
UNIVERSITI PUTRA MALAYSIA

# *NITROGEN, PHOSPHORUS AND COMPOST APPLICATION EFFECTS ON THE GROWTH, YIELD AND SEED QUALITY OF BAMBARA GROUNDNUT*

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# NITROGEN, PHOSPHORUS AND COMPOST APPLICATION EFFECTS ON THE GROWTH, YIELD AND SEED QUALITY OF BAMBARA GROUNDNUT

By

**MD. MAHMUDUL HASAN**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science**

**June 2018**

## DEDICATION

I would like to dedicate this work to those who taught, motivated and helped me throughout my study.

To my respected father late Md. Jahangir Hossain who always dreams for my study in abroad and my mother most. Gulshan Ara Begum who sacrificed her valuable time and always keep praying for me day and night to achieve my goal and to all my friends, teacher and colleague who supported me all those past years.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

**NITROGEN, PHOSPHORUS AND COMPOST APPLICATION EFFECTS ON THE GROWTH, YIELD AND SEED QUALITY OF BAMBARA GROUNDNUT**

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**June 2018**

**Chairman : Md. Kamal Uddin, PhD**
**Faculty: Agriculture**

Bambara groundnut (*Vigna subterranea*) is an indigenous African crop. Its seeds contain 63% carbohydrate, 19% protein, 6.5% oil and good source of fibre, calcium, iron and potassium. Hence, this study aimed to determine the effect of nitrogen (N), phosphorus (P) and compost on growth, yield and seed quality of bambara groundnut. Two pot experiments were conducted in Ladang15 at the Faculty of Agriculture, Universiti Putra Malaysia. Both of the experiments were arranged in a Randomized Complete Block Design. The first experiment was conducted in a factorial design with four levels of N (0, 10, 20, 30 kg $ha^{-1}$) and P (0, 20, 40 and 60 kg $ha^{-1}$). The second experiment was conducted using different levels of nitrogen, phosphorus, compost, biofertilizer and gypsum. Mineral composition of the seed was determined by dry ashing method. Amino acid content in the seed was determined by HPLC. Fiber determination was carried out by utilizing fibertec system. An extraction of lipid was utilized by using soxtec system. In the first experiment, the vegetative growth of the plant i.e. plant height (20.65 cm), leaves number (262), branch number (86.50) and leaf area (2140.54 $cm^2$) was attained at N and P ($N_{30}$ + $P_{60}$ kg $ha^{-1}$) application. The maximum pod number per plant (47.25) was attained in the treatment of $T_{16}$ ($N_{30}$ and $P_{60}$ kg $ha^{-1}$) i.e. the highest amount of N and P application. From the results, it is revealed that the seed of bambara groundnut contains 20.30% protein, 5.01% fibre, cysteine 11.3 mg $kg^{-1}$, alanine 42.5 mg $kg^{-1}$, 663.3 mg $kg^{-1}$ Ca, and 650.5 mg $kg^{-1}$ Mg. In the second experiment, compost, biofertilizer, gypsum was used along with the combination of N and P (two best selected treatments from the first study and also recommended dose of N and P). In this study, N and P fertilizers played dominating role for vegetative growth of the plant. Plant height (21.73 cm), leaves number (265.50) and leaf area (2802.9 $cm^2$) increased with the application of highest level of N and P i.e. $T_1$ (control) ($N_{30}$ + $P_{60}$ kg $ha^{-1}$) application. The maximum number of pod (41.75) and highest pod weight (49.68 g) were also attained by $T_1$ ($N_{30}$ + $P_{60}$ kg $ha^{-1}$). Protein 19.95%, fiber 5.20%, histidine 30 mg $kg^{-1}$, methionine 14.8 mg $kg^{-1}$, potassium 448.8 mg $kg^{-1}$ and manganese 24.4 mg $kg^{-1}$ were contained in the seed of bambara groundnut. From the two experiments, it is presented that application of compost and different levels of fertilizer had no major changes in the nutritional value of bambara groundnut. However, the application of $N_{30}$ and $P_{60}$ kg $ha^{-1}$ fertilizer, vegetative growth and yield of the plant was better than all other treatments in both experiments. For

getting maximum growth, yield and seed quality of bambara groundnut $N_{30}$ kg $ha^{-1}$ and $P_{60}$ kg $ha^{-1}$ could be recommended.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**KESAN NITROGEN, FOSFORUS DAN KOMPOS KE ATAS PERTUMBUHAN, HASIL DAN KUALITI BIJI BENIH POKOK KACANG BAMBARA**

Oleh

**MD. MAHMUDUL HASAN**

**Jun 2018**

**Pengerusi : Md. Kamal Uddin, PhD**
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Kacang bambara (*Vigna subterranea*) ialah tanaman yang berasal dari Afrika. Biji benihnya mengandungi 63% karbohidrat, 19% protein dan 6.5% minyak dan merupakan sumber serat, kalsium, zat besi dan kalium. Oleh itu, kajian ini mengkhususkan tentang penentuan kesan nitrogen, fosforus dan kompos ke atas pertumbuhan, hasil dan kualiti biji benih kacang bambara. Dua eksperimen rumah kaca telah dijalankan di Ladang 15, Fakulti Pertanian, Universiti Putra Malaysia. Kedua-kedua eksperimen dijalankan menggunakan rekabentuk blok rawak lengkap (RBRL). Eksperimen pertama dilakukan dalam bentuk factorial melibatkan empat kadar nitrogen (0, 10, 20, 30 kg $ha^{-1}$) and fosforus (0, 20, 40 and 60 kg $ha^{-1}$). Eksperimen kedua pula dijalankan dengan menggunakan kadar nitrogen, fosforus, kompos, biobaja dan gipsum yang berbeza. Komposisi mineral biji kekacang ini telah dianalisis menggunakan kaedah "dry ashing" manakala kandungan asid amino telah ditentukan dengan HPLC. Penentuan serat dilakukan dengan menggunakan sistem fibertec. Pengekstrakan lipid telah digunakan dengan menggunakan sistem soxtec. Dalam eksperimen pertama, pertumbuhan vegetative pokok iaitu tinggi pokok (20.65 cm), jumlah daun (262), jumlah dahan (86.50) dan luas daun (2140.54 $cm^2$) telah terhasil dengan penggunaan N dan P padakadar $N_{30}$ dan $P_{60}$ kg $ha^{-1}$. Jumlah maksimum pod setiap pokok (47.25) terhasil daripada rawatan $T_{16}$ ($N_{30}$ dan $P_{60}$ kg $ha^{-1}$) iaitu penggunaan N dan P yang terbanyak. Hasil kajian ini menunjukkan bahawa biji benih kacang bambara mengandungi 20.30% protein, 5.01% serat, 11.3 mg $kg^{-1}$ cysteine, 42.5 mg $kg^{-1}$ alanine, 663.3 mg $kg^{-1}$ Ca dan 650.5 mg $kg^{-1}$ Mg. Dalam eksperimen kedua, kompos, biobaja dan gypsum telah digunakan bersama-sama dengan kombinasi N dan P (dua rawatan terbaik daripada kajian pertama dan juga kadar N dan P yang disyorkan). Dalam kajian ini, baja, N dan P mendominasi peranan untuk partumbuhan vegetative pokok. Tinggi pokok (21.73 cm), jumlah daun (265.50) dan luas daun (2802.9 $cm^2$) meningkat dengan aplikasi N dan P yang tertinggi iaitu $T_1$ (kawalan) ($N_{30}$ + $P_{60}$ kg $ha^{-1}$). Jumlah maksimum pod (41.75) dan berat pod (49.68 g) yang tertinggi juga terhasil daripada rawatan $T_1$ ($N_{30}$ + $P_{60}$ kg $ha^{-1}$). Protein 19.95%, serat 5.20%, histidine 30 mg $kg^{-1}$, methionin 14.8 mg $kg^{-1}$, kalium 448.8 mg $kg^{-1}$ dan mangan 24.4 mg $kg^{-1}$ terkandung dalam biji benih kacang bambara. Dua eksperimen ini jelas menunjukkan aplikasi kompos dan kadar baja yang berbeza tidak mempengaruhi secara

ketara nilai nutrisi kacang bambara. Tetapi, aplikasi baja sebanyak $N_{30}$ kg $ha^{-1}$ dan $P_{60}$ kg $ha^{-1}$ menyebabkan pertumbuhan vegetative dan hasil pokok yang lebih berbanding rawatan yang lain dalam kedua-dua eksperimen. Untuk mendapatkan pertumbuhan maksimum hasil dan kualiti biji benih bambara $N_{30}$ kg $ha^{-1}$ dan $P_{60}$ kg $ha^{-1}$ boleh disyorkan.

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I certify that an examination committee has met on 1 June 2018 to conduct the final examination of Md. Mahmudul Hasan on his Master of Science thesis entitled "Nitrogen, Phosphorus and Compost Application Effects on Growth, Yield and Seed Quality of Bambara Groundnut" in accordance with UniversitiPertanian Malaysia (Higher Degree) act 1980 and UniversitiPertanian Malaysia (Higher Degree) regulations 1981. The committee recommends that the candidate be awarded the relevant degree

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This thesis is submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date:

**Declaration by graduate student**

I hereby confirm that:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
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## LIST OF ABBREVIATION

| | |
|---|---|
| Ala | Alanine |
| Arg | Arginine |
| ANOVA | Analysis of Variance |
| CFU | Colony Forming Unit |
| Cys | Cysteine |
| Gly | Glycine |
| His | Histidine |
| HPLC | High Performance Liquid Chromatography |
| Leu | Leucine |
| Lys | Lysine |
| Meth | Methionine |
| mg | Milligram |
| SAS | Statistical Analysis System |
| UPM | Universiti Putra Malaysia |
| Val | Valine |

# CHAPTER 1

## INTRODUCTION

Bambara groundnut (*Vigna subterranean*) is an African leguminous crop. This crop is also cultivated in many other countries as the most important and efficent pulse crop. It has the ability to resists disease, drought and also to produce a good yield in the poor soils. Bambara groundnut seed contain enough carbohydrate, protein and fat to make it as a complete food (Kwaga *et al.,* 2015).

Bambara groundnut responds positively on many agronomic parameter with the application of nitrogen fertilizer. Nitrogen stability is the quality of fixed N minus and amount of nitrogen detached in collected grain (Idikut *et al*., 2011) and is a determine of the net nitrogen input of legumes to soil nitrogen. The condition of nitrogen in the legume is affected then nodulation is also being affected.

Following nitrogen, phosphorus is considered as crucial mineral fertilizer for the production of the crop. In the plant, during its basic functions it manipulates the development of the nodule. Many physiological factors in the legume like photosynthesis, growth of the root, sugar translocation are directly or indirectly manipulate by phosphorus. In the soil, phosphorus is remaining as a key constitute and produced phosphate mineral (Marschner, 2012). For the successful crop production there is numerous information on the use of inorganic fertilizer and this information also have a preference that the use of inorganic fertilizer is beneficial for the growth and productivity of the crops.

Organic fertilizer has positive effects and enhance the nutrient availability in the soil (Islam *et al.,* 2016). Compost is well recognized among all the organic fertilizer. In the soil, compost supply many nutrient, organic matters and also microorganism which are useful and these things develop the health of the crop growth, quality and yields. In the degraded and low fertility soil, it can get better in the characteristics of soil and also a good source of N, P and K for the plant (Aziz *et al*., 2017).

Bambara groundnut not only cultivated as a single stand but also it can be grown intercropped with many other crops. In the light soil the harvesting of bambara groundnut is not so difficult. Vegetative growth of the plant is higher in the soil which is rich in N and for that reason seed produced is hampered (Adegbola and Bamishaiye, 2011). The condition of getting the higher yield in bambara groundnut plant is the preparation of good seed bed and also the field is extremely ploughed. It gains maximum size and also stats to form pod within 30 days after the application of fertilizer.

The most important characteristics of the seed are generally viability, storability and vigor. The seed can be eaten at mature and immature stage also. Bambara groundnut seed also is eaten after boiling. The method of cooking of seed is very easy (Berchie *et. al*., 2010). The seed contain 65% carbohydrate, 18% protein and 6.5% of fat and also the amount of calcium, fibre, iron and potassium is also good. Amount of protein is high in the seed of bambara groundnut (Massawe *et al.,* 2005). Bambara groundnut seed also contain a good amount of protein, moisture, fat, ash and total carbohydrate are 16, 9.7, 5.9, 2.9 and 64.9 percent, respectively. The seed of bambara groundnut is believed as a balance human diet because its full of nutritional value (Mazahib *et al.,* 2013).

There are many studies on bambara groundnut on its abilities to withstand drought stress but less about the level of nitrogen, phosphorus and compost to get optimum growth, yield and seed quality specifically in Malaysia. Research priorities need to be simplified in order to get the development of some underutilized crops, like bambara groundnut.

The objectives of this experiment were as following:

1. To determine the effect of N and P application rates on the growth, yield and seed quality of bambara groundnut.

2. To evaluate the effect of selected application rates of N, P and compost on the growth, yield and seed quality of bambara groundnut.

## REFERENCES


Abdul Jabbar, B.K. and Saud, H.M. (2012). Effect of phosphorus on biological nitrogen fixation in soyabean under irrigation using saline water. *Global Journal of Science Frontier Research Agriculture and Biology*, 12: 65-72.

Abbasdokht, H. and Gholami, A. (2010). The effect of seed inoculation and different levels of fertilizers on yield and yield components of wheat cultivars. *World Academy of Science Engineering and Technology*, 68: 979-983.

Abdulsalami, M., and Sheriff, H. (2010). Effect of processing on the proximate composition and mineral content of bambara groundnut (*Voandezeia subterranean*). *Bayero Journal of Pure and Applied Sciences*, 3(1): 188-190.

Adam, M., Abdualrahman, Y., Ali, A. O. and Elkhalifa, E. A. (2015). Chemical, minerals, fatty acid and amino acid compositions of sudanese traditional khemiss-Tweria supplemented with peanut and bambara groundnuts. *American Journal of Food Technology*, 3: 100–108.

Adegbola, O. M. B. J. A. and Bamishaiye, E. I. (2011). Bambara groundnut : an under-utilized nut in Africa. *Advances in Agricultural Biotechnology*, 1: 60–72.

Adeyeye, E. I. (2011). Effects of processing on the nutritional and anti-nutritional factors of *(Arachis hypogaea)* groundnut seed flour. *International Journal of Chemical Science*, 1: 131-142.

Afolabi, T.A. (2012). Synthesis and physiochemical properties of carboxymethylated bambara groundnut (*Voandzela subterranean*) starch. *International Journal of Food Science and Technology*, 3: 445-451.

Akwetey, Worlah Y.E., William O. and Oduro, I.N. (2012). Using whole cowpea flour (WCPF) in frankfurter-type sausages. *Journal of Animal and Veterinary Advances*, 10: 450-455.

Al Abboud, M.A., Ghany, T.A. and Alawlaqi, M.M. (2014). Role of biofertilizer on in agriculture: a brief revew. *Mycopath*, 11(2): 95-101.

Alhassan, G.A. and Egbe, M.O. (2014). Bambara groundnut / maize intercropping : Effects of planting densities in Southern guinea savanna of Nigeria. *African Journal of Agricultural Research*, 4: 479–486.

Altab, M.H. and Hamid, A. (2007). Effect of nitrogen, phosphorus and zinc application on yield and uptake of nutrients by groundnut. *Bangladesh Journal of Agrilculture Research*, 3: 369–374.

Anhwange, B.A. and Atoo, G. H. (2015). Proximate composition of indigenous bambara groundnuts (*Vigna subterranean* (L.) Verdc). *Journal of Pure and Applied Science*, 1: 11–16.

Aviara, N. A., Lawal, A. A., Atiku, A. A. and Haque, M. A. (2013). Bambara groundnut processing, storage and utilization in north eastern Nigeria. *International Journal of Engineering Science,* 8(1): 28-36.

Ayo1, J. A. and Andrew, E. (2016). Effect of added Bambara groundnut on the quality of acha-date palm based biscuit. *International Journal of Biotechnology and Food Science*, 4(3): 34-38.

Aziz, M. A., Ahmad, H. R., Corwin, D. L., Sabir, M., Hakeem, K. R. and Ozturk, M. (2017). Influence of farmyard manure on retention and availability of nickel, zinc and lead in metal-contaminated calcareous loam soils. *Journal of Environmental Engineering and Landscape Management*, 3: 289–296.

Bamshaiye, O.M., Adegbola, J.A. and Bamishaiye, E.I. (2011). Bambara groundnut: an under-utilized nut in Africa. *Advances in Agricultural Biotechnology* l: 60-72.

Bandopadhyay, P., Samui, R. C. and Bera, P. S. (1998). Performance of kharif groundnut (*Arachis hypogaea*) cultivars with different sources of sulphur in West Bengal. *Indian Agriculturist*, 42(3): 175-179.

Baudoin, J.P. and Mergeai, G. (2001). Effects of plant density, *Rhizobium* inoculation and microelements on nodulation, chlorophyll content and yield of chickpea (*Cicer arietinum* L.). *Journal of Biology and Agricultural Research*, 23: 1067-1178.

Begemann, F., and Mushonga, J. N. (1997). Proceedings of the workshop on conservation and improvement of bambara groundnut (*Vigna subterranea* (L.) Verdc.): 14-16 November 1995, Harare, Zimbabwe. Bioversity International.

Belel, M. D., Halim, R. A., Rafii, M. Y. and Saud, H. M. (2014). Intercropping of corn with some selected legumes for improved forage production : A Review. *Journal of Agricultural Science*, 3: 48–62.

Belimov, A.A., Kojemiakov, P.A. and Chuvarliyeve, C.V. (1995). Interaction between barley and mixed cultures of nitrogen fixing and phosphate solubilizing bacteria, *Plant Soil*, 17: 29-37.

Benoi, K. B. (2013). Assessment of twenty bambara groundnut (*Vigna subterranea* L. Verdc) landraces using quantitative morphological traits. *International Journal of Plant Research*, 3: 39–45.

Benvindo, S. M. M. V. (2014). Effects of manure, lime and phosphorus fertilizer on soil Properties and soybean (*Glycine max* l.) yields in Embu County, Kenya (Doctoral dissertation).

Berchie, J.N., Sarkodie-Addoo, J., Adu-Dapaah, H., Opoku, M., Addy, S., Asare, E. and Donkor, J. (2010). Yield evaluation of three early maturing bambara groundnut (*Vigna subterranean* L. verdc.). Landraces at the CSIR-crops research institute fumesua khumasi, Ghana. *Journal of Agronomy,* 4: 175-179.

Bhuiyan, M.M.H., Rahman.M.M., Afroze, F., Sutradhar, G.N.C. and Bhuiyan, M.S.I. (2008). Effect of phosphorus, molybdenum and *Rhizobium* inoculation on growth and nodulation of mungbean. *Journal of Soil and Nature*, 2: 25-30.

Biswas, J.C., Ladha, J.K. and Dazzo, F.B. (2000). Rhizobia inoculation improves nutrient uptake and growth of lowland rice. *Pakistan Journal of Botany*, l64: 1644-1650.

Boswell, C. C. and Friesen, D. K. (1993). Elemental sulfur fertilizers and their use on crops and pastures. *Fertilizer research*, 35(1-2); 127-149.

Brink, M. and Belay, G. (2006). Cereals and pulses (Vol. 1). PROTA.

Chu, G.X., Shen, Q.R., and Cao, K.L. (2004). Nitrogen fixation and N transfer from peanut to rice cultivated in aerobic soil in an intercropping system and its effect on soil N fertility. *Plant and Soil*, 263(1): 17-27.

Cotteine, A. (1980). Soil and plant testing as a basis of fertilizer recommendation. F.A.O. Soil Bulletin 6. F.A.O. Rome, Italy. p.100.

Devi, K. N., Singh, L. N. K., Singh, M. S., Singh, S. B. and Singh, K. K. (2012). Influence of sulphur and boron fertilization on yield, quality, nutrient uptake and economics of soybean (*Glycine max*) under upland conditions. *Journal of Agricultural Science*, 4(4): 1.

Dikr, W. and Belete, K. (2017). Review on the effect of organic fertilizers, biofertilizers and inorganic fertilizers (NPK) on growth and flower yield of marigold. *Academic Research Journal of Agricultural Science and Research*, 5(3): 192-204.

Ellah, M.M. and Singh, A. (2008). Bambara groundnut (*Vigna subterranea*) yield as influenced by phosphorus and cultivars in the semi-arid Savanna of Nigeria. *Journal of Plant Sciences*, 3:176-181.

Enwere, N. J. and Hung, Y. C. (1996). Some chemical and physical properties of bambara groundnut (*Voandzeia subterranea*) seed and products. *International journal of food sciences and nutrition*, 47(6): 469-475.

FAO. (1982). Legume in human nutrition, FAO Food and Nutrition Paper No. 20, Food and Agriculture Organization of the United Nation, Rome, Italy.

Fenton, T. W. and Fenton, M. (1979). An improved procedure for the determination of chromic oxide in feed and feces. *Canadian Journal of Animal Science*, 3: 631-634.

Fukui, R., Schroth, M.N. Hendson, M. Hancock, J.G. and Firestone. M.K. (1994). Growth patterns and metabolic activity of *Pseudomonas* in sugar beet spermospheres: Relationship to pericarp colonization by *Pythium ultimum*. *Phytopathol*, 84: 1331-1338.

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures for Agricultural Research, John and Wiley.

Gonzalez, D, Alvarez, R. and Matheus, J. (2001). Comparison of three organic fertilizers for the production of sweetcorn (*Zea mays*). Inter *American Society for Tropical Horticulture*, 45: 106-109.

Halvorson, A.D., Follett, R.F., Bartolo, M.E. and Schweissing, F.C. (2002). Nitrogen fertilizer use efficiency of furrow-irrigated onion and corn. *Agronomy Journal*, 94: 442-449.

Harries, R.S. and Loesecke, H.V. (1960). Nutritional evaluation of food processing. John Wiley and Sons, Inc. New York. 69p.

Hayat, R., Iftikhar-ul-hassan, M., Akram, S. and Sheirdil, R. A. (2012). Evaluation of compost application for improving legumes yield and $N_2$ fixation. *African Journal of Biotechnology*, 41: 9758–9764.

Hossain, M. A., Hamid, A., and Nasreen, S. (2007). Effect of nitrogen and phosphorus fertilizer on N/P uptake and yield performance of groundnut (*Arachis hypogaea* L.). *Journal of Agricultural Research*, Pakistan.

Idikut, L. and Kara, S. N. (2011). The effects of previous plants and nitrogen rates on second crop corn. *Turkish Journal of Field Crops*, 2: 239-244.

Idowu, R.F. (2007). Nitrogen fixation by legumes. Extension Agronomists, Department of Extension Plant Sciences, New Mexico State University. p. 1–4.

Ijarotimi, O.S. and Esho, T.R. (2009). Comparison of nutritional composition and anti-nutrient status of fermented, germinated and roasted bambara groundnut seeds (*Vigna subterranea).British Food Journal* 4: 376–386.

Ikenganyia, E. E., Anikwe, M. A. N. and Ngwu, O. E. (2017). Responses of bambara groundnut *Vigna subterranea*(L.) Verdc. to phosphate fertilizer rates and plant spacing and effects on soil nutrient statues in a degraded tropical ultisol Agbani Enugu South East Nigeria. *International Journal of Plant and Soil Science*, 17(4): 1-17.

Iman, A., Farag, A. and Ahmed A.Z. (2014). Groundnut (*Arachis hypogaea* L.) growth and yield responses to seed irradiation and mineral fertilization. *Journal of Agriculture and Veterinary Science*, 5: 63–70.

Islam, M.A., Boyce, A.N., Rahman, M.M., Azirun, M.S., and Ashraf, M. A. (2016). Effects of organic fertilizers on the growth and yield of bush bean, winged bean and yard long bean. *Brazilian Archives of Biology and Technology*, 59: 1–9.

Jagadeeswaran, R. Murugappan, V. and Singaram, P. (2001). Effect of ferrogypsum on yield, nutrient uptake and quality in groundnut. *Madras Agricultural Journal*, 88: 210-213

Jakusko, B.B., Dakato, M.E., Ali, A. and Makanda, I. (2012). Mycorrhiza-*RhizobiumVigna subterranea* dual symbiosis : Impact of microbial symbionts for growth and sustainable yield improvement, 1: 915–921.

Jonah, P.M., Aliyu, B., Adeniji, T.O. and Bello, D. (2012). Seasonal variation and pearson correlation in yield and yield components in bambara groundnut. *World Journal of Agricultural Sciences* 1: 26-32.

Khan, A., Jan, M.T., Marwat, K.B. and Arif, M. (2009). Organic and inorganic nitrogen treatments effects on plant and yield attributes of maize in a different tillage systems. *Pakistan Journal of Botany*, 41(1): 99-108.

Kizilkay, R. (2008). Yield response and nitrogen concentrations on spring wheat inoculated with *Azobacter chroococcum* strains. *Ecological Engineering*, 33: 150-156.

Kjeldahl, J. (1883). A new method for the determination of nitrogen in organic matter. *Journal of Analytical chemistry,* 1: 366-382.

Kumaran, S., Solaimalai, A., Ravisankar, N. and Chandrasekaran, B. (2000). Role of organic, inorganic fertilizers and gypsum application in groundnut: a review. Agricultural reviews-agricultural research communications centre India, 21(3): 193-198.

Kwaga, Y.M., Simon, M., and Kwada, S.B. (2015). Effect of different rates of pendimenthalin on weed control in bambara groundnut (*Vigna subterranean* L . Verd.) in semi- arid Savanna , Nigeria. *Global Advanced Research Journals*, 12: 905–910.

Laldinthar R, and Dkhar, M.S. (2015). Relationship between soil bacterial population and various physico-chemical properties at two broad leaved forest stands of Meghalaya differing in altitudes. *Transcriptomics,* 3: 125.

Leconte, M. C., Mazzarino, M. J., Satti, P., and Crego, M. P. (2011). Nitrogen and phosphorus release from poultry manure composts: the role of carbonaceous bulking agents and compost particle sizes. *Biology and fertility of soils*, 47 (8): 897-906.

Lin, H., Li, Z. C., Yong-qing Z. and Wen-hui. (2006). Effect of dietary traditional chinese medicines on apparent digestibility coefficients of nutrients for white shrimp. *Aquaculture*, 253: 495–501.

Linnemann, A. R. (1992). Bambara groundnut (*Vigna subterranea*) literature: a revised and updated bibliography. Department of Tropical Agriculture, Wageningen Agricultural University.

Mabhaudhi, T., Modi, A. T. and Beletse, Y. G. (2013). Growth, phenological and yield responses of a bambara groundnut (Vigna subterranea L. Verdc) landrace to imposed water stress: II. Rain shelter conditions. *Water SA*, 2: 191-198.

Maidala, A. and Jarmari, S. M. (2017). Nutritional evaluation of toasted bambara nut meal (*Vigna subterranean* L. Verde) on growth performance and carcass characteristics of harco cockerels. *Journal of Science, Technology and Education*, 4: 23-29.

Mairura, F.S. Mugendi, D.N., Mwanje, J.I., Ramisch, J.J., Mbugua, P.K. and Chianu, J.N. (2007). Integrating scientific and farmer's evaluation of soil quality indicators in central Kenya. *Geoderma,* 139: 134-143.

Makanda, I., Tongoona, P., Madamba1, R., Icishahayo, D., and Derera, J. (2009). Evaluation of bambara groundnut varieties for off-season production in Zimbabwe. *African Crop Science Journa,* 3: 175–183.

Mandal, A., Patra, A.K., Singh, D., Swarup, A. and Ebhin, M.R. (2007). Effect of long term application of manure and fertilizer on biological and biochemical activities in soil during crop developmet stages. *Bioresorces Technology*, 98:

3585-3592.
Manga, T.A., Sanchi, I.D., Baba, M.D. and Dabai, J.S. (2014). Costs and returns of groundnut rocessing among rural women in Sokoto state, Nigeria. *The Journal of Agriculture and Natural Resources Sciences*, 1(4): 214-219.
Marschner, P. and Rengel, Z. (2012). Nutrient availability in soils. In Marschner's Mineral Nutrition of Higher Plants (Third Edition). p. 315-330.
Mathur, B.S. (1994). Acid soils of Bihar their characteristics and management. SSAC (BAU) Ranchi, Research Bull. No. 1/94.
Massawe, F. J., Mwale, S. S. and Roberts, J. A. (2005). Breeding in bambara groundnut (*Vigna subterranea* (L.) Verdc.) strategic considerations. *African Journal of Biotechnology*, 6: 463–471.
Materechera, S.A., Motsuenyane, B., and Modise, J.R. (2007). The effects of soil amendments and mulch on emergence, pod development and yield of Bambara groundnut (*Vigna subterranea* L.) in a hard-setting soil. *South African Journal of Plant and Soil*, 2: 100–105.
Mazahib, A.M., Nuha, M.O., Salawa, I.S. and Babiker, E.E. (2013). Some nutritional attributes of bambara groundnut as influenced by domestic processing. *International Food Research Journal*, 3: 1165–1171.
Mazzilli, S.R., Kemanian, A.R., Ernst, O.R., Jackson, R.B. and Pineiro, G. (2015). Greater humification of below ground than above ground biomass carbon into particulate soil organic matter in no-till corn and soybean crops. *Soil Biology and Biochemistry*, 85: 22–30.
McCauley, A., Jones, C. and Jacobsen, J. (2009). Soil pH and organic matter. *Nutrient management module*, 8: 1-12.
Meena, S., Malarkodi, M. and Senthilvalavan, P. (2007). Secondary and micronutrients for groundnut-A review. Agricultural reviews-agricultural research communications centre India, 28(4): 295.
Minka, S.R. and Bruneteau, M. (2000). Partial chemical composition of bambara bean (*Vigna subterranean* (L.) verdc). *Food Chemistry* 68: 273-276.
Mohammed, M.S., Shimelis, H.A. and Laing, M.D. (2016). Preliminary investigation on some agronomic and morphological variations of within and between bambara groundnut landraces. *Journal of Agricultural Science and Technology*, 18: 1909–1920.
Mune, M.A., Minka, S.R., Lape, M.I. and Etoa, F.X. (2011). Nutritional potential of bambara bean protein concentrate. *Pakistan Journal of Nutrition,* 10: 112-119.
Mune, M.A., Mbome, L.I. and Minka, S.R. (2007), Improving the nutritional quality of cowpea and bambara bean flours for use in infant feeding. *Pakistan Journal of Nutrition*, 6: 660-664.
Murevanhema, Y.Y. and Jideani, V.A. (2013). Potential of bambara groundnut (*Vigna subterranean* (L.) Verdc.) milk as a probiotic beverage- a review. Critical reviews in *Food Science and Nutrition,* 53: 9.
Nordin, N. and Singh, A. (2015). Seedling emergence of bambara groundnut (*Vigna subterranea* (L.) Verdc.) landraces at various temperature conditions. *Procedia Environmental Sciences*, 29: 201–202.
Ntundu, W., Shillah, S., Marandu, W., and Christiansen, J. L. (2006). Morphological diversity of bambara groundnut (*Vigna subterranea* L. Verdc.) landraces in Tanzania. *Genetic Resources and Crop Evolution*, 53: 367-378.
Nweke, I.A. and Emeh, H.O. (2013). The Response of bambara groundnut (*Vigna Subterranea* (L.) Verdc). To phosphate fertilizer levels in igbariam South East Nigeria. *Journal of Agriculture and Veterinary Science*, 1: 28–34.
Nyau, V., Prakash, S., Rodrigues, J. and Farrant, J. (2015). Antioxidant activities of

Bambara groundnuts as assessed by FRAP and DPPH assays. *American journal of Food and Nutrition*, 3: 7-11.

Nyoki, D., and Ndakidemi, P.A. (2014). Effects of *Bradyrhizobium japonicum* and phosphorus supplementation on the productivity of legumes. *International Journal of Plant and Soil Science,* 7: 894–910.

Okonkwo, S.L. and Opera, M.F. (2010). The analysis of bambara groundnut (*Vonandzeia subterranean* L.) for sustainability in Africa research. *Journal of Applied Science,* 6: 394-396.

Okon, J. E. (2016). Effects of groundnut spacing on yield and weed control in the rainforest agro-ecological zone of Nigeria. *Research Journal of Agriculture and Food Science*, 12: 374–377.

Olivera, M.N., Tejera, C., Iribarne, A., Ocana and Lluch, C. (2004). Growth, nitrogen fixation and ammonium assimilation in common bean *(Phaseolus vulgaris*): effect of phosphorus. *physiologia plantarum*, 121: 498-505.

Patra, A.K., Samui, R.C., Tripethy, S.K., Mohhapatr, S.C. and Nanoda, M.K. (1995). Physiological basis of yield variation in kharif groundnut as influenced by variety, potassium and planting methods. *Indian Journal of Agricultural Sciences*, 38: 233- 238.

Ponmurugan, P. and Gopi, C. (2006). Distribution pattern and screening of phosphate solubilizing bacteria isolated from different food and forage crops. *Agronomy Journal*, 5: 600-604.

Rahman, M.A., Haque, E., Hasanuzzaman, M., Muhuri, S.R. and Shahid, I.Z. (2011). Evaluation of antinocieptive and antidiarrhoeal properties of *Pistia stratiotes* (*Araceae*) leaves. *Journal of Pharmacology and Toxicology, 6: 596-601.*

Ross, D. S. and Ketterings, Q. (1995). Recommended methods for determining soil cation exchange capacity. Recommended soil testing procedures for the northeastern United States, 2: 62-70.

Sabiel, A.I.S., Mohamed, I., Elgailani, I.A. and Osman, K.A. (2014). Enetic variation of groundnut (*Arachis hypogaea* L.) genotypes in semi-arid zone Sudan. *International Journal of Environment*, 3: 16–23.

Salehin, F. (2012). Effects of zinc and nitrogen fertilizer and their application method on yield and yield components of *Phaseolus vulgaris* L*., Agricultural Sciences*, 1: 9–13..

Shazana, M. A. R. S., Shamshuddin, J., Fauziah, C. I. and Syed Omar, S. R. (2013). Alleviating the infertility of an acid sulphate soil by using ground basalt with or without lime and organic fertilizer under submerged conditions. *Land Degradation and Development*, 2: 129-140.

Shegro, A.G., Atilaw, A., Pal, U.R. and Geleta, N. (2010). Influence of varieties and planting date on productivity of soybean in Metekel zone, North Western Ethiopia. *Journal of Agronomy*, 9: 146-156.

Shegro, A.G., Jansen V.R. and Adebola, P.O. (2013). Assessment of genetic variability in Bambara groundnut (*Vigna subterrenea* L. Verdc.) using morphological quantitative traits. *Academia Journal of Agricultural Research*, 1: 45-51.

Soil Survey Staff: Keys to soil taxonomy, 12th ed. USDA-Natural Resources Conservation Service, Washington, DC, 2014.

Song, C.J., Ma, K,M., Qu, L.Y., Liu, Y., Xu, X.L. and Fu, B.J. (2010). Interactive effect of water, nitrogen and phosphorus on the growth biomass partitioning and water use efficiency of *Bauhina faberi* seedlings. *Journal of Arid Environment*, 74(9): 1003-1012.

Soto, P.O., Jahn, E.B. and Arredondo, S.S. (2004). Improvement of protein percentage in corn silage with an increase in and partitioning of nitrogen fertilization. *Agricultura Técnica,* 64(2): 156-162.

Srikumar, T.S. and Ackerman, P.A. (1990). The effect of fertilization and manuring on the content of some nutrient in potato. *Food Chemistry*, 37(1): 47-60.

Strydom, D.J. and Cohen, S.A. (1994). Comparison of amino acid analyses by phenylisothiocyanate and 6-aminoquinolyl-n-hydroxysuccinimidyl carbamate precolumn derivatization. *Analytical Biochemistry*, 222: 19-28.

Swanevelder, C.J. (1998). Bambara food for Africa: *Vigna subterranean* bambara groundnut. National department of Agriculture, South Africa Vurayai,

Tairo, E. V. and Ndakidemi, P. A. (2014). Micronutrients uptake in soybean (*Glycine max* L.) as affected by *Bradyrhizobium japonicum* inoculation and phosphorus (p) supplements. *World Journal of Soil and Crop Sciences Research*, 1: 1-9.

Tauro, T.P., Nezomba, H., Mtambanengwe, F. and Mapfumo, P. (2010). Population dynamics of mixed indigenous legume fallows and influence on subsequent maize following mineral P application in smallholder farming system of Zimbabwe. *Nutrient Cycling in Agroecosystems*, 88: 91-101.

Tim, T. K. (2012). Edible medicinal and non-medicinal plants, Fruits. 4: 1-1022

Toungos, D.T., Sajo, A.A. and Gungula, D.T. (2010). Effects of $P_2O_5$ on the yield and yield Components of bambara groundnut (*Vigna subterranea* (L) verde) in Yola Adamawa State, Nigeria. *World Journal of Fungal and Plant Biology*, 1: 01-07.

Tweneboah, C. K. (2000). Modern agriculture in the tropics. Food Crops. Co. wood publishers, p. 37-191.

Unigwe, A.E., Gerrano, A.S., Adebola, P. and Pillay, M. (2016). Morphological variation in selected accessions of bambara groundnut (*Vigna subterranea* L. Verdc) in South Africa. *Journal of Agricultural Science*, 11: 69.

Van, R., Diman, M., Arthur, D.H., Bram, M.V.V., Henk, W.S. and Adriaan, H. (1994). Soil acidity in relation to groundnut-*Bradyrhizobium* symbiotic performance. *Plant and Soil*, 2: 165-175.

Verma, L. N. (1993). Biofertiliser in agriculture. In: P.K. Thampan (ed.) Organics in soil health and crop production. Peekay tree crops development foundation, cochin, India, pp :152-183.

Vigil, M.F. and Kissel, D.E. (1995). Rate of nitrogen mineralized from incorporated crop residues as influenced by temperature. *Soil Science Society of America Journal,* 59: 1636-1644.

Walley, F.L.G.O., Tomm. A.E.S. and Kessel, C.V. (1996). Allocation and cycling of nitrogen in an alfalfa-bromegrass sward. *Agronomy Journal*, 88: 834-843.

Wamba, O.F., Taffouo, V.D., Youmbi, E., Ngwene, B. and. Amougou, A. (2012). Effects of organic and inorganic nutrient sources on the growth, total chlorophyll and yield of three bambara groundnut landraces in the coastal region of cameroon. *Journal of Agronomy,* 11: 31-42.

Willits. C.O. (1951). Methods for determination of moisture-oven drying. *Analytical Chemistry,*8: 1058–1062.

Yagoub, S.O. Ahmed, W. M. A. and Mariod, A. A. (2012). Effect of urea, NPK and compost on growth and yield of soybean (*Glycine max* L.), in semi-arid region of Sudan. Internationl scholarly research notices. *Agronomy*, p. 1–6.

Yao, D.N., Kouassi, K.N., Erba, D., Scazzina, F., Pellegrini, N., and Casiraghi, M. C. (2015). Nutritive evaluation of the bambara groundnut Ci12 landrace (*Vigna subterranea* (L.) Verdc.) produced in Cote d'Ivoire. *International Journal of Molecular Sciences*, 9: 21428–21441.

Yazdani, M., Bahmanyar, M.A., Pirdashti, H. and Esmaili, M.A. (2009). Effect of phosphate solubilization microorganisms (PSM) and plant growth promoting rhizobacteria (PGPR) on yield and yield components of corn (*Zea mays* L.*)*. *World Academy of Science, Engineering and Technology*, 37: 90-92.

Zandvakili, O.R, Allahdadi, I., Mazaheri, D., Akbari, G.A., Jahanzad, E., and Mirshekari, M. (2012). Evaluation of quantitative and qualitative traits of forage sorghum and lima bean under different nitrogen fertilizer regimes in additive-replacement series. *Journal of Agricultural Science*, 6: 223–235.

Zafar, M., Abbasi, M.K., Nasir, R., Abdul, K., Aqil, S., Muhammad, J. and Muhammad, S. (2013). Influence of integrated phosphorus supply and plant growth promoting rhizobacteria on growth, nodulation, yield and nutrient uptake in *Phaseolus vulgaris*. *African Journal of Biotechnology*, 10: 16781-16792.

Zahran, H.H. (1999). Rhizobium-legume symbiosis and nitrogen fixation under severe conditions and in an arid climate. *Microbiology and Molecular Biology Reviews,* 4: 968–89.

Zarcinas, B.A, Mclaughlin, M.J. and Smart, M.K. (1996). The effect of acid digestion technique on the performance of nebulization systems used in inductively coupled plasma spectrometry. *Communications in Soil Science and Plant Analysis,* 27: 1331-1345.

Zhang, J.J.J., Xiao Y. L., Philippe M., Chuang H., Pei X. S., Raghvendra P.C., Wen F.W.T. (2016). Association of white clover (*Trifolium repens* L.) with rhizobia of sv. trifolii belonging to three genomic species in alkaline soils in North and East China. *Plant and Soil*, 1-2: 417-427.