# 

EFFECT OF VARIETAL DIFFERENCES AND SSP RATES ON THE GROWTH PERFORMANCE OF BAMBARA GROUNDNUT (*Vigna subterranea* L. Verd.) IN GOMBE STATE, NIGERIA

*ABSTRACT*

*Growth performance of certain important underutilized legume crops like Bambara groundnut can be affected by* varietal variations *as well as nutrient supply rates. As result, there* is a need for application of SSP to stimulate nodulation for optimum production since legumes require more phosphorus for nitrogen fixation and energy transformation to achieve maximum function. However, this information is still deficit in some parts of Nigeria as most farmers still grow Bambara-nut on poor soils without SSP, thus leading to poor performance of the crop. Therefore, the broad objective of the present study is to determine the real effect of varietal differences and SSP rates on the growth performance of Bambara groundnut (Vigna subterranea l. verd.) in Gombe State, Nigeria.

Field *trials were conducted at the Teaching and Research Farm of the Faculty of Agriculture, Federal University of Kashere and at Tabra in the Sudan Savanna Agroecological Zone of Nigeria. The treatments consisted of two Bambara groundnut (white and red) varieties and five SSP rates (0, 20, 40, 60 and 80kg/ha). The treatments were* factorially combined in a 2 x 5 and *laid out in a Randomized Complete Block Design (RCBD) with 3 replications. The plot size was 3 x 2m (6m2). Data collected on canopy height, number of leaves per plant, number of branches per plant, leaf area, number of days to 50% flowering, and number of nodules per plant, were subjected to Analysis of Variance, and mean separation done with LSD at 5% probability level. The result showed that at Kashere only, SSP Rate at 80kg/ha produced the significantly the highest value (6.63) over others, except SSP Rate at 60kg (6.08), whereas the control yielded the least number (4.10). Again, on days to 50% flowering, the red variety significantly (P<0.05) produced a higher values at both Tabra and Kashere with 45.40% and 45.38% respectively over the white variety. Meanwhile, at Keshere only, White variety significantly produced a higher value on canopy height (28.16cm) over red variety (27.14cm). But SSP rate at 80kg/ha recorded the highest means on plant height at Tabra (23.86cm) and Keshere (31.83cm). On the number of leaves per plant, only SSP rate at 80kg/ha produced the highest values (13.24leaves/plant) only at Keshere. In terms of Number of branches per plant, Red variety recorded a significantly higher value of (6.45) at Kashere only over white variety (4.77), and SSP rates did the same as 80kg/ha and 60kg/ha significantly (P<0.05) produced higher values (6.38/plant and 6.05/plant respectively) among others. Finally, variety and SSP rates interactions also showed significant differences some parameters like plant height, number of branches, leaf area, days to 50% flowering, number of leaves/plant, canopy height etc.* From the results, *the white variety of Bambara Groundnut performed optimally better than the red variety in terms of growth parameters*. *Therefore, farmers in the study areas are recommended to adopt the White variety and 80 kg/ha of SSP rate for optimal growth of Bambara Groundnut.*

***Keyword****s****:*** *-**Bambara Groundnut, Variety, SSP, application, Tabra, Kashere and Growth.*

# 1.0 INTRODUCTION

Bambara groundnut (*Vigna subterranean* L.) which belongs to the genus *Vigna* and family *Fabacea* is a legume crop widely cultivated in Sub-Saharan Africa. Its Centre of origin is thought to be Bambara, near Timbuktu in Central Mali, West Africa, hence its name Bambara groundnut (Nyamangara and Nyagumbo, 2010; Aliyu *et al*., 2016). The crop has also been widely cultivated in tropical regions since the seventeenth century and was also domesticated in the semi- arid zone of West Africa, probably around the head waters of the Niger River from where it spread in ancient times to Central Africa and more recently to the Madagascar Republic (Tweneboah, 2000; Boateng, 2006; Asante *et al*., 2021).

Bambara groundnut, like other grain legumes, increases the biological diversity in the ecosystem (Doku, 1995; Masawe *et al*., 2005). The seeds of Bambara groundnut contain sufficient quantities of protein (19%), carbohydrate (63%), fat (6.5%) and essential amino acids such as lysine, cysteine and methionine (Oliviera, 1976; Chai *et al*., 2017). Thus, the crop produces a balanced food, high in protein content and as a source of plant protein for man (Cynthia, 2016; Effa *et al.*, 2016).

Meanwhile, the production of the crops like Bambara groundnut in Sub-Saharan Africa is hindered by several factors such as drought, low soil fertility as well as restricted access to mineral fertilizers (Golli *et al*., 1995; Nyamangara and Nyagumbo, 2010). Though Bambara groundnut, being a leguminous crop, is associated with nitrogen fixation aided by some *Rhizobium* bacteria for optimal growth and development, since generally, in legumes, atmospheric nitrogen (N2) fixation happens in the nodules (Broughton et al., 2003). Nodules grow in the roots that are produced by N2-fixing rhizobial bacteria (Broughton et al., 2003). However, while nitrogen fixation is a sustainable way of producing nitrogen (N) which is vital in forming chemical fertilizer, several factors posse some limitations (Andres et al., 2012). Some biotic and abiotic factors affect the mutual interaction between legumes and their micro-symbiont partner (Andres et al., 2012; Lira et al., 2005). Legume productions are adversely impacted by several factors such as drought (Andres, 2012), low pH levels (Lin et al., 2012), salinity (Abd-Alla et al., 2013) heavy metals (Schue et al., 2011), extreme temperatures and low nutrient availability on the soil where legumes are grown (Wei et al., 2010) like SSP. More importantly, decrease in the availability of phosphorus in soil also has an impact in legume production (Doi Sulieman and Tran, 2015), which can be obtained from SSP.

The meaning of SSP is Single Super Phosphate (SSP) and it is one of the most widely used phosphorus (P) fertilizers in agriculture, especially in developing countries (FAO, 2000). It is mainly applied to mitigate phosphorus deficiencies in soils, encouraging root development and improving crop yields (Roy et al., 2006). SSP contains about 16–22% P₂O₅ apart from other two micronutrients (FAI, 2023; Tandon, 2013) and thus making it a phosphorus source which is essential for plant growth. SSP is environmentally safer as against some high-analysis fertilizers like Triple Super Phosphate (TSP) on account of its lower phosphorus concentration and minimal risk of leaching. It is often applied at the beginning of the planting season to encourage strong early growth (Chien et al., 2011). Economically, SSP is cost-effective for small-scale and resource-limited farmers, particularly in South Asia and Africa (Roy et al., 2006).

Phosphorus (P) being a major component of mineral fertilizer plays a vital role in the growth and development of plants as it is needed in the molecular structure of plants, facilitating transformation of energy and regulation of several enzymatic activities as well (Schulze et al., 2006). Therefore, inadequate phosphorus in soil gravely affects the growth and development of plants. Hence, supplementary amount of SSP is needed in the soil for optimal crop performance of plants. For instance, lack of phosphorus alone affects crop leaf development and ability to carry out photosynthesis thereby causing the plant not to produce sufficient food to support optimal growth (Doi Sulieman and Tran, 2015).

In Nigeria, farmers are always faced with the problem of low soil fertility which has been considered as the most important constraint to crop yield and productivity (Odendo *et al*., 2004). Generally, nutrient management is a major aspect of cultural practices aimed at improvement of most crops (Nnadi *et. al*., 2025). Crop growth and yield development requires mineral nutrition at an appropriate amount which can be supplied to crops as a fertilizer. Application of SSP can therefore be a low cost alternative to alleviating low soil fertility on Bambara groundnut (Odendo *et al*., 2004). SSP fertilizer is a nutrient source for crop production (Harry *et al.*, 2011) and has been shown to increase soil available SSP (Heller *et al*., 1997).

When SSP is incorporated into the soil, it promotes transformation and mineralization of SSP, which results into higher SSP concentrations and higher total SSP uptake by plants (Heller *et al*., 1997). However, in Northern Nigeria, little is known is about the use of SSP fertilizers and their effects on crops especially Bambara groundnut for efficient utilization.

In other crops, studies indicate that significant variation among mung bean and cowpea genotypes has been reported for growth parameters like plant height, including number of pods per plant at low and adequate SSP levels (Balole *et al.,* 2003; Bamishaiye *et al*., 2011). This varied response to SSP application demonstrate the usefulness of this nutrient in promoting productivity of legumes as well as the need to grow suitably adapted cultivars to achieve optimal use of the limited resource. Furthermore, in related a research, morphological attributes including number of leaves, plant height, number of branches and leaf area of cowpea were significantly improved due to the supplementation of SSP (Nweke and Emeh*,* 2013). Somta *et al.* (2011) assert that SSP requirements of the shoot and root tips are high due to increased metabolism and cell division occur at high rate.

Results of a certain study revealed that Bambara Groundnut (*Vigna subterranea*) has characteristics to grow in the marginal soil, tolerant into the drought condition and also has a potential of nitrogen fixation. As already highlighted, Nitrogen is the key plant nutrient that stimulates root and shoot growth. SSP application significantly improves many aspects of plant physiology including photosynthesis, flowering, fruiting and maturation which ultimately result in better yield (Hasan *et al.*, 2018).

Adeyeye *et al*. (2019) conducted a trial on the effect of organic and inorganic Nutrient Sources on The Growth and Seed Yield of Bambara Groundnut (*Vigna Subterranean* (L) Variety in Wukari, Nigeria. Results showed that N fertilizer application rate of 30 kg N per hectare produced significant number of leaves, nodes, flowers and plant height.

Agyeman *et al.* (2022) carried out a research on enhancing the productivity and sustainability of Bambara Groundnut (*Vigna subterranea* (L.) production using inorganic SSP fertilizer. Results showed that Bambara Groundnut genotypes had excellent performance based on growth and yield analysis, and the results indicated a positive significant interaction between landraces and SSP fertilizer rates. The biological suitability of 60 kg P205 per hectare increased the number of nodules per plant for Tiga Necuru, Kenya Capstone and Nav Red by 42.8%, 51.3% and 42.1% respectively, over control plots. The same for pod yield is 12%, 28% and 52% significantly higher than when SSP was applied at 45, 30 and 0 kg P205 per hectare, respectively.

A research study was conducted by Temegne *et al.* (2015) on theeffect of phosphate deficiency on growth and SSP content of three Bambara Groundnut (*Vigna subterranea* (L.) varieties. Results obtained showed that from 1000 to 0µMPi, *Vigna subterranea* shoot fresh biomass reduced by 13.48%, 9.46% and 14.57% for V3 varieties, white variety and red variety, respectively. Its total fresh biomass also reduced by 8.29% for white variety, 3.32% for red variety and 6.94% for V3. But SSP deficiency (0 µM Pi) led to an increase in root fresh biomass (red variety: 8.82% and V3: 7.90%) and root/shoot ratio (white variety: 15.17%, red variety: 21.57% and V3: 25%).

Also, according to Temegne *et al.* (2015), these results show a preferential allocation of biomass to the roots in SSP deficient plants. SSP deficiency had no significant effect on the number of emerged leaves and the plant water content of *Vigna subterranea*. However, it increased the specific leaf weight (0.027 for 0 µm SSP and 0.023gm/cm2 for 1000 µm SSP in white variety). The total leaves and roots SSP content of SSP deficient plants significantly decreased compared to non-deficient plants (1000). The SSP deficient plants showed better efficiency in SSP assimilation. White variety had the best vegetative growth, red variety showed highest SSP use efficiency and V3 contained more SSP in its organs. The results further revealed that days to flowering and maturity, the plant height, the number of branches and dry matter increased significantly at each level of SSP fertilizer. SSP is a vital element required for nodulation, stomatal regulation and photosynthesis in legume crops. SSP deficiency in tropical soils limits the growth and productivity of Bambara Groundnuts.

As a legume crop, Bambara groundnut of any variety can improve the soil fertility in varying degrees by nitrogen fixing bacteria present in the root nodules, but this alone cannot satisfy the nitrogen requirements of the plants (Chiezey *et al*., 1991), due partly to problems mentioned above including low SSP. For successful crop production, SSP is considered as an essential mineral nutrient after nitrogen. SSP helps in root system and many aspects of plant physiology. In fact, different levels of SSP can have different effects on growth and yield of the crop Boateng (2006).

Since Nitrogen fixation by bacteria is essential for sustaining the growth, development, and yield of legumes (Bitire et al., 2023), then, there is a need for application of SSP to stimulate nodulation for optimum production (Toungos *et al.*, 2010) as judicious use of chemical fertilizers is also essential to maintain soil fertility (Vasilas *et al*., 1988). For enhanced growth, adequate supply of nitrogen is necessary as it has been found to be beneficial for promoting cell division and cell enlargement, among others (Shehu *et al.*, 2010). Again, studies indicate that legumes require more phosphorus for nitrogen fixation to achieve maximum function. More phosphorus is required in legumes since phosphorus is needed in energy transformation in nodules (Rotaru and Sinclair, 2009). This knowledge remains deficit in some parts of Africa especially Nigeria as there is no research focusing directly on SSP and its real impact on Bambara groundnut. Hence, a full research study targeted at exploring the beneficial effect of SSP on legumes especially Bambara nut is necessary to bridge this gap.

Again, Bambara groundnut is usually grown with low input by subsistence farmers without fertilizer application which supplies SSP in most of the farms and this makes its production to be marginal. Therefore, the broad objective of the present study is to determine effect of varietal differences and SSP rates on the growth performance of Bambara groundnut (*Vigna subterranea* l. verd.) in Gombe State, Nigeria. Specific objectives of the study are:-

1. to evaluate the effects of SSP rates on the growth of Bambara groundnut in the study areas.
2. to evaluate the effects of varieties on the growth of Bambara groundnut in the study areas.
3. to investigate the interaction effect of SSP rates and Bambara variety on its growth in the study area.
4. to ascertain the SSP rate most suitable for optimal growth of Bambara in the study area

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# 2.0 MATERIALS AND METHODS

# 2.1 Experimental Sites

Field trials were conducted during the 2023 rainy season at the Teaching and Research Farm of the Faculty of Agriculture, Federal University of Kashere and at Tabra in Gombe State North Eastern, Nigeria.

# 2.2 Treatments and Experimental Design

The two trials were factorially combined in a 2 x 5 and laid out in a Randomized Complete Block Design (RCBD) with three replications. The treatments consisted of two Bambara groundnut varieties (white and red) and five SSP rates of (0, 20, 40, 60 and 80kg per hectare). There were ten (10) plots and were replicated three times, making a total of thirty in the field. The plot size was 3 x 2m at as pacing of 50 x 50cm, with a 0.5m path between plots and 1m path between replications.

# 2.3 Agronomic Practices

The land was cleared manually using simple farm tools such as a cutlass, hand hoe and rake. The layout was designed and pegged using a hand hoe. Three seeds were sown per hole and later thinned to two plantsper stand after emergence. Weeding was done manually with the use of a hoe at 3, 6 and 9 weeks after sowing.

# 2.4 Data Collection

# *2.4.1 Soil analysis*

Initial nutrient status of the experimental sites was assessed before designing the experiment, three portions was selected randomly at two soil depths; 0-15 and 15-30 cm to give a composite soil sample. Thereafter, the samples were analyzed to determine the physical and chemical analysis of the experimental site.

# *2.4.2 Canopy height (cm)*

Canopy height was measured from the base of the plant to the end from the five sampled plants in each treatment using a measuring tape graduated in cm, the average taken and recorded.

# *2.4.3 Number of leaves per plant*

Total number of leaves per plantfrom the five sampled plants in each treatment was obtained by physical counting, the average taken and recorded.

# *2.4.4 Number of branches per plant*

Total number of branches per plantfrom the five sampled plants in each treatment was obtained by physical counting, the average taken and recorded.

# *2.4.5 Leaf area (cm2)*

Leaf area (cm2) was measured manually from the five sampled plants in each treatment and the average was taken and recorded. Measurement was done by determining the leaf length and breadth and was multiplied by a factor of 0.80 (constant).

# *2.4.6 Days to 50 % flowering*

Days to 50% flowering were the number of days when 50% of plants in each treatment have flowered.

# *2.4.7 Number of nodules per plant*

Number of nodules per plant was obtained by physical counting of the number of nodules in each treatment using a destructive sample, the average taken and recorded.

# 2.5 Data Analysis

Data collected was analyzed using analysis of variance (ANOVA). Means was separated using the least significant difference at 5% level of probability (Gomez and Gomez, 1984).

3.0 **RESULTS**

# *3.1 Canopy height (cm) and number of leaves per plant*

Table 1 shows the effects of varieties and SSP rates on canopy height at Tabra, Kashere and the mean. The results revealed that there was no significant difference (P>0.05) among the varieties of Bambara groundnut on canopy height at Tabra and the mean, however there was a significant difference (P<0.05) at Kashere. White variety significantly produced a higher mean on canopy height of (28.16) over red variety which produced a lower mean of (27.14). There was also a significant difference (P<0.05) among the SSP rates on canopy height at Tabra, Kashere and the mean. The control treatment of no SSP applied, significantly produced a lower mean of (19.63, 23.05 and 22.57), followed by SSP rate at 20kg per hectare which produced means of (20.51, 25.91 and 23.21), followed by SSP rate at 40kg per hectare which produced means of (21.98, 27.67 and 24.83), followed by SSP rate at 60kg per hectare which produced means of (22.53, 29.33 and 25.93) and SSP rate at 80kg per hectare produced the highest means on plant height of (23.86, 31.83 and 27.86).

The results in Table 1 also shows that there was no significant difference (P>0.05) among the varieties of Bambara groundnut on the number of leaves per plant at Tabra, Kashere and the mean (Table 1). There was also no significant difference (P>0.05) at Gombe among the SSP rates on the number of leaves per plant. However, there was a significant difference among the SSP rates on the number of leaves per plant at Kashere and the mean. The control treatment of no SSP applied, significantly produced a lower mean of (9.27 and 10.19), followed by SSP rate at 20kg per hectare which produced means of (10.10 and 10.73), followed by SSP rate at 40kg per hectare which produced means of (11.63 and 11.51), followed by SSP rate at 60kg per hectare which produced means of (12.24 and 11.35) and SSP rate at 80kg per hectare produced the highest means on number of leaves per plant of (13.24 and 11.35).

Table 1: Effects of varieties and SSP Rates on Plant Height (cm) and Number of Leaves per Plant of Bambara Groundnut (*Vigna subterranea* L.) at Tabra, Kashere and Mean in Gombe State, Nigeria

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatments | Canopy Height (cm) | | | Number of Leaves per Plant | | |
| Variety (V) | Tabra | Kashere | Mean | Tabra | Kashere | Mean |
| White variety | 21.76 | 28.16 | 24.96 | 11.22 | 10.70 | 10.96 |
| Red variety | 21.65 | 27.14 | 24.40 | 11.18 | 11.90 | 11.54 |
| LSD | 1.014 | 0.810 | 0.912 | 1.157 | 2.503 | 1.830 |
| SSP Rates (kg) per Hectare |  |  |  |  |  |  |
| 0 | 19.63 | 23.50 | 22.57 | 11.10 | 9.27 | 10.19 |
| 20 | 20.51 | 25.91 | 23.21 | 11.35 | 10.10 | 10.73 |
| 40 | 21.98 | 27.67 | 24.83 | 11.38 | 11.63 | 11.51 |
| 60 | 22.53 | 29.33 | 25.93 | 10.46 | 12.24 | 11.35 |
| 80 | 23.86 | 31.83 | 27.86 | 11.72 | 13.24 | 12.48 |
| LSD (0.05) | 1.604 | 1.282 | 1.443 | 1.830 | 2.101 | 1.965 |
| Interaction |  |  |  |  |  |  |
| V x P | NS | 1.270 | NS | NS | 1.345 | NS |

## LSD = Least Significant Difference at 5% Level of Probability

# *3.2 Interaction between varieties with SSP rates on canopy height (cm) at Kashere*

Table 2 shows the interaction between varieties with SSP rates at Kashere in Sudan savanna agro-ecologicla zone of Nigeria on canopy height of Bambara Groundnut. White variety with SSP rate at 80kg per hectare, significantly produced a higher interaction of (31.85), followed by red variety with SSP rate at 80kg per hectare which produced a significant interaction of (31.81), followed by white variety with SSP rate at 60kg per hectare which produced a significant interaction of (29.81), followed by white variety with SSP rate at 60kg per hectare which produced a significant interaction of (28.84), followed by white variety with SSP rate at 40kg per hectare which produced a significant interaction of (28.33), followed by red variety with SSP rate at 40kg per hectare which produced a significant interaction of (27.00), followed by white variety with SSP rate at 20kg per hectare which produced a significant interaction of (26.82), followed by red variety with SSP rate at 20kg per hectare which produced a significant interaction of (25.00), followed by white variety with SSP rate at 0kg per hectare which produced a significant interaction of (23.95) and followed by red variety with SSP rate at 0kg per hectare which produced a significant interaction of (23.05).

Table 2: Interaction Between Varieties with SSP Rates on Canopy Height (cm) of Bambara Groundnut (*Vigna subterranea* L) at Kashere in Gombe State, Nigeria

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SSP Rates  (kg) per Hectare | 0 | 20 | 40 | 60 | 80 |
| Variety |  |  |  |  |  |
| White variety | 23.95 | 26.82 | 28.33 | 29.81 | 31.85 |
| Red variety | 23.05 | 25.00 | 27.00 | 28.84 | 31.81 |
| LSD |  |  | 1.270 |  |  |

## LSD = Least Significant Difference at 5% Level of Probability

# *3.3 Interaction between varieties and SSP rates on number of leaves per plant at Kashere*

Table 3 shows the interaction between varieties with SSP rates at Kashere in Sudan savanna agro-ecological zone of Nigeria on the number of leaves per plant. Red variety with SSP rate at 80kg per hectare, significantly produced a higher interaction of (14.26), followed by red variety with SSP rate at 60kg per hectare which produced a significant interaction of (12.61), followed by white variety with SSP rate at 80kg per hectare which produced a significant interaction of (12.18), followed by white variety with SSP rate at 60kg per hectare which produced a significant interaction of (11.86), followed by red variety with SSP rate at 40kg per hectare which produced a significant interaction of (11.67), followed by white variety with SSP rate at 40kg per hectare which produced a significant interaction of (11.38), followed by red variety with SSP rate at 0kg per hectare which produced a significant interaction of (10.71), followed by red variety with SSP rate at 20kg per hectare which produced a significant interaction of (10.00), followed by white variety with SSP rate at 20 kg per hectare which produced a significant interaction of (9.49) and followed by white variety with SSP rate at 0 kg per hectare which produced a significant interaction of (8.54).

Table 3: Interaction between Varieties with SSP Rates on Number of Leaves per Plant of Bambara Groundnut (*Vigna subterranea* L) at Kashere in Gombe State, Nigeria

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SSP Rates  (kg) per Hectare | 0 | 20 | 40 | 60 | 80 |
| Variety |  |  |  |  |  |
| White variety | 8.54 | 9.49 | 11.38 | 11.86 | 12.18 |
| Red variety | 10.71 | 10.00 | 11.67 | 12.61 | 14.26 |
| LSD |  |  | 1.345 |  |  |

## LSD = Least Significant Difference at 5% Level of Probability

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# *3.4 Number of branches per plant and leaf area (cm2)*

Table 4 shows the effect variety and SSP rates on the number of branches per plant of Bambara groundnut in the Sudan savanna agroecological zone of Nigeria. There was no significant difference (P>0.05) among the varieties at Tabra and the mean. However, there was a significant difference (P<0.05) at Kashere on the number of branches per plant. Red variety significantly produced a higher mean of (6.45) over white variety which produced a lower mean of (4.77). There was also no significant difference (P>0.05) among the SSP rates at Tabra and the mean. However, there was a significant difference (P<0.05) at Kashere on the number of branches per plant. The control treatment of no SSP applied, significantly produced a lower mean of (4.58), followed by SSP rate at 20kg per hectare which produced a mean of (5.50), followed by SSP rate at 40kg per hectare which produced a mean of (5.55), followed by SSP rate at 60 which produced a mean of (6.05) and SSP rate at 80 kg per which produced a mean of (6.38), but were not significantly different from SSP rate at 60kg per hectare.

Table 4 also displays the effect variety and SSP rates on leaf area per plant of Bambara groundnut in the Sudan savannah agro-ecological zone of Nigeria. There was no significant difference (P>0.05) among the varieties at Tabra, Kashere and the mean on leaf area per plant. There was also no significant difference (P>0.05) among the SSP rates at Gombe and the mean leaf area per plant. However, there was a significant difference (P<0.05) at Kashere on leaf area per plant. The control treatment of no SSP applied, significantly produced a lower mean of (29.69), followed by SSP rate at 20kg per hectare which produced a mean of (30.53), followed by SSP rate at 40kg per hectare which produced a mean of (32.31), followed by SSP rate at 60kg/ha which produced a mean of (34.07) and SSP rate at 80kg per hectare which produced a mean of (38.54).

Table 4: Effects of Varieties and SSP Rates on Number of Branches per Plant and Leaf Area (cm2) Per plant of Bambara Groundnut (*Vigna subterranea* L.) at Tabra, Kashere and Mean in Gombe State, Nigeria

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatments | Number of Branches per Plant | | | Leaf Area (cm2) | | |
| Variety (V) | Tabra | Kashere | Mean | Tabra | Kashere | Mean |
| White variety | 4.18 | 4.77 | 4.48 | 33.07 | 32.91 | 32.99 |
| Red variety | 4.34 | 6.45 | 5.40 | 31.02 | 31.94 | 31.48 |
| LSD | 0.365 | 0.779 | 0.572 | 2.120 | 2.314 | 2.217 |
| SSP Rates (kg)  per Hectare |  |  |  |  |  |  |
| 0 | 4.13 | 4.58 | 4.36 | 30.20 | 29.69 | 29.95 |
| 20 | 4.15 | 5.50 | 4.83 | 31.20 | 30.53 | 30.37 |
| 40 | 4.09 | 5.55 | 4.82 | 31.80 | 32.31 | 32.06 |
| 60 | 4.32 | 6.05 | 5.19 | 33.00 | 34.07 | 33.54 |
| 80 | 4.62 | 6.38 | 5.50 | 35.81 | 38.54 | 37.18 |
| LSD | 0.577 | 1.231 | 0.904 | 3.590 | 3.659 | 3.625 |
| Interaction |  |  |  |  |  |  |
| V x P | 0.074 | NS | NS | NS | 1.450 | NS |

## LSD = Least Significant Difference at 5% Level of Probability

# *3.5 Interaction between varieties with SSP rates on number of branches per plant at Tabra*

Table 5 shows the interaction between varieties and SSP rates at Tabra in Sudan savanna agroecological zone of Nigeria on the number of branches per plant at Tabra. White variety with SSP rate at 60kg per hectare, significantly produced a higher interaction of (4.78), followed by white variety with SSP rate at 80 kg per hectare which produced a significant interaction of (4.75), followed by red variety with SSP rate at 0kg per hectare which produced a significant interaction of (4.59), followed by red variety with SSP rate at 80kg per hectare which produced a significant interaction of (4.48), followed by red variety with SSP rate at 20kg per hectarewhich produced a significant interaction of (4.46), followed by red variety with SSP rate at 40 kg per hectare which produced a significant interaction of (4.30), followed by white variety with SSP rate at 40kg per hectare which produced a significant interaction of (3.87), followed by red variety with SSP rate at 60 kg per hectare which produced a significant interaction of (3.86), followed by white variety with SSP rate at 0kg per hectare which produced a significant interaction of (3.67) and followed by white variety with SSP rate at 20kg per hectare which produced a significant interaction of (3.63).

Table 5: Interaction Between Varieties with SSP Rates on Number Branches per Plant of Bambara Groundnut (*Vigna subterranea* L) at Tabra in Gombe State, Nigeria

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SSP Rates  (kg) per Hectare | 0 | 20 | 40 | 60 | 80 |
| Variety |  |  |  |  |  |
| White variety | 3.67 | 3.63 | 3.87 | 4.78 | 4.75 |
| Red variety | 4.59 | 4.46 | 4.30 | 3.86 | 4.48 |
| LSD |  |  | 0.074 |  |  |

## LSD = Least Significant Difference at 5% Level of Probability

# *3.6 Interaction between varieties with SSP rates on leaf area (cm2) at Kashere*

Table 6 shows the interaction between varieties and SSP rates at Kashere in Sudan savanna agroecological zone of Nigeria on leaf area at Kashere. White variety with SSP rate at 80kg per hectare, significantly produced a higher interaction of (36.15), followed by red variety with SSP rate at 80kg per hectare which produced a significant interaction of (34.92), followed by white variety with SSP rate at 60kgper hectare which produced a significant interaction of (34.91), followed by red variety with SSP rate at 60kg per hectare which produced a significant interaction of (33.23), followed by white variety with SSP rate at 40kg per hectare which produced a significant interaction of (32.72), followed by red variety with SSP rate at 40kg per hectare which produced a significant interaction of (31.89), followed by white variety with SSP rate at 20kg per hectare which produced a significant interaction of (30.90), followed by red variety with SSP rate at 20kgper hectare which produced a significant interaction of (30.16), followed by white variety with SSP rate at 0kg per hectare which produced a significant interaction of (29.88) and followed by red variety with SSP rate at 0kg per hectare which produced a significant interaction of (29.50).

Table 6: Interaction Between Varieties with SSP Rates on Leaf Area (cm2) of Bambara Groundnut (*Vigna subterranea* L) at Kashere in Gombe State, Nigeria

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SSP Rates  (kg) per Hectare | 0 | 20 | 40 | 60 | 80 |
| Variety |  |  |  |  |  |
| White variety | 29.88 | 30.90 | 32.72 | 34.91 | 36.15 |
| Red variety | 29.50 | 30.16 | 31.89 | 33.23 | 34.92 |
| LSD |  |  | 1.450 |  |  |

**LSD = Least Significant Difference at 5% Level of Probability**

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# *3.7 Number of nodules per plant and days to 50% flowering*

Table 7 shows the effects varieties and SSP rates on the number of nodules per plant of Bambara groundnut in the Sudan savanna agroecological zone of Nigeria. There was no significant difference (P>0.05) among the varieties at Tabra, Kashere and the mean on the number of nodules per plant. There was also no significant difference (P>0.05) among the SSP rates at Tabra and the mean. However, there was a significant difference (P<0.05) at Kashere on the number of nodules per plant. The control treatment of no SSP applied, significantly produced a lower mean of (4.10), followed by SSP rate at 20kg per hectare which produced a mean of (4.50), followed by SSP rate at 4kg per hectare which produced a mean of (5.71), followed by SSP rate at 60 which produced a mean of (6.08) and SSP rate at 80kg per hectare which produced a mean of (6.63), but were not significantly different from SSP rate at 60kg per hectare.

Table 7 also shows the effect of variety and SSP rates on days to 50% flowering of Bambara groundnut in the Sudan savanna agroecological zone of Nigeria. There was a significant difference (P<0.05) among the varieties at Tabra and Kashere, but no significant difference on the mean. At Tabra and Kashere, red variety significantly produced a higher mean of (45.40 and 45.38) over white variety on days to 50% flowering which produced a lower mean of (43.00 and 43.24). There was also no significant difference (P>0.05) among the SSP rates at Tabra, Kashere and the mean on days to 50% flowering.

Table 7: Effects of Varieties and SSP Rates on Number of Nodules per Plant and Days to 50% Flowering of Bambara Groundnut (*Vigna subterranea* L.) at Tabra and Kashere in Gombe State, Nigeria

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Treatments | Number of Nodules per Plant | | | Days to 50% Flowering | | |
| Variety (V) | Tabra | Kashere | Mean | Tabra | Kashere | Mean |
| White variety | 2..04 | 5.24 | 3.64 | 43.00 | 43.24 | 43.12 |
| Red variety | 2.24 | 5.58 | 3.91 | 45.40 | 45.38 | 45.39 |
| LSD | 0.410 | 0.734 | 0.572 | 2.089 | 2.069 | 2.079 |
| SSP Rates (kg)  per Hectare |  |  |  |  |  |  |
| 0 | 2.33 | 4.10 | 3.22 | 42.90 | 42.84 | 42.87 |
| 20 | 2.48 | 4.52 | 3.50 | 43.58 | 43.52 | 43.55 |
| 40 | 2.70 | 5.71 | 4.21 | 44.86 | 44.35 | 44.61 |
| 60 | 2.84 | 6.08 | 4.46 | 45.26 | 44.80 | 45.03 |
| 80 | 3.10 | 6.63 | 4.87 | 47.18 | 46.07 | 46.63 |
| LSD | 0.430 | 1.160 | 0.795 | 3.124 | 3.303 | 3.214 |
| Interaction |  |  |  |  |  |  |
| V x P | NS | NS | NS | NS | 2.321 | NS |

**LSD = Least Significant Difference at 5% Level of Probability**

# 

# *3.8 Interaction between varieties with SSP rates on days to 50% flowering at Kashere*

Table 8 shows the interaction between varieties with SSP rates at Kashere in Sudan savanna agroecological zone of Nigeria on days to 50% flowering at Kashere. Red variety with SSP rate at 80kg per hectare, significantly produced a higher interaction of (46.25), followed by red variety with SSP rate at 60kg per hectare which produced a significant interaction of (45.90), followed by white variety with SSP rate at 80kg per hectare which produced a significant interaction of (45.89), followed by red variety with SSP rate at 40kg per hectare which produced a significant interaction of (45.55), followed by red variety with SSP rate at 20kg per hectare which produced a significant interaction of (45.07), followed by red variety with SSP rate at 0kg per hectare which produced a significant interaction of (44.20), followed by white variety with SSP rate at 60kg per hectare which produced a significant interaction of (43.70), followed by white variety with SSP rate at 40kg per hectare which produced a significant interaction of (43.15), followed by white variety with SSP rate at 20kg per hectare which produced a significant interaction of (41.97) and followed by white variety with SSP rate at 0kg per hectare which produced a significant interaction of (41.46).

Table 8: Interaction Between Varieties with SSP Rates on Days to 50% Flowering of Bambara Groundnut (*Vigna subterranea* L) at Kashere in Gombe State, Nigeria

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SSP Rates  (kg) per Hectare | 0 | 20 | 40 | 60 | 80 |
| Variety |  |  |  |  |  |
| White variety | 41.46 | 41.97 | 43.15 | 43.70 | 45.89 |
| Red variety | 44.20 | 45.07 | 45.55 | 45.90 | 46.25 |
| LSD |  |  | 2.321 |  |  |

## LSD = Least Significant Difference at 5% Level of Probability

**4.0 DISCUSSION**

In this study, parameters such as canopy/plant height, number of leaves, branches and nodules and leaf-area were observed to have increased correspondingly with increasing application of SSP relative to the control treatment. The increased growth parameters associated with increasing SSP rates is similar to the result obtained by Nwake and Emeh (2013) who observed that growth attributes like plant height, number of leaves, and number of branches and leaf area of cowpea significantly improved due to the supplementation of SSP. The outcome is also in agreement with obtained by Temegne *et al.* (2015) who observed that plant height, the number of branches and dry matter including days to flowering and maturity increased significantly at each level of SSP fertilizer. The result of this present study could be attributed to the ability of SSP to stimulate Nitrogen fixing bacterial at the root nodules to fix sufficient nitrogen as it is a key component of proteins and nucleic acids, which are essentials for cell growth and development, including cell division, enlargement, and overall plant structure.

This stimulation as highlighted above could be by way of energy supply since according to Rotaru and Sinclair (2009) that more phosphorus is required or needed in legumes for energy transformation in nodules. Again, according to Somta et al. (2011), SSP requirements of the shoots and tips are high due to increased metabolism and cell division occurs at high rate. The control plants produced the shortest plants as they had to rely on the native soil fertility which from the result of the chemical analysis was slightly deficient in nutrients.

The white variety of Bambara Groundnut performed optimally better than the red variety in terms of plant height. Number of leaves per plant was significantly higher among the two varieties of Bambara Groundnut, with the white variety producing more leaves than the red one. This observation is similar to the findings of Boudion and Mergeai (2001); Azman-Ali (2001); Balole *et al*. (2003); Bamishaiye *et al.* (2011); Aliyu *et al*. (2016); Asante *et al*. (2021) who reported that there exist varietal variations among Bambara Groundnut genotypes with some performing much better than others in terms growth.

Again, there are slight differences observed in the values of some growth parameters with respect to different locations, namely Kashere and Tabra. The slight differences in values obtained from the two locations could be traceable to the effects of environmental factors differentials arising from those locations. And this outcome tends to agree with Andres et al. (2012) and Lira et al. (2005) who asserted that some biotic and abiotic factors affect the mutual interaction between legumes and their micro-symbiont partner

In terms of early flowering observed in the treated plots, it could be attributed to the effect of SSP on increased growth parameters like leaf and plant height since increase in leaf number and leaf area could lead to increase in net photosynthesis, transpiration rate and intracellular concentration of CO2, as Anjum *et al.* (2011) observed such in maize plant. Similar reasons were attributed to early flowering observed in cucumber plant treated with Foliar Plus (Nnadi et al., 2025). Meanwhile, the results agree with the findings of Coudert (1984); Doku (1995); Ellah and Singh (2008); Cynthia (2016); Chai *et al.* (2017) who reported that SSP application reduced number of days to 50% flowering compared to the untreated plots.

Furthermore, observation showed that as regard to SSP rates, 80kg SSP significantly gave higher growth parameters (canopy height, leaf number etc.) over the rest of the treatments and the control giving the least canopy height and number of leaves per plant. The reason could be that 80kg SSP provided the most suitable proportion of phosphorous required for energy supply in nitrogen fixation, thus resulting to optimized growth parameters of the crop. However, in general, SSP treated plots increased growth parameters of Bambara Groundnuts. These observations are similar to the findings of Chiezey *et al.* (1991); Akombo and Asema (2013); Effa *et al*. (2016); Adeyeye *et al.* (2019) who reported that the performances of Bambara Groundnut are enhanced greatly by the application of SSP.

Finally, both positive and negative interactions of SSP and variety observed in the study suggest that optimal performance of crop is likely dependent on the combined use of genetically viable varieties and good agronomical management of fertilizer involved.

**5.0 CONCLUSION**

Growth patterns of certain important crops like Bambara groundnut can be affected by varietal variations as well as nutrient supply rate.

White variety and SSP rate at 80 kg per hectare gave the best result in terms of monitored growth parameters like canopy height, number of leaves per plant, number of branches per plant, leaf area, number of days to 50% flowering, and number of nodules per plant. In terms of leaf area, White variety with SSP rate at 80 kg/ha, significantly exacted a higher interaction effect of (36.15) whereas red variety with SSP rate at 0 kg/ha produced the significantly least interaction effect (29.50).Variety and SSS rates interactions also showed significant differences on other parameters like days to 50% flowering, number of leaves/plant, canopy height. Finally, from the results, the white variety of Bambara Groundnut performed optimally better than the red variety in terms of growth parameters. Therefore, farmers in the study areas are recommended to adopt the White variety and 80 kg/ha of SSP rate for optimal growth of Bambara Groundnut.

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**REFERENCES**

[Abd-Alla, M. H., El-Enany, A. W. E., Bagy M. K, Bashandy, S. R. (2013). Alleviating the Inhibitory Effect of Salinity Stress on Nod Gene Expression in Rhizobium tibeticum- fenugreek (*Trigonella foenum graecum*) Symbiosis by Isoflavonoids Treatment. *J Plant Int* 9: 275-284.](http://www.tandfonline.com/doi/pdf/10.1080/17429145.2013.824622)

Adeyeye, A. S, Dimas, A. E, Olalekan, K. K., Lamidi, W. A., Othman, H. J. and Ishaku, M. A. (2019). The Effect of Organic and Inorganic Nutrient Sources on the Growth and Seed Yield of Bambara Groundnut (*Vigna subterranea* (L). *World Journal of Agriculture and Soil Science,* 2(3): 1-9.

Agyeman, K., Joseph, N. B., Eric, O. D., Sylvester, A., Agbesi, K. K., Paul, M., Elvis, A.O., Joseph, A. P., Atta, P. S., Joseph A. S., Bernard, S., Michael. O. Q. (2022). Enhancing the Productivity and Sustainability of Bambara Groundnut (*Vigna subterranea* (L.) Production Using Inorganic SSP. *Fertilizer Agricultural Sciences,* 13: 1117-1135

Akombo, R. A. Asema, U. S. (2013). Effect of Different Levels of SSP and Potassium Combinations on the Growth and Yield of Bambara Groundnut (*Vigna subterranea* L.) in Yandev. *International Journal of Development and Sustainability,* 2(3): 1744-1748.

[Aliyu, S., Massawe, F., Mayes, S. (2016). Genetic Diversity](https://link.springer.com/article/10.1007/s10722-016-0406-z) [and Population Structure of Bambara groundnut](https://link.springer.com/article/10.1007/s10722-016-0406-z) [(*Vigna subterranea* L.): Synopsis of the Past](https://link.springer.com/article/10.1007/s10722-016-0406-z) [two Decades of Analysis and Implications for Crop](https://link.springer.com/article/10.1007/s10722-016-0406-z) [Improvement Programs. *Genetic Resources* of *Crop Evol*](https://link.springer.com/article/10.1007/s10722-016-0406-z)ution, [63(3): 925-943.](https://link.springer.com/article/10.1007/s10722-016-0406-z)

Andres, J. A., Rovera, M., Guinazu L. B., Pastor N. A., Rosas, S. B. (2012). Interactions between legumes and rhizobia under stress conditions. In: Dinesh KM (Ed.), Bacteria in Agrobiology. Stress Management. Springer-Verlag, Berlin, Germany, pp. 77-94.

Anjum, S. A., Wang, L., Farooq, M., Xue, L. and Ali, S. (2011). Fulvic Acid Application Improves the Maize Performance under Well‐watered and Drought Conditions. *Journal of agronomy and crop science, 197, 409-417.*

Asante, B. O., Richard, A., Kennedy, A. Stephen, J., Ayeh, R. A. and Daniel, A. (2021). Preference for Improved Varietal Attributes of Bambara Groundnut Among Smallholder Farmers in Ghana. *African Journal of Agricultural and Resource Economics,* 16(2): 155-168.

Azam-Ali, S. N. (2001). Evaluating the Potential of Bambara Groundnut as a Food Crop for Semi-Arid Africa. *Proceedings of the third SADC Regional Conference on Land and Water Management, Harare,* October, 203-217.

Balole, T. V., Karikari, S. K., Khonga, E. B., Ramole-Mana, G. and Legwaila, G. (2003). Effect of Earthening up of Bambara Groundnut (*Vigna subterraea* (L.) Landraces Grown in Botswana in EU FP5/INCO-DC (eds.) *Bambara Groundnut*. *Proceedings of an International Symposium held at Botswana College of Agric. Botswana*. CTA/EU: 165-170.

[Bamishaiye, O. M., Adegbola, J. A., Bamishaiye, E. I. (2011)](http://cropsfordrylands.com/wp-content/uploads/Bambara-groundnut-an-Under-Utilized-Nut-in-Africa.pdf). [Bambara Groundnut: An Under-Utilized Nut in Africa.](http://cropsfordrylands.com/wp-content/uploads/Bambara-groundnut-an-Under-Utilized-Nut-in-Africa.pdf) [*Advances in Agricultural Biotechnol*ogy, 1: 60-72.](http://cropsfordrylands.com/wp-content/uploads/Bambara-groundnut-an-Under-Utilized-Nut-in-Africa.pdf)

Baudoin, J. P. and Mergeai, G. (2001). *Grain Legumes in Crop Production of Tropical Africa,* 313-317.

Bitire, T. D., Abberton, M., Tella, E.O., Edemodu, A., Oyatomi, O., Babalola O. O. (2023). Impact of nitrogen-fixation bacteria on nitrogen-fixation efficiency of Bambara groundnut [*Vigna subterranea (L) Verdc*] genotypes. Front Microbiol;14:1187250. doi: 10.3389/fmicb.2023.1187250. PMID: 37822737; PMCID: PMC10562726.

Boateng, S. A. Zickermann, J. Kornahrens, M. (2006). Poultry Manure Effect on Growth and Yield of Maize. *West African Journal of Applied Agro-ecologicla zone,* 9: 1-11.

[Broughton, W. J., Zhang, F., Perret, X., Staehelin, C. (2003). Signals Exchanged between Eegumes and Agricultural Uses and Perspectives. *Plant Soil* 252(1): 129-137.](https://link.springer.com/article/10.1023/A:1024179717780)

[Chai, H .H., Ho, W.K., Graham, N. May, S. Massawe, F.](https://www.ncbi.nlm.nih.gov/pubmed/28241413) [(2017). A Cross-Species Gene Expression Marker-Based Genetic Map and QTL Analysis in Bambara](https://www.ncbi.nlm.nih.gov/pubmed/28241413) [Groundnut. *Genes*, 8(2): 84.](https://www.ncbi.nlm.nih.gov/pubmed/28241413)

Chien, S. H., Prochnow, L. I., & Cantarella, H. (2011). Recent developments of fertilizer production and use to improve nutrient efficiency and minimize environmental impacts. *Advances in Agronomy*, **114**, 267-322.

Chiezey, U. F., Yayock, J. Y., Ahmed, M. K. (1991). Effect of SSP and Plant Density on the Yield Components of Soybean (*Glycine max* L. Merrill). *Crop Science Research,* 4(1): 11-18.

Cynthia, N. W. **(**2016). Screening of Selected Bambara Groundnut (*Vigna subterranea* (L.) Landraces for Tolerance to *Fusarium* wilt and its Management using Farmyard Manure in Busia County, Western Kenya.*An M.Sc. Thesis* Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Award of Master of Science Degree in Plant Pathology of Egerton University, 78pp.

[Doi Sulieman, S, Tran L. S. (2015). Phosphorus Homeostasis in legume nodules as an Adaptive Strategy to Phosphorus Deficiency. *Plant Sci* 239: 36-43.](https://www.ncbi.nlm.nih.gov/pubmed/26398789)

Doku, E. V. (1995). Country Report Promoting the Conservation and Use of Under-Utilized and Neglected Crops. Bambara Groundnut *(Vigna subterranea).* Begemann F., Heller J. and Mushonga J. (Eds). *Proceedings of the Workshop on Conservation and Improvement of Bambara Groundnut* (*Vigna subterranea* (L.). Harare, Zimbabwe, 30-32.

[Effa, E.B.*,* Nwagwu, F. A., Osai, E. O., Shiyam, J. O. (2016)](http://iiste.org/Journals/index.php/JBAH/article/view/32511). [Growth and Yield Response of Bambara Groundnut](http://iiste.org/Journals/index.php/JBAH/article/view/32511) [(*Vigna subterranea* (L.) to Varying Densities](http://iiste.org/Journals/index.php/JBAH/article/view/32511) [and Phosphate Fertilizer Rates in Calabar, South](http://iiste.org/Journals/index.php/JBAH/article/view/32511) [Eastern Nigeria. *Journal of Biological, Agriculture and Healthcare*, 6(16): 14-20.](http://iiste.org/Journals/index.php/JBAH/article/view/32511)

[Ellah, M. M., and Singh, A. (2008). Bambara Groundnut (*Vigna*](https://scialert.net/abstract/?doi=jps.2008.176.181) [*subterranea* (L.) Yield as Influenced by](https://scialert.net/abstract/?doi=jps.2008.176.181) [SSP and Cultivars in the Semi-Arid Savanna of](https://scialert.net/abstract/?doi=jps.2008.176.181) [Nigeria. *Journal of Plant Science,* 3(2): 176-181.](https://scialert.net/abstract/?doi=jps.2008.176.181)

FAI. (2023). *Fertilizer Statistics*. The Fertiliser Association of India.

FAO. (2000). *Fertilizers and Their Use* (4th ed.). Food and Agriculture Organization of the United Nations.

Gomez, K. A., and Gomez, A. A. (1984). *Statistical Procedures for Agriculture Research*. John Willy and Sons, New York, 690 pp.

Golli, A. E. (1995). Characterization and Evaluation of IITA Bambara Groundnut Collection. *In:* Begemann, J.H., Mushonga J (Eds.). *Proceedings of the Workshop on Conservation and Improvement of Bambara Groundnut* (*Vigna subtarranea* (L.). Zimbabwe: International Plant Genetic Resources Institute.

Coudert, M. J., (1984). *Cowpea and Bambara Groundnut;* Prospects for Regional Trade Development in West Africa. FAO International Trade Centre, Geneva, Switzerland.

Harry, H. Schomberg, D.M. Endale, M. Jenkins, B. Dwight, S.F. (2011). Nutrient Source and Tillage Influences on Nitrogen Availability in a Southern Piedmonts Corn Rainy System. *Biology and Fertility of Soils,* 47: 823-831.

Hasan, M. M. U. (2018). Nitrogen, SSP and Compost Application Effects on the Growth, Yield and Seed Quality of Bambara Groundnut. *M.Sc. Thesis* Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science, 71pp.

Hasan, M. M. U., Tengku, M. M., Ali, M. M. and Motmainna, T. K. Z. (2019). Impact of Nitrogen and SSP Fertilizer on Growth and Yield of Bambara Groundnut. *Plant Archives*, 19(1): 501-504.

Heller, J., Begemann, F., Mushonga, J. (1997). Bambara Groundnut (*Vigna subterranea* (L.). Promoting the Conservation and Use of Underutilized and Neglected Crops. *Proceedings of the Workshop on Conservation and Improvement of Bambara Groundnut* (*Vigna subterranea* (L.), 14-16 November 1995, Harare, Zimbabwe.

[Lira Junior, M. A., Lima, A. S. T., Arruda, J. R. F., Smith, D. L. (2005). Effect of Root Temperature on Nodule Development of Bean, Lentil and Pea. *Soil Biol Biochem* 37: 235-239.](https://www.deepdyve.com/lp/elsevier/effect-of-root-temperature-on-nodule-development-of-bean-lentil-and-RegejEJRqf)

[Lin. M. H., Gresshoff, P. M., Ferguson, B. J. (2012). Systemic Regulation of Soybean Nodulation by Acidic Growth Conditions. *Plant Physiol* 160(4): 2028-2039.](http://www.plantphysiol.org/content/160/4/2028.full)

[Massawe, F. J., Mwale, S. S., Azam-Ali, S. N., Roberts, J. A](https://www.ajol.info/index.php/ajb/article/view/15123). [(2005). Breeding in Bambara Groundnut (*Vigna*](https://www.ajol.info/index.php/ajb/article/view/15123) [*subterranea* (L.): Strategic Considerations. *Afr*](https://www.ajol.info/index.php/ajb/article/view/15123)*ican* [*Journal of Biotechnology,* 4(6): 463-471*.*](https://www.ajol.info/index.php/ajb/article/view/15123)

Nnadi, K. J., Christo, I.E., Ogbuehi, H.C., Ogwudire, V. E., Kalu, C. B., Ejiogu, C. S. and Umar, I. F. (2025). Impact of Foliar Plus on Physiological Growth Attributes of Cucumber (*Cucumis sativus*) in Owerri, Nigeria. *Asian Journal of Research and Review in Agriculture*. 7(1); 26-38.

[Nweke, I. A. and Emeh, H. O. (2013). The Response of Bambara](http://www.iosrjournals.org/iosr-javs/papers/vol2-issue1/G0212834.pdf) [Groundnut (*Vigna subterranea* (L.) to](http://www.iosrjournals.org/iosr-javs/papers/vol2-issue1/G0212834.pdf) [Phosphate Fertilizer Levels in Igbariam South East](http://www.iosrjournals.org/iosr-javs/papers/vol2-issue1/G0212834.pdf) [Nigeria. *IOSR-JAVS* 2(1): 28-34.](http://www.iosrjournals.org/iosr-javs/papers/vol2-issue1/G0212834.pdf)

Nyamangara, J. and Nyagumbo, I. (2010). Interactive Effects of Selected Nutrient Resources and Tied Ridging on Plant Growth Performance in a Semi-Arid Smallholder Farming Environment in Central Zimbabwe. *Innovations as Key to the Green Revolution in Africa*, 357-363.

Odendo, M., Ojiem, J., Okwosa, E. (2004). *Potential for Adoption of Legume Green Manure on Smallholder Farms in Western Kenya.* In: Managing Nutrient Cycles to Sustain Soil Fertility in Sub-Saharan Africa, Bation (Ed) Academy Science Publishers, Nairobi, Kenya, 557-570.

Oliveira, J. S. (1976). Grain Legumes of Mozambique. *Trop. Grain Legume Bull*. 3: 13-15.

Rotaru, V., and Sinclair, T. R. (2009). Interactive Influence of Phosphorus and Iron on NitrogenFixation by Boybean. *Environ Exp Bot* 66: 94-99.

Roy, R. N., Finck, A., Blair, G. J., & Tandon, H. L. S. (2006). *Plant Nutrition for Food Security: A Guide for Integrated Nutrient Management*. FAO Fertilizer and Plant Nutrition Bulletin 16.

[Schulze, J., Temple G., Temple S. J., Beschow, H., Vance C. P. (2006) Nitrogen Fixation by White Lupin Under Phosphorus Deficiency. *Ann Bot* 98(4): 731-740.](https://www.ncbi.nlm.nih.gov/pubmed/16855013/)

[Schue, M., Fekete, A., Ortet, P., Brutesco, C., Heulin, T., et al. (2011) Modulation of Metabolism and Switching to Biofilm Prevail Over Exopolysaccharide Production in the Response of to Cadmium. *PLoS ONE* 6: e26771.](http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0026771)

Shehu, H. E. Joshua, D. Kwari, M. Sandabe, K. (2010). Effects of N, P and K Fertilizers on Yield, Content and Uptake of N, P and K by Sesame (*Sesamun indicum*). *International Journal of Agriculture and Biology,* 12(6): 845- 850.

[Somta, P., Chankaew, S., Rungnoi, O., Srinives, P. (2011.)](https://www.ncbi.nlm.nih.gov/pubmed/22017518) [Genetic Diversity of the Bambara Groundnut (*Vigna*](https://www.ncbi.nlm.nih.gov/pubmed/22017518) [*subterranea* (L.) as Assessed by SSR Markers.](https://www.ncbi.nlm.nih.gov/pubmed/22017518) [*Genome,* 54(11): 898-910.](https://www.ncbi.nlm.nih.gov/pubmed/22017518)

Tandon, H. L. S. (2013). *Fertilizers in Indian Agriculture – From 20th to 21st Century*. FDCO.

Temegne, C. N. Judith, M.T., Pierre, N., Emmanuel, Y., Victor, D. T. and Godswill, N. N. (2015). Effect of Phosphate Deficiency on Growth and SSP Content of three Bambara Groundnut (*Vigna subterranea* (L.). *IOSR Journal of Agriculture and Veterinary Science*, 8(9): 52-59.

[Toungos. D. T., Sajo, A. A., Gungula, D.T. (2010). Effect of](https://idosi.org/wjfpb/wjfpb1(1)10/1.pdf) [P on Yield Components of Bambara Groundnut](https://idosi.org/wjfpb/wjfpb1(1)10/1.pdf) [(*Vigna subterranea* (L.) in Yola Adamawa State,](https://idosi.org/wjfpb/wjfpb1(1)10/1.pdf) [Nigeria. *WJFPB*, 1(1): 1-7.](https://idosi.org/wjfpb/wjfpb1(1)10/1.pdf)

Tweneboah, C. K. (2000). *Modern Agriculture in the Tropics, Food Crops.* Co-Wood Publishers, 220 pp.

Vasilas, B. L., Esgar, R. W., Walker, W. M., Beck, R. H. and Mainz, M. J. (1988). Soybean Response to Potassium Fertility Under Four Tillage Systems. *Agronomy Journal,* 80:5-8.

[Wei M., Takeshima K., Yokoyama T., Minamisawa K., Mitsui H., et al. (2010) Temperature-Dependent Expression of Type III Secretion System Genes and its *Regulation in Mol Plant Microbe Int.* 23(5): 628-637.](https://www.ncbi.nlm.nih.gov/pubmed/20367471)