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# Selection of High Yielding and Farmers' Preferred Genotypes of Bambara Nut (*Vigna subterranea* (L.) Verdc) in Malawi

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## ABSTRACT

Bambara nut (*Vigna subterranea* (L.) Verdc) is a nutritious legume, however, its production is characterised by use of landraces, which have been maintained by farmers. Lack of improved varieties has contributed to low yields. This research was done to identify potentially high yielding and farmers' preferred genotypes for improved production of Bambara in Malawi. A completely Randomised Block Design experiment with eight genotypes (181CR, 181RD, 194, 137CR, 137RD, 317, 2762 and 2768) and four replicates was implemented at Chitedze, Chitala and Mbawa Research Stations to identify high yielding genotypes. In addition to the yield, farmers' criteria based on plant vigour, ability to fully bury its pods in the ground (mounding), yield at harvest, maturity period, seed colour, grain size, taste of boiled dry grain and taste of fresh pods were used to identify farmers' preferred genotypes. Significant yield differences were identified between genotypes ($P < 0.0001$), sites ($P < 0.001$) and interaction between genotypes and sites (environment) ($P < 0.001$). Yield means across sites show that genotype 181CR yielded highly (1322 kg/ha) followed by 2768 (1066 kg/ha), 181RD (1064 kg/ha) and 2762 (841 kg/ha). In contrast to the high yielding genotypes, genotype 137RD gave the lowest yield (485 kg/ha) followed by 194 (573 kg/ha), 317 (617 kg/ha) and 137CR (620 kg/ha). Mbawa Research Station showed significantly high yields with site mean of 1177 kg/ha compared with Chitedze and Chitala with site means of 703 kg/ha and 530 kg/ha respectively. Farmers ranked the eight accessions in order of importance as follows: 181RD, 181CR, 2768, 137CR, 194, 137RD, 2762 and 317. Combination of yield and farmers' preference identified three genotypes (181RD, 181CR and 2768) as potential varieties for production in Malawi. Accessions 181RD and 2768 were specifically selected for relish unlike 181CR, which has been selected for use as snack. However, further research on nutrition, value addition and marketing needs to be conducted on the identified genotypes.

**Keywords:** Genotype Characterisation; Genebank; *Vigna subterranea*

## 1. Introduction

Bambara nut (*Vigna subterranea* (L.) Verdc) is the third most important grain legume in Africa after groundnuts and cowpeas. It makes a complete food as it contains sufficient quantities of protein, carbohydrate and fat [1] and its gross energy exceeds that of other common pulses such as cowpea, lentils and pigeon pea [2]. Varying nutrition composition of Bambara nut is available. Recent nutrition analysis of Bambara nuts [3] and reviews [4-5] show that Bambara nut contains 47% - 64% carbohydrates, 19% - 22% protein, 7% oil and 3.24% - 4.8% ash. Further research on both macro and micro nutrients identified Bambara nut as one of the important sources of Calcium, Potassium, Magnesium, Sodium, Phosphorous, Copper, Iron and Zinc [6]. The nutritional composition of Bambara affirms the notion that Bambara nut can form a complete diet for rural communities where animal protein is in limited supply [5]. In terms of production, Bambara nut has relative advantages over other grain legumes in that it performs well under drought conditions, poor soils, and extreme heat and fixes nitrogen in the soil, hence making it a suitable crop for the low-input production systems [7].

Despite its relative advantages over other grain legumes, Bambara nut is still regarded as one of the neglected and underutilized crops in Africa due to limited research efforts [7]. This status has led to non-existent of improved and readily accepted varieties. Lack of improved varieties contributes to low yields which are as

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low as 400 kg/ha compared with potential yields of 4000 kg/ha [7]. Several efforts have been initiated to improve production of the crop at global level. There is a lot of germplasm diversity of Bambara nut and this offers higher prospects for crop improvement. The International Institute of Tropical Agriculture (IITA) has collected over 1800 accessions of different types of Bambara nut landraces [5,8,9]. Despite the existence of wide genetic diversity of Bambara nut, this valuable resource has not been fully exploited in terms of variety selection and development [10]. Therefore, development of varieties that are readily accepted by farmers remains a fundamental research gap, which requires immediate attention by most national programs including Malawi. In Malawi production of Bambara nut is characterized by use of landraces due to lack of improved varieties [11,12].

Integration of farmers' preference in varieties at an early stage of development enhances adoption rates [13]. This integration is achieved through various ways including participatory variety selection (PVS) [14]. In the PVS, farmers establish their criteria for selection with assistance/guidance from researchers [15]. Therefore, researchers need to involve farmers in development of varieties for enhanced adoption of new technologies.

Initial stage of promoting production of Bambara nut could be selection of promising genotypes with higher yields, farmers' preferred characteristics and wide or specific environmental adaptation. Therefore, this research aimed at identifying high yielding, adaptable and farmers' preferred genotypes for production in Malawi in the short term as breeding initiatives are underway.

## 2. Materials and Methods

### 2.1. Research Sites and Varieties

During the year 2001/2002, 56 genebank accessions collected from Malawi were preliminary characterized with the aim of identifying high yielding accessions. From the 56 accessions eight gave yields between 400 - 1500 kg/ha and were selected for multi-location trial. List of the selected accessions are provided in **Table 1** below. The eight accessions were then systematically evaluated at Chitedze (33.6˚E, 13.9˚S and Alt. 1146 m) in Lilongwe district, Chitala (34.3˚E, 13.7˚S and Alt. 606 m) in Salima district and Mbawa (33.4˚E, 12.1˚S and Alt. 1253 m) in Mzimba district during 2002/2003 and 2003/2004 seasons. In all the sites (**Figure 1**) and seasons, the experiment was laid in Randomised Complete Block Design (RCBD) replicated four times. Yield of unshelled nuts (kg/ha) was recorded.

### 2.2. Evaluation Procedures

For selection of farmers' preferred varieties, 20 farmers per site were invited for participatory variety selection.

**Table 1. List of accessions evaluated in three sites.**

| Accession | Seed characteristics |
|---|---|
| 181CR | Cream with black dots |
| 181RD | Red |
| 137CR | Cream |
| 137RD | Red |
| 194 | Brown |
| 317 | Light red |
| 2762 | Brown with black spots |
| 2768 | Cream white |

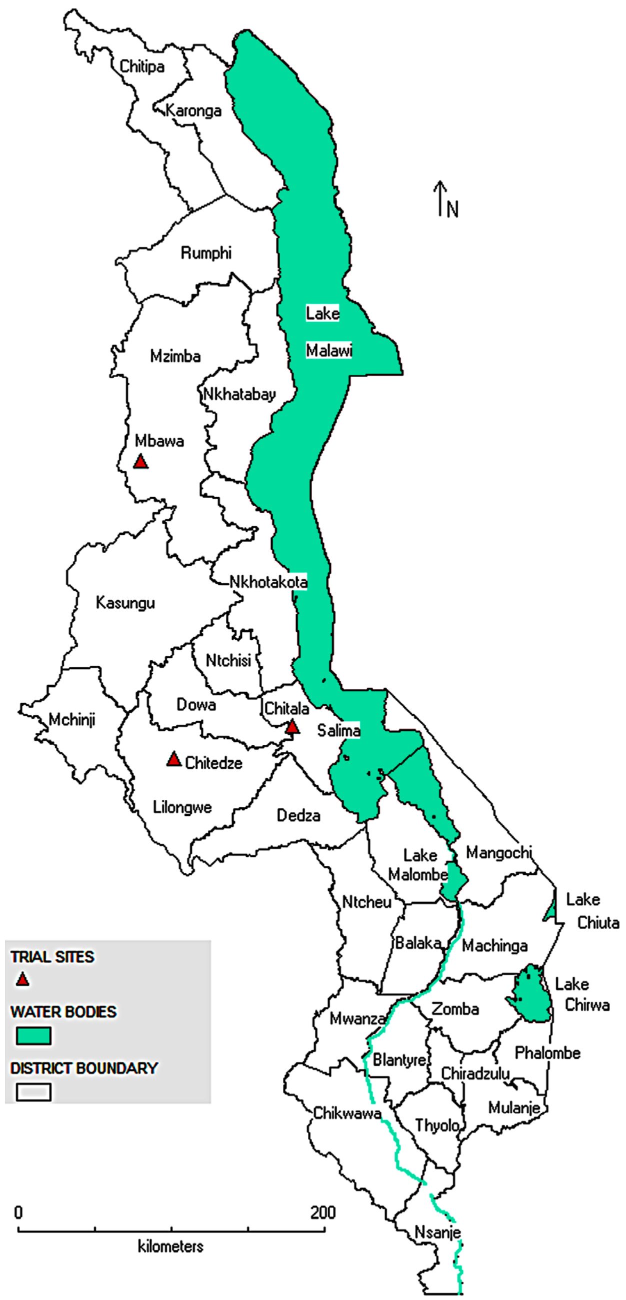

**Figure 1. Location of the three experimental sites.**

 

Farmers scored the accessions at vegetative, harvesting and post harvesting stages. Criteria for scoring were developed by farmers with assistance from researchers as follows: plant vigour in the field, ability to fully bury its pods in the ground, maturity period, seed colour, grain size, taste of boiled dry grain and taste of fresh pods. All the data for farmers were scored on a 1 - 5 scale with 1 representing lowest and 5 the highest.

### 2.3. Statistical Analysis

Data from experiments were subjected to pooled analysis of variance over the two seasons using general linear model (GLM) in SAS 9.2 statistical package (SAS Inc, USA). The data were pooled because there was no significant difference between the seasons. Significantly different variables were further analysed for mean separation using the Least Significant Difference (LSD) procedure at $\alpha = 0.05$. Performance of accessions across sites was compared using regression analysis where site means (environmental effect) was regressed against varietal means over the two years. Data from farmers were summarized to rank accessions based on desirable traits. Farmers' criteria and research experimental results were combined to identify high yielding and the most preferred genotypes for production.

## 3. Results and Discussion

Lack of improved Bambara varieties requires identification of high yielding genotypes from the existing diversity. In this study, significant yield differences ($P < 0.0001$) were observed for means in all genotypes and across the three sites (**Table 2**).

Accession means across sites ranged between 485 - 1322 kg/ha (**Table 3**). The high yielding accessions compare very well with yields from other studies and surpass the average farm yields in Malawi. In Malawi farmers realize an average yield of 400 kg/ha (Government of Malawi, 2000). The identification of high yielding genotypes (181CR, 181RD, 2768 and 2762) will significantly improve production of the crop in Malawi. Though these genotypes showed high yields, the yields still fall below the potential of 3500 kg/ha [5]. The yields could be further improved by crossing with exotic germplasm. The low yielding genotypes 194, 137CR, 137RD and 317 could be improved through crossing with the high yielding genotypes.

Environment (experimental site) had significant effects on Bambara yields. The results (**Tables 2** and **3**) show that yields differed significantly ($P < 0.0001$) across sites. Mbawa recorded the highest site mean of 1177 kg/ha followed by Chitedze and Chitala with 703 kg/ha and 590 kg/ha respectively. High yields at Mbawa could be attributed to favorable environmental conditions like rainfall, temperature and soil fertility. The low yields at Chitala could be due to high temperature, which may lead to high water loss through evapotranspiration despite that the site receives high annual rainfall compared to other sites. Chitala lies in the low altitude area (563 m above sea level) and experiences high temperatures ranging between 20˚C and 30˚C (**Table 4**). Mbawa and Chitedze have similar soil types originating from ferrous (Iron) parental material (Ferruginous and Ferrallitic latosols) compared with Chitala soils which are calcimorphic in nature [16]. This may indicate that Bambara nuts favour soils with high iron than calcium. Environment influences genetic performance of many quantitatively inherited traits including yield through genotype x environment (G × E) interaction [17]. In this study, the influence of site on yield of all the Bambara nuts has been demonstrated with Mbawa showing superior production for the different genotypes.

The tested genotypes showed significant interaction ($P < 0.001$) with environments (**Table 2**). The existing interaction indicates that some accessions did not yield consistently across sites. For instance, genotype 181CR gave highest yields at Chitedze and Chitala but not at Mbawa. However, genotype 2768 out yielded other genotypes at Mbawa unlike in other stations. This shows that genotype 2768 realised its highest potential at Mbawa

**Table 2. Analysis of variance for yield of the eight accessions across three sites over two seasons.**

| Source | DF[a] | SS[b] | Mean Square | F Value | Pr > F[c] |
|---|---|---|---|---|---|
| Accession | 7 | 15048577 | 2149796 | 34.99 | *** |
| Site | 2 | 12423825 | 6211912 | 101.10 | *** |
| Accession × Site | 14 | 2442890 | 174492 | 2.84 | *** |

[a]Degree(s) of freedom; [b]Sum of squares; [c]Statistically different at $P < 0.001$.

**Table 3. Mean comparison for yield of the eight accessions per and across sites.**

| Accession | Chitedze | Chitala | Mbawa | [a]Accession mean across sites |
|---|---|---|---|---|
| 181CR | 1146 ± 378A | 1159 ± 312A | 1660 ± 750A | 1322 ± 552A |
| 2768 | 814 ± 81BC | 694 ± 75BC | 1691 ± 197A | 1066 ± 471B |
| 181RD | 831 ± 76AB | 795 ± 185B | 1567 ± 263A | 1064 ± 407B |
| 2762 | 823 ± 259AB | 443 ± 52D | 1257 ± 173AB | 841 ± 382C |
| 137CR | 487 ± 149CD | 404 ± 45D | 970 ± 344BC | 620 ± 329D |
| 317 | 586 ± 202BCD | 475 ± 40CD | 790 ± 129BC | 617 ± 189D |
| 194 | 512 ± 36BCD | 421 ± 176D | 785 ± 161BC | 573 ± 207D |
| 137RD | 427 ± 243D | 330 ± 130D | 699 ± 269D | 485 ± 265D |
| Mean | 703 ± 208 | 590 ± 155 | 1177 ± 342 | 824 ± 370 |
| P-value[b] | *** | *** | *** | *** |

[a]Means that do not share a letter are significantly different; [b]Statistically different at $P < 0.001$.

**Table 4. Environmental and edaphic characteristics of the three experimental sites.**

| Factor | Chitedze | Chitala | Mbawa | Source |
|---|---|---|---|---|
| Latitude (˚S) | 13.9 | 13.7 | 12.1 | Not applicable |
| Longitude (˚E) | 33.6 | 34.3 | 33.4 | Not applicable |
| Annual rainfall (mm) | 1068 | 1108 | 973 | [18] |
| Minimum temperature (˚C) | 16 | 20 | 16 | [18] |
| Maximum temperature (˚C) | 28 | 3 | 28 | [18] |
| Altitude (m) | 1117 | 563 | 1213 | [18] |
| Soil type | Ferriginous latosol with sandy clay loam texture | Calcimorphic alluvial with clay loam texture | Ferrallitic latosol with sandy loam texture | [16] |

and should be targeted for production in areas with similar environmental conditions. For the low yielding genotypes, accession 137CR showed significant interaction with the environment. At Chitedze the accession gave the lowest yield of 404 kg/ha and yet at Mbawa it out yielded all the low yielding accessions. This means that conditions at Mbawa provided favourable environmental conditions. Exploring the interaction between the environment and genotypes ensures appropriate identification of genotypes for production in either wide or specific environments [17,19]. The interaction between the genotypes and environment should be considered as part of crop production system. In this study, we recommend production of four high yielding genotypes (181RD, 181CR, 2762 and 2768) in all areas with similar environments to all the three sites. However, 2768 could do much better in areas with environmental conditions similar to Mbawa. In order to recommend production zones for these genotypes, we suggest that further research on modeling using environmental and agronomic variables should be conducted. Modeling of Bambara has been done to understand global production zones and Southern Africa region which Malawi belongs to, was identified as one of the most suitable production zones [20].

Farmers used eight different parameters to select the most preferred genotypes. Significant variations ($P < 0.0001$) were observed for all the parameters including the final score derived from all the eight parameters (**Table 5**). Based on the final score, accessions 181RD, 181CR and 2768 topped the list with 4.2, 3.8 and 3.5 scores respectively. Farmers recommended the three accessions for production. Accession 181RD showed positive attributes of high plant vigour, early maturity, short cooking time, good taste of dry boiled grains, requires no mounding and has pure red seed colour. Accession 181CR showed positive attributes of high plant vigour, cream colour with black spots, big grain size and good taste for fresh cooked pods (snack). Accession 2768 exhibited the following positive attribute: quick cooking time, early maturity, pure white cream colour and good taste for dry boiled grain.

**Table 5. Mean scores of characters used by farmers for ranking eight Bambara nut accessions.**

| Accession | PV[a] | MP[b] | GS[c] | TBG[d] | TFP[e] | CT[f] | NM[g] | SC[h] | FS[i] |
|---|---|---|---|---|---|---|---|---|---|
| 181RD | 5.0A | 3.9A | 3.3C | 4.0B | 2.8D | 4.6A | 5.0A | 4.7A | 4.2A |
| 181CR | 4.8B | 3.5B | 4.1A | 2.9D | 5.0A | 2.5D | 2.1F | 4.0C | 3.8B |
| 2768 | 4.7B | 3.8A | 2.5D | 4.6A | 2.6DE | 4.6A | 2.4E | 4.3B | 3.5C |
| 137CR | 3.5DC | 3.9A | 2.4D | 3.5C | 4.5B | 3.7B | 3.6B | 1.3G | 3.3D |
| 194 | 3.7C | 3.1C | 3.6B | 2.9D | 2.5E | 3.7B | 2.8D | 3.5D | 3.3D |
| 137RD | 2.5E | 2.8D | 1.9E | 3.4C | 4.5B | 3.3C | 3.3C | 2.1E | 2.9E |
| 2762 | 3.4D | 1.2F | 2.5D | 1.8E | 3.1C | 2.5D | 3.2C | 1.6F | 2.4F |
| 317 | 2.6E | 2.1E | 2.5D | 1.8E | 3.1C | 3.7B | 3.2C | 1.6F | 2.4F |
| Mean | 3.7 | 3.0 | 2.8 | 3.1 | 3.5 | 3.6 | 3.2 | 2.9 | 3.2 |
| $LSD_{0.05}$ | 0.2 | 0.3 | 0.3 | 0.3 | 0.2 | 0.2 | 0.2 | 0.3 | 0.1 |
| P-value[j] | *** | *** | *** | *** | *** | *** | *** | *** | *** |

[a]Plant vigour; [b]Maturity period; [c]Grain size; [d]Taste of boiled grain; [e]Taste of fresh pod (snack); [f]Cooking time; [g]No mounding; [h]Seed colour; [i]Final score; [j]Significant at $P < 0.001$.

Selection of varieties based on seed colour has impact on marketing and utilization potential. In Zimbabwe, red seeds of Bambara fetch higher prices as compared to white seeds which fetch high prices in Ghana [5]. However, farmers in this study selected both red and white/ cream seeds which may indicate potential market of the two types. Market research of these varieties needs to be conducted to verify the influence of seed colour on marketing. Research on utilisation of different coloured seeds has shown that red seeds contain more Iron and is good for use in areas with iron deficiency and the white seeds are rich in Calcium [5]. Promotion of red and white varieties in Malawi would contribute to reduction of malnutrition which is very high in many parts of the country [21]. In addition to the nutritional elements, the white seeded varieties may have a comparative advantage in milk processing than red ones. Milk from Bambara nut was ranked first in comparison with milk from cowpea, pigeon pea and soybean [22]. Farmers highlighted that pure coloured seeds were selected with reference prevalent varieties of common bean (*Phaseolus vulgaris*). The red seeded Bambara nuts tasted like red beans while the white seeded nuts tasted like white beans. We hypothesize that farmers' selection using seed colour may have the intrinsic nutrition values not just seed appearance. However, more work needs to be done on nutrition analysis of the selected genotypes.

Utilisation of Bambara nut has generally been hampered by cooking time. It is reported that on average boiling dry seeds takes about 3 - 4 hours [23] which requires a lot of a lot of fuel and water. In this study, cooking time has contributed to selection of genotypes 181RD and 2768. Farmers indicated that 181RD and 2768 took less than three hours and compares well with both cowpeas and beans. In Ghana farmers indicated that fast cooking varieties are preferred as they reduce time, energy and water for cooking [24]. Promotion of the two genotypes would contribute to energy and water use efficiency more especially this time when both fuel wood and water are scarce due to high levels of deforestation in Malawi [25].

Plant characteristics and agronomic practices contribute to selection of varieties by farmers. All the most-preferred varieties exhibited high plant vigour. Intuitively, this character is associated with photosynthesis in plants and farmers used it as one of the key characteristics for selection. In plant physiology, genotypes that are more vigorous have high photosynthetic capacity, which contribute to high yields. The three accessions correspondingly gave high yields (**Table 3**). Accession 181RD scored highest on agronomic practice of not requiring mounding. This is a labour saving genotype, as it does not require additional practice of mounding. This genotype has special ability to bury its pods deep in the ground. Mounding has been identified as a common practice which enhances yield in Bambara [26]. However, the practice is an additional operation which increases production cost. Therefore, production genotype 181RD may reduce production costs as it does not require mounding.

Farmers identified grain size as another good selection criterion. Both big and small seeds were selected based on the use. Small seeded genotypes (181RD and 2768) were selected for relish and big seeded genotype (181CR) was selected for snack use. Farmers indicated that the small seeds are preferred for relish because they resemble cowpeas and common beans. Accession 181CR was selected for snack because of high dry matter. Preference of both seed types in Malawi is in contrast with findings in Ghana where farmers prefer big seeded varieties and the preference is not linked to any specific use except for high yield [24]. The distinct preference of varieties in Malawi may be advantageous for future breeding work targeting varieties for relish and snack use.

Comparison between yield (**Table 3**) and farmers' preference (**Table 5**) has shown that not all the four high yielding genotypes (181RD, 181CR, 2762 and 2768) were liked by farmers. Accession 2762 was not liked by farmers because of brown with black spots seeds, long cooking time, poor taste of boiled grain and long maturity period. This shows that yield alone without farmers' preference may lead to identification and promotion of varieties not readily accepted by farmers. A case for genotype 2762 supports the theory that if agricultural technologies are not in harmony with farmers' preference, impact of such technologies is usually marginal due to poor adoption levels [13].

## 4. Conclusion

This study has combined knowledge from breeders and farmers to identify potentially high yielding Bambara genotypes with farmers' preferred attributes. From the experiment it has been shown that an appreciable yield as high as 1600 kg/ha can be obtained. Much as decisions on variety release usually depend on yield, farmers' preferences need to be considered. This is true as observed by the fact that the genotype 2762, which was among the top four in terms of yield, did not appear among the best four of the farmers' preference list. 181RD and 2768 were specifically identified for relish and 181CR was recommended for use as a snack. This is the first detailed study, which has led to the identification of potentially high yielding genotypes of Bambara in Malawi. In absence of improved varieties, we recommend that farmers adopt genotypes 181RD, 181CR and 2768 for production because of their high yields and farmers' preferred attributes. To enhance attainment of potential yield of the crop we recommend production of Bambara in areas with similar environmental conditions as Mbawa where highest site means were realised. Although these genotypes have been identified, continued production of the crop requires further research on breeding, nutrition, value addition and marketing.

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## REFERENCES

[1] A. E. Goli, "Bibliographical Review," In: F. Begemann

and J. N. Mushonga, Eds., *Bambara Groundnut Vigna subterranea* (*L.*) *Verdc*: *Proceedings of the Workshop on Conservation and Improvement of Bambara Groundnut* (*Vigna Subterranea* (*L.*) *Verdc*), International Plant Genetic Resources Institute, Harare, 1997, pp. 4-10.

[2] FAO, "Legumes in Human Nutrition," Food and Agriculture Organization of the United Nations, Rome, 1982.

[3] S. I. Okonkwo and M. F. Opra, "The Analysis of Bambara Nut (*Voandzeia subterranean* (L.) Thouars) for Sustainability in Africa," *Research Journal of Applied Science,* Vol. 5, No. 6, 2010, pp. 394-396. doi:10.3923/rjasci.2010.394.396

[4] S. Basu, J. Roberts, S. Azam-Ali and S. Mayes, "Bambara Groundnut," In: C. Kole, Ed., *Pulses*, *Sugar and Tuber Crops*, Springer, Berlin, 2007, pp. 159-173. doi:10.1007/978-3-540-34516-9_10

[5] R. J. Hillocks, C. Bennett and O. M Mponda, "Bambara Nut: A Review of Utilisation, Market Potential and Crop Improvement," *African Crop Science Journal*, Vol. 20, No. 1, 2012, pp. 1-16.

[6] J. O. Amarteifio, O. Tibe and R. M. Njogu, "The Mineral Composition of Bambara Groundnut (*Vigna subterranea* (L.) Verdc) Grown in Southern Africa," *African Journal of Biotechnology*, Vol. 5, No. 23, 2006, pp. 2408-2411.

[7] National Research Council, "Lost Crops of Africa: Vegetables," Vol. 2, National Academies Press, Washington DC, 1996.

[8] Bioversity International, "Plant Genetic Resources Accession Level Data Provided by: International Institute of Tropical Agriculture (IITA)," 2011. www.genesys-pgr.org

[9] A. E. Goli, F. Begemann and N. Q. Ng, "Characterisation and Evaluation of IITA's Bambara Groundnut Collection," In: F. Begemann and J. N. Mushonga, Eds., *Bambara Groundnut Vigna subterranea* (*L.*) *Verdc: Proceedings of the Workshop on Conservation and Improvement of Bambara Groundnut* (*Vigna subterranea* (*L.*) *Verdc*.), International Plant Genetic Resources Institute, Harare, 1997, pp. 101-118.

[10] F. Massawe, S. Mwale, S. Azam-Ali and J. Roberts, "Breeding in Bambara Groundnut (*Vigna subterranea* (L.) Verdc): Strategic Considerations," *African Journal of Biotechnology*, Vol. 4, No. 6, 2005, pp. 463-471.

[11] Government of Malawi, "Guide to Agricultural Production and Natural Resources Management," Extension Aids Branch, Ministry of Agriculture and Food Security, Lilongwe, 2000.

[12] C. Mkandawire, "A Monograph Of Bambara Groundnut (*Vigna subterranea* (L.) Verdc.); An Underutilized Crop in Malawi," 3*rd Bunda College Research Dissemination Conference*, University of Malawi, Bunda College of Agriculture, Lilongwe, 2006.

[13] E. Wale and A. Yalew, "Farmers' Variety Attribute Preferences: Implications for Breeding Priority Setting and Agricultural Extension Policy in Ethiopia," *African Development Review*, Vol. 19, No. 2, 2007, pp. 379-396. doi:10.1111/j.1467-8268.2007.00167.x

[14] K. Nkongolo, L. Chinthu, M. Malusi and Z. Vokhiwa, "Participatory Variety Selection and Characterization of Sorghum (*Sorghum bicolor* (L.) Moench) Elite Accessions from Malawian Gene Pool Using Farmer and Breeder Knowledge," *African Journal of Agricultural Research*, Vol. 3, No. 4, 2008, pp. 273-283.

[15] L. Rusinamhodzi and R. Delve, "Participatory Variety Selection of Pulses under Different Soil and Pest Management Practices in Kadoma District, Zimbabwe," In: A. Bationo, B. Waswa, J. M. Okeyo, F. Maina and K. J. Maguta, Eds., *Innovations as Key to the Green Revolution in Africa*," Springer, Berlin, 2011, pp. 1015-1022. doi:10.1007/978-90-481-2543-2_103

[16] A. Saka, P. Rao and W. Sakala, "Evaluating Soil Physical and Chemical Characteristics for Describing Nutrient Leaching in Agricultural Soils," *Malawi Journal of Agricultural Sciences*, Vol. 2, No. 1, 2003, pp. 8-20.

[17] C. Aremu, O. Ariyo and B. Adewale, "Assessment of Selection Techniques in Genotype × Environment Interaction in Cowpea (*Vigna unguiculata* (L.) Walp)," *African Journal of Agricultural Research*, Vol. 2, No. 8, 2007, pp. 352-355.

[18] R. J. Hijmans, S. E. Cameron, J. L. Parra, P. G. Jones and A. Jarvis, "Very High Resolution Interpolated Climate Surfaces for Global Land Areas," *International Journal of Climatology*, Vol. 5, No. 15, 2005, pp. 1965-1978. doi:10.1002/joc.1276

[19] O. O. Adeigbe, B. D. Adewale and I. O. Fawole, "Genetic Variability, Stability and Relationship among Some Cowpea, *Vigna unguiculata* (L.) Walp Breeding Lines," *Journal of Plant Breeding and Crop Science*, Vol. 3, No. 9, 2011, pp. 203-208.

[20] S. N. Azam-Ali, A. Sesay, S. K. Karikari, F. J. Massawe, J. Aguilar-Manjarrez, M. Bannayan and K. J. Hampson, "Assessing the Potential of an Underutilized Crop—A Case Study Using Bambara Groundnut," *Experimental Agriculture*, Vol. 37, No. 4, 2001, pp. 433-472. doi:10.1017/S0014479701000412

[21] M. Sassi, "Short-Term Determinants of Malnutrition among Children in Malawi," *Food Security*, Vol. 4, No. 4, 2012, pp. 1-14.

[22] S. H. Brough, S. N. Azam-Ali and A. J. Taylor, "The Potential of Bambara in Milk Production and Basic Functionality Systems," *Food Chemistry*, Vol. 47, No. 3, 1993, pp. 277-283. doi:10.1016/0308-8146(93)90161-8

[23] I. S. Barimalaa and S. E. Anoghalu, "Effect of Processing on Certain Antinutrients of Bambara Groundnuts (*Vigna subterranea*) Cotyledons," *Journal of Science*, *Food and Agriculture*, Vol. 73, No. 2, 1997, pp. 186-188. doi:10.1002/(SICI)1097-0010(199702)73:2<186::AID-JSFA643>3.0.CO;2-M

[24] H. B. Abu and S. S. J. Buah, "Characterization of Bambara Groundnut Landraces and Their Evaluation by Farmers in the Upper West Region of Ghana," *Journal of Developments in Sustainable Agriculture*, Vol. 6, No. 1, 2011, pp. 64-74.

[25] B. Rivard and D. S. Reay, "Future Scenarios of Malawi's Energy Mix and Implications for Forest Resources," *Carbon*, Vol. 3, No. 4, 2012, pp. 369-381. doi:10.4155/cmt.12.35

 

[26] M. Ouédraogo, B. Zagre M'bi, S. T. Jørgensen and F. Liu, "Effect of Mounding Times on Yield of Bambara Groundnut (*Vigna subterranea* (L.) Verdc.) Landraces in Sahel-Burkina Faso," *African Journal of Agricultural Research*, Vol. 7, No. 32, 2012, pp. 4505-4511. doi:10.5897/AJAR12.974