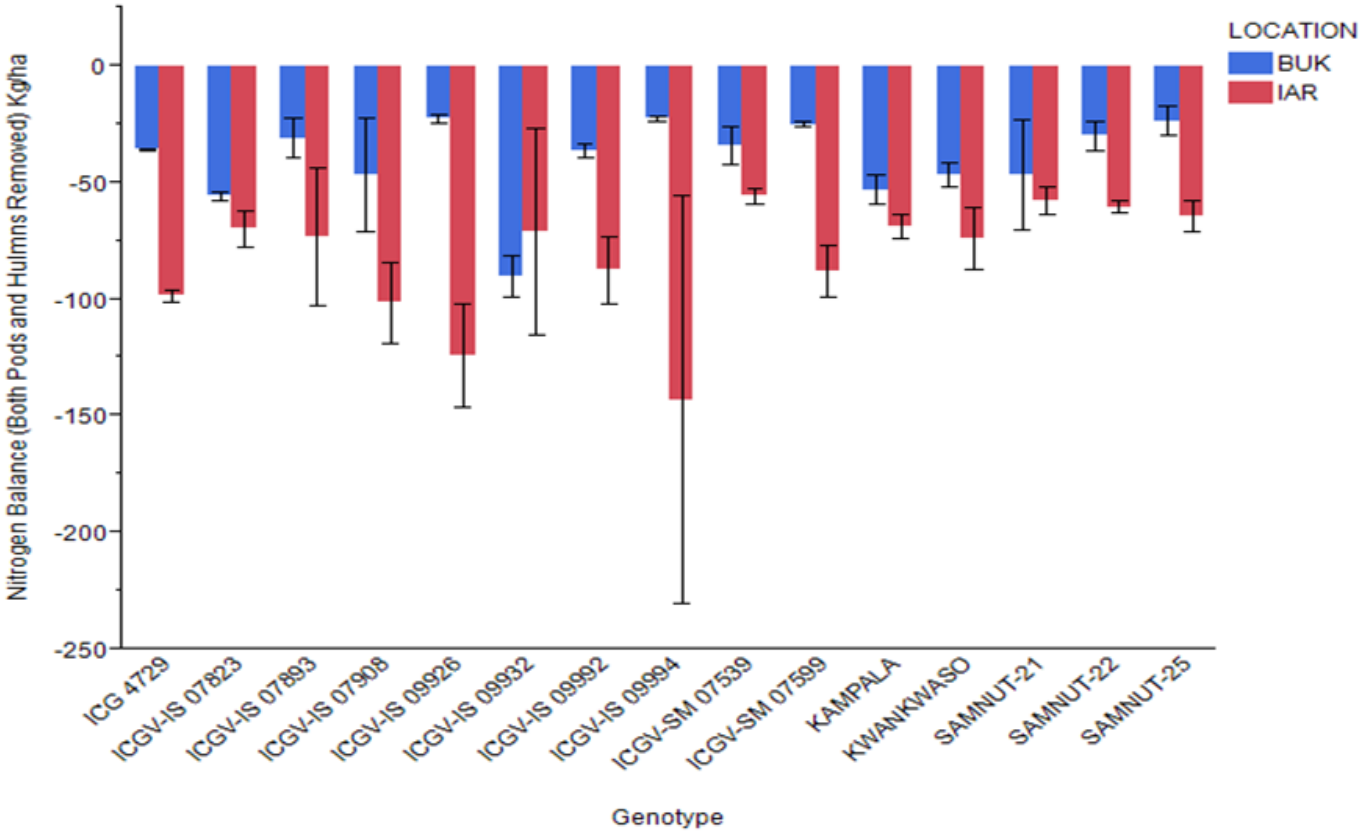


Fig. 9: Effect of Genotype and Location on Nitrogen Balance 2 (Both pods and Biomass removed)

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